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SLEEP REGULATION IN OLD PEOPLE: THE ROLE OF BRIGHT LIGHT AND MELATONIN

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Abstract

Given that bright light and melatonin are believed to be related to the regulation of sleep patterns, the investigator wondered if sleep could be controlled by inducing changes in melatonin rhythm by using bright light. This study focused on investigating the relationships between bright light, melatonin and sleep in elderly people.

A quasi-experimental study utilising convenience sampling with intra-subject comparison was employed. The study was mainly conducted in community-based homes that care for elderly people. It was divided into two parts – The main study and the further field trial. The main study was the core of the study. The further field trial was conducted to verify the main study results. Thirty-eight institutionalized women (mean age = 79.84 years old ± SD 6.17 years old) successfully completed the main study. Ten finished the further field trial. As a result, 48 women (mean age = 80.61 years old ± SD 6.20 years old) accomplished the study. They had undergone a 6-day experimental condition in which they were exposed to red dim light in the pre- and post-bright light exposure stages and white bright light (2500 lux for 3 hours) in the bright light exposure stage. Each stage lasted two days. Data on sleep patterns were collected using a sleep log and a wrist actigraph. To monitor the changes in melatonin secretion patterns, the urinary 6-sulphatoxymelatonin (aMT6s) level was measured by the radioimmunoassay (RIA) technique.

The main study results showed that there were no significant light-induced effects on sleep satisfaction level, sleep-wake parameters and 6-sulphatoxymelatonin levels, except the number of waking after sleep onset (WASOf) on Day 6. Nevertheless, the subjects indicated improvement in their quality of sleep after bright light exposure. There were significant changes in the associated sleep efficiency (SE), sleep-wake ratio (SWR), total sleep time (TST), sleep onset time (SOT) and the total time of waking after sleep onset (WASOt) on Day 5. In terms of sleep-wake parameters, only

WASOf showed significant change after bright light exposure. SE. SWR and sleep onset latency (SOL) were mainly increased. while WASOf showed a decrease in about 40% of the subjects. The shift in SOT was mainly forward and was not associated with that of the sleep offset time (SoffT). When total bed time (TBT) was increased. TST tended to increase. Prominent alterations in the related sleep satisfaction level (SSL) were reported in SE. SWR. TST. TBT and WASOt after bright light exposure. In the Light On Period in the bright light exposure stage. more subjects had their aMT6s levels decreased as compared with the day before. No prominent trend of changes in the mean level were observed in the Light Off Period in the post-bright light exposure stage. The related SSLs were mainly unchanged. Subjects with the mean levels decreased tended to show an increase in SE. SWR. TST. SOL. WASOf and a decrease in WASOt.

In the combined findings. no significant light-induced effects were identified on SSL. sleep-wake parameters and aMT6s levels except the WASOf on Day 6. Unlike the main study results. significant changes in the related sleep-wake parameters were found on both Days 5 and 6. The corresponding shifting in SoffT but not the SOT was significantly correlated with the alteration in SSL. In terms of the sleep-wake parameters. significant changes in the related SSLs were only found when SE. SWR were increased on Day 5. TST was increased on Days 5 and 6 and WASOt was decreased on Day 5 in the combined findings. For the mean aMT6s levels. the combined findings showed that the corresponding SOL altered significantly on Day 5. when the mean level increased.

This study did not find strong evidence confirming light-induced changes in melatonin for sleep regulation in elderly people. The change trends provided valuable information for formulating a protocol for sleep management. defining sleep satisfaction and applying light treatment on elderly people. Discussion takes place on the utilisation of the findings in sleep management. The feasibility of conducting sleep studies in a field setting is demonstrated. This is important for a better understanding of sleep and the development of evidence based sleep management.

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Acknowledgements

"Unless the LORD builds the house, its builders labor in vain. Unless the LORD watches over the city, the watchmen stand guard in vain. In vain you rise early and stay up late, toiling for food to eat - for he grants sleep to those he loves." Psalm 127:1

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Chapter 1

Introduction

Sleep disturbance is one of the health concerns. Lack of sound sleep interferes with all aspects of a person's daily living activities. Emotionally, sleep deprivation may bring about anger, irritability and antisocial behaviour. Intellectually, it may contribute to poor concentration and memory (Dewan, 1970, Hirshkowitz, Moore and Minhoto, 1997). Animal studies suggested that an extremely long period of sleep deprivation might result in death, as sleep might have a physically restorative function (Hartmann, 1973). Johnston (1994), in addition, claimed that sleep deprivation was associated with an increase in accidents. As shown by Medline, over a thousand studies have focused on sleep and health in the past ten years.

The administration of sleeping pills is a popular but not a desirable method of tackling sleep disturbance (Orr, Altshuler and Stahl, 1982). It is necessary to encourage the development of alternative methods for managing sleep problems. Sleeping pills cannot promote a natural sleep and cause hangover effects, particularly with elderly people (Kearnes, 1989). Because of their harmful effects, different kinds of non-pharmacological methods have been introduced. Self-administered relaxation training has been suggested to be a cheap, convenient, and effective means of treating insomnia (Gustafson, 1992). Exercise, regular habits and removal of any disturbing elements from the

bedroom are other choices to relieve sleep disturbances (Johnston. 1994). Acupressure has been found effective in enhancing the quality of sleep in institutionalized elderly people (Chen. Lin. Wu and Lin. 1999). Recently. melatonin preparations have been found effective in dealing with sleep disturbances. In addition to its relationship with light. it is possible that endogenous melatonin will be included in the regulation of sleep in the future.

Melatonin preparations have been commended as effective sleep-inducing agents (Reiter and Robinson. 1995: Pierpaoli. Regelson and Colman. 1996). They have been found helpful in relieving sleep problems in healthy subjects with jet lag (Arendt. Aldhous. English. Marks and Arendt. 1987) and in elderly people with insomnia (Haimov. et al.. 1995: Wurtman and Zhdanova. 1995). Numerous studies have been conducted recently to examine their effects on sleep patterns (Folkard. Arendt and Clark. 1993: Matsumoto. 1999: Dalton. Rotondi. Levoitan. Kennedy and Brown. 2000: Luboshitzky. et al.. 2000). Although exogenous melatonin is effective in dealing with certain sleep disturbances. undesirable effects such as daytime fatigue. headache. increase in irritability and increase in mental load have been identified (Folkard. Arendt and Clark. 1993: Zhdanova and Wurtman. 1997). In addition. the quality control of melatonin preparations is varies world-wide. Exogenous melatonin remains imperfect for sleep management. Instead of melatonin preparations. endogenous melatonin. however. may be a choice.

The similarities between melatonin secretion rhythm and sleep-wake cycle have initiated the studies on their relationship. Melatonin secretion is diurnal

in nature and the nocturnal blood level of pineal melatonin is higher than that during the day (Laakso, Porkka-Heiskanen, Alila, Peder and Johansson, 1988). Its level in elderly people is lower than that of young adults (Waldhauser, et al., 1988) and its rhythms shift forwards (Reiter and Robinson, 1995). In parallel with the change in melatonin secretion rhythm, sleep architecture undergoes certain changes in old age. The sleep phase is advanced by an hour (Swift and Shapiro, 1993). Observing the similarities between sleep and the diurnal nature of melatonin secretion, many researchers have become interested in investigating the relationship between melatonin secretion rhythms and sleep-wake patterns.

The association between melatonin levels and core body temperature (CBT) has substantiated the investigation. In reality, endogenous melatonin has been found in relation to sleep-wake patterns. Both melatonin levels and CBT are primary phase markers for circadian rhythm (Dijk and Cajochen, 1997). They hold a fixed phase relationship with each other (Shanahan and Czeisler, 1991). It can be argued that if CBT is associated with sleep-wake patterns (Dumont and Carrier, 1997; Campbell and Murphy, 1998), a relationship between melatonin and sleep is even more likely because melatonin has a stronger entraining power than CBT (Cagnacci, Elliot and Yen, 1992; Deacon and Arendt, 1995; Reiter and Robinson, 1995). Owing to the presence of association between CBT and sleep-wake patterns, it is possible that endogenous melatonin can influence sleep-wake patterns. Actually, some studies have not demonstrated significant correlation between melatonin and sleep (Vaughan, Allen and De La Peña, 1979; Claustrat, Brun, Garry,

Roussel and Sassolas. 1986: L'Hermite-Baleriaux. et al.. 1989) but others have identified some association (Birkeland. 1982: Morris. Lack and Barrett. 1990: Nakagawa. Sack and Lewy. 1992: Tzischinsky. Shlitner and Lavie. 1993). Together with its relationship with light. endogenous melatonin should have a role in sleep regulation.

Light. as a major synchronizer. can affect both the phase and amplitude of circadian cycle (Czeisler. Kronauer. Mooney. Anderson and Allan. 1987: Campbell. et al.. 1995b). Its entraining effect is stronger than that of sleep-wake cycle (Duffy. Kronauer and Czeisler. 1996). It can phase shift the sleep-wake cycle (Akata. et al.. 1993: Campbell. Dawson and Anderson. 1993: Tzischinsky and Lavie. 1997) and change the magnitude of the sleep-wake parameters (Hansen. Bratlid. Lingiärde and Brenn. 1987: Campbell. Dawson and Anderson. 1993: Cooke. Kreydatus. Atherton and Thoman. 1998). Moreover. it can reduce sleepiness in some subjects (Partonen. Vakkuri and Lamberg-Allardt. 1995). Patients with depression (Kripke. Risch and Janowsky. 1983: Meesters. Jansen. Beersma. Bouhuys and van den Hoofdakker. 1993: Partonen. 1994). dementia (Mishima. et al.. 1994) or Alzheimer's disease (Satlin. Volicer. Ross. Herz and Campbell. 1992) had been found to gain benefit from bright light exposure. Their symptoms were reduced and their related sleep problems were ameliorated.

Apart from the sleep-wake cycle. light also has a phase shifting effect on melatonin secretion rhythm (Dijk. Beersma. Daan and Lewy. 1989). It can suppress melatonin production (Daurat. Foret. Touitou and Benoit. 1996:

Leproult. Van Reeth. Byrne. Sturis and Van Cauter. 1997). Since melatonin secretion is closely related to light reception (Reiter. 1988: Weissbluth and Weissbluth. 1992). it is possible to induce changes in melatonin secretion using light. Since light can synchronize both sleep-wake cycle and melatonin secretion rhythm. and endogenous melatonin has been found to be related to sleep-wake patterns. it follows that sleep can be regulated by light-induced changes in the melatonin rhythm. Sleep deprivation can make a big impact on us. It is customary for health care professionals to administer sleeping pills in dealing with sleep deprivation. However. the shortcomings of sleeping pills such as hangover effects in elderly people (Kearnes. 1989) have led sleep researchers to consider developing alternative methods of sleep management. Bright light and melatonin may be a means in sleep management.

To explore the possibility of using both bright light and melatonin in sleep regulation. this study was designed using white bright light at 2500 lux for three hours within two evenings to induce changes in the sleep-wake cycle and the melatonin secretion rhythm. By recording the sleep satisfaction level. the sleep-wake parameters and urinary 6-sulphatoxymelatonin level. the investigator observed the relationships between sleep. bright light and melatonin. The relationships were further confirmed by an additional field trial. In this way. the proposition that regulating one's sleep via light-induced changes in melatonin levels might be clarified. These light-induced changes in melatonin could be applied to sleep management in everyday nursing practice. The related hypothesized relation between bright light. melatonin

and sleep and scope of the study are described in the rest of this chapter.

Hypothesized relation between bright light, melatonin and sleep

In this study, it was hypothesized that sleep could be regulated via light-induced changes in melatonin levels. Bright light has been found effective in ameliorating sleep problems in some patients. Melatonin levels have been found in relation to sleep-wake patterns as well as light. Since light is a strong synchronizer, it can entrain both sleep-wake cycle and melatonin secretion rhythm. The entrainment of sleep-wake cycle will cause changes in sleep quality which can be shown by the alterations in the sleep-wake parameters (sleep efficiency, sleep-wake ratio, total sleep time, total bed time, sleep onset latency, sleep onset time, wake after sleep onset and sleep offset time) and sleep satisfaction level. For the synchronization of melatonin secretion rhythm, both amplitude and phase of melatonin secretion will be affected. Hence, the purpose of this study was to investigate whether the regulation of sleep via bright light could bring about an alteration in the melatonin secretion rhythm (Figure 1.1). To explore the relationships between bright light, melatonin and sleep, the investigator hoped that the review of these relationships and the associated changes in sleep quality might be helpful in developing an alternative natural method for sleep management.

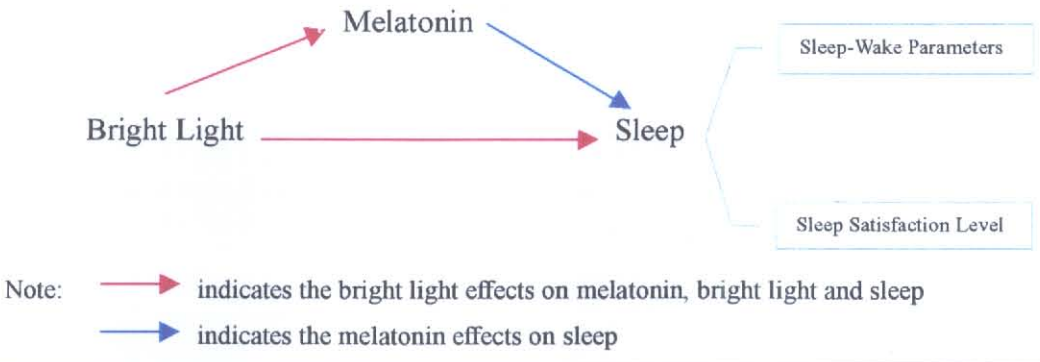


Figure 1.1 The hypothesized relation between bright light, melatonin and sleep

Scope of the study

The target population of this study was elderly women living in elderly care homes. To assess the sleep promoting measures in this setting, the investigator employed wrist actigraph and sleep log. Detailed description of sleep quality monitoring can be referred to "The measurement of bright light effects on sleep and melatonin secretion level – The measurement of the quality of sleep" of Chapter 3. Levels of melatonin were ascertained by measuring urinary 6-sulphatoxymelatonin (aMT6s). Urine samples were collected according to the voiding needs of the subjects during the experiment, so the interference on their sleep would be minimized. Subjects did not save urine samples during the day so as to prevent any disturbances in their daily routine. Neural activity of these sympathetic fibers is provoked during the daily dark period (Reiter, 1988; Weissbluth and Weissbluth, 1992) and is suppressed by light during the day (Reiter, 1988). Nocturnal urine samples were collected for analysis in this study.

The research questions

In order to ascertain if the sleep-wake cycle can be regulated by light-induced changes in endogenous melatonin, the relationships between bright light, melatonin and sleep should be clarified with reference to sleep-wake parameters, sleep satisfaction level and excreted melatonin levels. Since sleep histories of the subjects could be helpful in understanding the findings, relevant data was also collected. Based on these uncertainties, nine research questions were posed:

1. What were the common sleep disturbances reported by the institutionalized elderly women?
2. What were the differences between the good and poor sleepers in terms of their sleep-wake parameters?
3. Were there any differences between the good and poor sleepers in terms of their excreted melatonin levels?
4. Was there any relationship between bright light and sleep satisfaction level?
5. Was there any relationship between sleep satisfaction and sleep-wake parameters?
6. Was there any relationship between sleep satisfaction level and excreted melatonin level?
7. Was there any relationship between bright light and sleep-wake parameters?

8. Was there any relationship between sleep-wake parameters and excreted melatonin level?

9. Was there any relationship between bright light and excreted melatonin level?

The relationships between sleep-wake parameters, excreted melatonin level and sleep satisfaction level, could be detected by observing the effects of light-induced changes in them on the other two variables.

Hypotheses

From the research questions, the following hypotheses were formulated:

1. There is a relationship between bright light and each of the three measurements (sleep satisfaction level, sleep-wake parameters and excreted melatonin level).
2. There is a relationship between sleep-wake parameters and excreted melatonin level.
3. There is a relationship between sleep-wake parameters and sleep satisfaction level.
4. There is a relationship between excreted melatonin level and sleep satisfaction level.

Variables

There were four variables identified in this study. **Bright light** that acted as the independent variable in the first hypothesis was used to induce changes in other variables. Values for the remaining three variables (sleep satisfaction level. sleep-wake parameters and excreted melatonin level) were used as independent and dependent variables. When **sleep-wake parameters** acted as the independent variable in the second and third hypotheses. the other two variables were the dependent variables. These variables were categorized according to the predicted relationships with sleep-wake parameters. When **excreted melatonin level** was the independent variable (in the second and fourth hypotheses). the remaining two variables were treated as dependent variables. They were grouped according to the changes in excreted melatonin level. Similarly. when **sleep satisfaction level** was adopted as an independent variable in the third and fourth hypotheses. both sleep-wake parameters and excreted melatonin level were the dependent variables. They were classified according to changes in sleep satisfaction level.

Definition of terms

In this study, the following terms were defined as below:

Afternoon

The time period between 1200 hours and 1800 hours.

Bedtime

It is the time when one goes to bed and attempts to fall asleep.

Evening

The time period between 1800 hours and the bedtime for nocturnal sleep.

Morning

The time period between the final waking of the nocturnal sleep and 1200 hours.

Nap

Intentional or unintentional episodes of daytime sleep (Floyd, 1995).

Elderly people

Those age sixty-five and above.

Sleep

The period of time in which subjects decrease their responsiveness to the environment with recurrent spontaneous episodes of motor quiescence (Hayter. 1983; Fordham. 1988).

Sleep efficiency (SE)

An index which is calculated by total sleep time over total bed time and multiplying by 100% (Friedman. Brooks III. Bliwise and Yesavage. 1993).

Sleep onset latency (SOL)

The period of time measured from the point at which one attempts to sleep to the commencement of sleep (Guilleminault and Dement. 1979).

Sleep onset time (SOT)

The time one begins to fall asleep. that is. the commencement of sleep.

Sleep offset time (SoffT)

The final waking time after the commencement of sleep.

Sleep-wake parameters

In this study. they refer to sleep efficiency (SE). sleep-wake ratio (SWR). total sleep time (TST). total bed time (TBT). sleep onset latency (SOL). sleep onset time (SOT). wake after sleep onset (WASO). sleep offset time (SoffT).

Sleep-wake ratio (SWR)

An index which is calculated by total sleep time over total waking time after sleep onset.

Total bed time (TBT)

The total time in bed at night, which is estimated by the subjects.

Total sleep time (TST)

The total time that the subject falls asleep between the bedtime at night and the rising time in the morning.

Wake after sleep onset (WASO)

It happens between the sleep onset time at night and the final waking time in the morning. It is usually described according to its occurrence frequency (WASOf – number of waking after sleep onset), duration (WASOd – duration of each waking after sleep onset) and total amount of time (WASOt – total time of waking after sleep onset).

Assumptions

There are three assumptions in this study.

1. Sleep is a crucial factor of one's wellness.
2. Sleep quality is reflected by both self-reported sleep satisfaction level and

sleep-wake parameters.

3. The desire to improve sleep quality is an indication of the need to seek a better sleep.

Organization of thesis

The remainder of this thesis is organized as follows. Chapter 2 describes the background to the study. The purpose of conducting this research is explained. To substantiate the intention, a review of the relevant literature is presented in Chapter 3. The method employed in this study is displayed in Chapter 4 with the feasibility of the experiment confirmed by the pilot study in Chapter 5. The results of the study are shown in four chapters. The characteristics of the subjects are reported in Chapter 6. The effects of bright light on the subjects in accordance with the changes in sleep satisfaction level, actigraphic sleep-wake parameters and 6-sulphatoxymelatonin level are summarized separately in Chapter 7 to 9. Based on these findings, the related summary, conclusion and discussion are presented in Chapter 10. Chapter 11 describes the results of the additional field trial while Chapter 12 concludes the findings and discussion of the main study and the additional field trial. The recommendations for future research direction are also included in this chapter.

Chapter 2

Background to the Study

Introduction

According to the Census and Statistics Department. 10.1% of the population were aged 65 and above in 1997. The population size of this age group had increased from 87.900 to 629.600 over the past 35 years (Census and Statistics Department. Hong Kong. 1997). In the middle of 2000. 11.2% of the population belonged to this age group (http://www.info.gov.hk/censtatd/eng/hkstat/fas/pop/by_age_sex_index.html). With an increasing life expectancy in Hong Kong. elderly people will become dominant in the population. As sleep architecture changes with advancing of age. this is becoming a growing problem in Hong Kong.

In a previous study of elderly people living in long-termed care facilities. 71% of them were reported to have habitual sleep medication consumption (Clapin-French. 1986). For elderly people living at home. more than one in three individuals reported insomnia (Morgan. Dallosso. Ebrahim. Arie and Fentem. 1988). According to the National Institutes of Health. among 29 million elderly people (aged over 65). more than half of them had some degree of sleep disturbance (National Institutes of Health. 1990). Adopting a definition

of sleep problem as a total sleep time less than 7 hours or more than 8 hours. it was found that 57.1% (N = 712) of a sample of elderly people in Hong Kong complained of sleep problems (Chi and Lee. 1990). In 1999. a district survey indicated that 75% of the respondents reported occasional or persistent sleep disturbance with 38.2% experiencing insomnia (Chiu. et. al.. 1999). As sleep problems are common among elderly people (Morin and Gramling. 1989). there is a need to study sleep disturbance in this age group.

Sleep management

Orr. Altshuler and Stahl (1982) claimed that pharmaceutical measures were frequently employed in tackling sleep problems. Swift and Shapiro (1993) stated that the consumption of sleeping pills was increasing in hospital. residential and nursing homes. According to one major psychiatric hospital in Hong Kong. 24.1% of its geriatric consultations in May 1997 related to sleep complaints. Sleeping pills were prescribed to 69.2% of these cases regardless of the sleep complaint being a primary or secondary cause of consultation. Even though it is known that the administration of sleep medications can cause hangover effects particularly on elderly people (Kearnes. 1989). it remains a popular method of sleep management.

Exogenous melatonin has been suggested as an effective sleep-inducing agent (Reiter and Robinson. 1995: Pierpaoli. Regelson and Colman. 1996). Instead

of sleeping pills. Haimov and associates (1995) and Wurtman and Zhdanova (1995) recommended the use of melatonin preparations in elderly people. The appearance of melatonin preparations can be good news for those suffering from sleep disturbance. However, there needs to be further confirmation of its safety. In Hong Kong, melatonin preparations are sold as a "health food". They are exempted from any control on their quality and labelling. According to an article printed in the South China Morning Post on 12 October 1998 (Mathewson, 1998), the Government Chief Pharmacist Anthony Chan Wing-kin found it unnecessary to control the selling of melatonin tablets as strictly as other drugs. Conversely, Professor Pang Shiu-fun of the University of Hong Kong, who has studied melatonin for 30 years, asked for tighter supervision. He questioned the purity of the preparations under different brands of melatonin when control was lax. He even pointed out that melatonin was banned in Britain and New Zealand while it became popular in Hong Kong (Mathewson, 1998). It is undeniable that melatonin preparations seem to be an effective and convenient way to ease sleep problems. In response to the safety issue, the investigator agrees that further clarification of their side effects and purity is essential before the promotion of their usage. Therefore, the exploration of sleep management cannot stop at the administration of melatonin preparations. Endogenous melatonin is another target for the sleep researchers to explore.

Endogenous melatonin and light may play a role in sleep regulation. Endogenous melatonin has been found to be related to sleep in some studies (Birkeland, 1982; Morris, Lack and Barrett, 1990; Nakagawa, Sack and Lewy,

1992; Tzischinsky, Shlitner and Lavie, 1993). It is, therefore, implicated in sleep regulation. The light-dark cycle is an effective synchronizer. Its entraining power is stronger than that of the sleep-wake cycle (Duffy, Kronauer and Czeisler, 1996) and the melatonin secretion rhythm (Dijk, Beersma, Daan and Lewy, 1989). It can induce changes in these two circadian cycles. Hence, it was wondered if sleep could be regulated by the light-induced changes on melatonin levels.

The utilisation of bright light by Hong Kong doctors has been restricted to relieving jaundice in new born babies and promoting wound healing in pressure sore cases. In fact, bright light has been implicated in more therapeutic processes. Artificial bright light had been included in some treatment programmes for sleep problems (Akata, et al., 1993; Campbell, Dawson and Anderson, 1993). Light is the preferred way in regulating sleep rather than the administration of melatonin preparations, because light comes naturally from the sun. It is hoped that this natural resource can be introduced into sleep management. First, because people do not need to pay for it. Second, the use of sunlight is not like the administration of sleeping pills which may cause hangover effect in elderly people (Kearnes, 1989). Third, there is no need to worry about the purity of sunlight. With the clarification of the role of light-induced changes in melatonin in sleep regulation, it is expected that an appropriate and safe protocol for sunlight exposure will be formulated in the future. Through health education, sufferers can tackle their sleep disturbances by themselves.

Conclusion

Sleep complaints are common among elderly people. Facing these complaints, the administration of sleep medications is the usual mode of sleep management even though the related harmful effects are realized. The administration of melatonin preparations is already a convenient and popular method for relieving sleep problems. Recently, some researchers have identified that both melatonin and bright light are related to sleep. In view of the queries concerning the purity and safety of melatonin preparations, the investigator hesitated in promoting the usage of exogenous melatonin but remained interested in the role of endogenous melatonin in sleep regulation using bright light. As we can receive abundant bright light from the sun, we can take advantage of this if bright light is found to be implicated in sleep regulation. The investigator hoped that by examining the relationships between sleep, bright light and melatonin, the role of light-induced changes in melatonin in sleep regulation could be clarified. Therefore, sunlight can be included in sleep management in the future.

Chapter 3

Literature Review

Introduction

Recently, numerous studies have focused on the investigation of melatonin. Different dosages of melatonin preparations are used to test the medical regimes for various sleep disturbances. The alterations of sleep-wake cycle and melatonin secretion rhythm are alike throughout life. Hence, any changes in one of them will have an effect on the other. In addition to the unfavourable effects brought by the sleeping pills, the evidence in dealing with jet lag (Arendt, Aldhous, English, Marks and Arendt, 1987) and insomnia (Wurtman and Zhdanova, 1995) effectively by melatonin preparations has further promoted the study of melatonin.

Melatonin preparations are good enough to deal with sleep disturbances conveniently. As compared with light, the contribution provided by the preparations may not be as much as light. Light, as a major synchronizer for the endogenous circadian cycles (Dijk, et al., 1995), can entrain both melatonin cycle and sleep-wake cycle. It can adjust phase and amplitude of circadian cycles

(Czeisler, Kronauer, Mooney, Anderson and Allan, 1987; Campbell, et al., 1995b). When light is set at a certain wavelength, intensity, duration, timing and position, changes can be induced in both melatonin secretion rhythm and sleep-wake cycle. Such light-induced changes are important in regulating the person's melatonin secretion rhythm and sleep-wake pattern.

To examine the possible relationships between light, sleep-wake cycle and melatonin secretion rhythm, a lot of information related to sleep and melatonin were reviewed. Also, issues concerning the formulation of bright light exposure schedule were studied and discussed. Further, the measurements of sleep quality were also of thought to be of relevance. All the articles presented in this chapter are searched from MEDLINE (Key words: phototherapy, sleep, melatonin and elderly), the sleep home pages (http://www.sleephomepages.org) and the reference list at the end of each article.

Sleep

Sleep is not just a state in which one is not awake. It is divided into two categories: rapid eye movement (REM) sleep and non-rapid eye movement (NREM) sleep. NREM sleep comprises four stages (Dement and Kleitman, 1957). These sleep categories and stages change with age. The availability of

polysomnography (PSG) allows the sleep researcher to realise the changes in the related electroencephalogram (EEG), electromyogram (EMG) and electrooculogram (EOG) during sleep. "The nature of sleep" and "Age-related sleep changes" help in understanding the sleep architecture and related changes as one grows old.

Sleep does not just occur at night. It happens in daytime. It is not clear whether a nap during daytime can compensate for any bad sleep at night (Morin and Gramling, 1989). Napping is one of the factors to be considered when the quality of sleep is evaluated. Apart from napping, there are many factors affecting one's sleep. Some of them are described in the following sections on "Sleep-related factors". Sleep can be disturbed in various ways. Sleep disturbance is commonly classified as difficulty in initiating sleep (DIS), difficulty in maintaining sleep (DMS) and early morning awakening (EMA). Further details are presented in a subsequent section on "Sleep disturbance". To manage sleep disturbance, health care professionals usually use sleeping pills as their chief strategy. In view of the harmful effects of sleeping pills particularly on elderly people, the investigator will discuss the use of sleeping pills in regulating sleep in the section on "Sleep management".

The nature of sleep

Sleep can be categorized into rapid eye movement (REM) sleep and non-

rapid eye movement (NREM) sleep. NREM sleep is further divided into four stages. Ideally, the person will go from waking to NREM (all the 4 stages) first. Then, the stages will revert from stages 4 to 2. Afterwards, the first REM period will take place and be followed by another NREM period (stages 2 to 4, then stages 4 to 2). With the repetition of the NREM-REM periods, the episode of NREM and REM sleep actually appears in a cyclic fashion (Mendelson, Gillin and Wyatt, 1977). The length of the REM period will increase gradually but that of the NREM period will decrease as the cycle repeats. Therefore, the latter part of sleep at night will be mainly dominated by REM sleep (Orr, Altshuler and Stahl, 1982). Generally, the duration of each cycle is estimated to be about 90 minutes (Mendelson, Gillin and Wyatt, 1977; Orr, Altshuler and Stahl, 1982). Sometimes, it may range from 70 to 120 minutes (Mendelson, Gillin and Wyatt, 1977).

NREM sleep is crucial for physical restitution (Hartmann, 1973). After its deprivation of up to 100 hours, people will report feelings of lethargy, depression and discomfort. Indefinite physical complaints are also reported (Canavan, 1986). During NREM sleep, blood pressure, respiratory rate and basal metabolic rate will decrease (Guyton, 1987). The person will change from wakefulness to sleep and his or her eyeball movements and muscle tone will decline when experiencing stages 1 to 4. Stage 1 is the lightest level of sleep in terms of arousability. It is the stage

in which a person goes from wakefulness to sleep. This stage usually lasts for 30 seconds to about 7 minutes (Lacks. 1987). When a person is awake and in a restful state. the EEG record mainly includes sinusoidal alpha waves mixing with lower amplitude irregular beta waves. At this time. the person still maintains high muscle tone and eyeball movements. Proceeding from wakefulness to stage 1. alpha activity is halved. Beta and the slower theta activity become dominant in this stage. The movements of eyeballs will decline (Mendelson. Gillin and Wyatt. 1977). Stage 2 is regarded by many sleep researchers as "true sleep" (Lacks. 1987). It is characterised by the presence of sleep spindles and k-complexes. Theta waves are also dominant in this stage (Mendelson. Gillin and Wyatt. 1977: Lacks. 1987). Stages 3 and 4 are referred to as slow-wave sleep (SWS). These stages are characterised by the presence of delta waves. Stage 3 shows moderate amounts (20-50%) of delta waves whereas stage 4 is characterised by more than 50% of these waves (Mendelson. Gillin and Wyatt. 1977). Going through the four stages of NREM sleep. the person will return from stages 4 to 2. then undergo REM sleep (Figure 3.1).

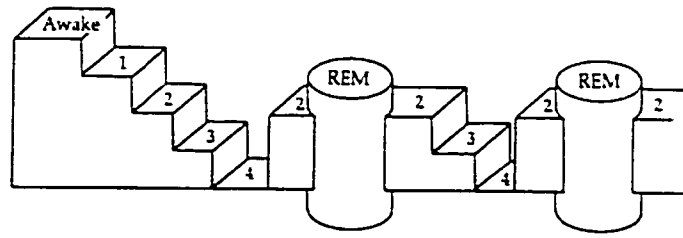


Figure 3.1 The cyclical pattern of sleep stages (Borbély. 1986)

Unlike NREM sleep. REM sleep is related to memory and intellectual functions (Dewan. 1970. Hirshkowitz. Moore and Minhoto. 1997). It is also associated with dreaming (Aserinsky and Kleitman. 1953). Deprivation of REM sleep will lead to irritability and emotional liability (Agnew. Webb and Williams. 1967). During REM sleep. heart rate and respiration become irregular. Small muscles may twitch even though the large ones remain immobilised (Guyton. 1987). The main feature of REM sleep includes the presence of rapid eye movement and a mixed frequency EEG pattern. After returning from stages 4 to 2 in the NREM sleep. the REM sleep will show an EEG changing back to a mixed frequency pattern similar to that in stage 1. During REM sleep. eye movements are detected and muscle tone remains very weak (Mendelson. Gillin and Wyatt. 1977: Borbély. 1986: Lacks. 1987). After the REM sleep has finished. there will be another NREM-REM sleep cycle. This process will repeat for three to four times throughout the night (Orr. Altshuler and Stahl. 1982). Concluding the characteristics of the NREM and REM sleep. the deprivation of either one of them will affect our quality of life.

Age-related sleep changes

When we were babies. our sleep is fragmented. As we grow. the time we spend in sleep decreases and we mainly sleep at night. With the

advancing age, we start to suffer sleep disturbance. Our sleep goes back to being fragmented again when we become old. Newborn babies sleep at all times throughout the day and wake up at intervals of two to six hours. Their REM sleep and NREM sleep equally occupy their total sleep time. Their REM sleep resembles that of adults but they are comparatively more restless during this period. Unlike the sequence of sleep stages in adults, they have their REM sleep immediately following wakefulness. Such a sequence changes to wakefulness-NREM sleep-REM sleep after they are two to three months old. At the age of three months, they mainly sleep at night. They maintain twelve hours of sleep a day even though they are six months old. Newborn babies sleep stages are not well defined. Sleep spindles, k-complexes and delta waves appear only after their EEG becomes mature in the first year. Together with the percentage of time spent in REM sleep, the total sleep time decreases as babies grow up. However, the demand for sleep suddenly increases in adolescence. At that time, young people find it difficult to awake spontaneously. In adults, their sleep-wake patterns are most likely dependent on their work schedules. Following the changes in their sleep architectures as they grow old, people may complain about their sleep (Orr, Altshuler and Stahl, 1982; Borbély, 1986).

In elderly people, sleep architecture undergoes certain changes. The amount and amplitude of slow waves decreases. Spindles, the

characteristic feature of stage 2 sleep, are abnormally presented. During REM sleep, eye movements decrease. Although elderly people spend longer time in bed, their sleep efficiencies are reduced as their total sleep time decreases. And, the decrease in arousal threshold is accompanied by an increase in the number and duration of waking. The time from the onset of sleep to REM sleep and the REM period decreases. The number of shifts from one stage of sleep to another increases. Frequency of daytime napping increases. The amplitude and strength of synchronization of circadian rhythms decline. The sleep phase is found to be advanced for an hour (Swift and Shapiro, 1993). As a result, elderly people usually complain of sleeping less and waking frequently at night. They find it difficult to return to sleep after waking (Orr, Altshuler and Stahl, 1982).

Nap

A nap is a daytime sleep which occurs intentionally or unintentionally (Floyd, 1995). Similar with nocturnal sleep, it changes along the life. From childhood to puberty, the amount of napping declines. Later, napping tendency returns. The amount of napping increases with advancing of age (Webb, 1989). Such increase is thought to be partially related to sensory impairment in elderly people. The impairment is thought to weaken the effects of external time cues on them so that

regulatory biological processes are not maintained (Clapin-French. 1986). Napping may be related to poor sleep at night. Elderly people who nap habitually tended to have a longer total sleep time (Gislason. Reynisdóttir. Kristbjarnarson and Benediktsdóttir. 1993). longer sleep latencies and an increase in the number of night time waking (Floyd. 1995). Although such associations may reflect poor sleep at night. napping is not confined to poor sleepers. There is no significant difference between good and poor sleepers in their daytime sleep (Morin and Gramling. 1989). It is not clear whether napping can compensate for any bad sleep at night (Morin and Gramling. 1989).

Despite the unclear function of napping. it was suggested that a short nap was. to a certain extent. beneficial in relieving short-term effects caused by poor sleep as napping for about twenty minutes and no more than three hours could make people feel refreshed and alert (Ferrer. Bisson and French. 1995: Reiter and Robinson. 1995). Napping for about twenty minutes only allows the occurrence of sleep stages 1 or 2 but not 3 or 4. Therefore. a person can feel refreshed and alert after a short nap. But. after napping for a long time. long enough for sleep proceeding to the slow-wave sleep but not long enough to have the stages returning back. the person feels groggy and disoriented (Reiter and Robinson. 1995). To avoid this. a 30-minute nap has been recommended for refreshing effects (Ferrer. Bisson and French. 1995).

Sleep-related factors

There are many factors interfering with one's sleep, such as smoking, caffeine, alcohol, dairy products, exercise, sunlight exposure, supper time and snack. A sleeping partner, some illnesses and drugs may also affect sleep quality. In addition, other factors, such as, stress, environment and pain, are thought to influence sleep.

Smoking Kearnes (1989) claimed that withdrawal symptoms during sleep were found in smokers during sleep. A survey has shown that smoking is related to fragmented sleep. In addition, difficulty in falling asleep and getting up in the morning is often reported by smokers (Reiter and Robinson, 1995). In the light of the disturbances caused by smoking, it has been recommended that people should not smoke before bedtime or during the night (Roger, 1997). Nicotine causes tachycardia, increase in cardiac output, constriction of the blood vessels and elevation in blood pressure. These changes will affect sleep (Sweeney, 1989).

Caffeine Caffeine is commonly found in coffee, tea, cocoa and cola drinks. Inhibiting the binding of adenosine to its receptor sites in the brain and the periphery, caffeine can stimulate the central nervous system. Such stimulation can counteract the sense of fatigue. Aircrews often use caffeine as a stimulant (Ferrer, Bisson and French, 1995). Caffeine, on the

one hand, can be beneficial to us in improving our alertness level; on the other hand, it can disturb our sleep. In a follow-up sleep study in elderly people, poor sleepers had higher level of tea consumption (6.0 cups/day versus 4.7 cups/day). Tea possessed both diuretic and stimulant properties, so the researchers did not find the result surprising (Morgan, Healey and Healey, 1989). As caffeine clearance falls with age (Curless, French, James and Wynne, 1993), the effects of tea on sleep should not be neglected especially in elderly people. To achieve a desirable improvement in alertness and attention, caffeine should be at a low concentration because at high concentration (more than 600 mg per day), it can induce wakefulness, anxiety and tremor (Curless, French, James and Wynne, 1993; Ferrer, Bisson and French, 1995). A caffeine concentration of 500 mg in 24 hours, is considered to be an "overdose". This concentration is equivalent to three cups of coffee, two headache tablets containing caffeine and a drink of cola (Kearnes, 1989). After the ingestion of caffeine-containing products, the related effects will appear in about 15 to 45 minutes. The plasma half-life is about 5 to 6 hours. Since caffeine can disturb one's sleep cycle, it is recommended not to ingest caffeine-containing products within 6 hours before sleep (Ferrer, Bisson and French, 1995).

Alcohol Though alcohol can induce sleep, the quality of sleep is compromised, easily disrupted and not deep enough (Ferrer, Bisson and

French. 1995). Lobo and Tufik (1997) have demonstrated in their study that alcohol can modify one's REM sleep by reducing the period of REM sleep. The shortening of REM sleep may have some effects on one's memory and intellectual functions (Hirshkowitz. Moore and Minhoto. 1997). Consequently. alcohol is not considered to be a good sleep-inducing agent.

Dairy Products It has been suggested that a warm milk drink before bedtime can promote sleep. Dairy products such as malted milk have been said to be more effective in facilitating sleep than milk alone (Adam. 1980). Milk may be viable in the regulation of sleep because it is relatively high in tryptophan. Tryptophan. the precursor of melatonin. may shorten the time for sleep onset (Sweeney. 1989; Reiter and Robinson. 1995). Thus. dairy products may act as a sleep-inducing agent.

Exercise It has been proposed that regular exercise can facilitate sleep (Orr. Altshuler and Stahl. 1982). After an hour of walking from 1500 hours to 1600 hours. polysomnographic results of elderly people showed no significant changes in sleep stages. But. their perceived sleep qualities were improved (Bevier. Bliwise. Bliwise. Bunnell and Horvath. 1992). Exercise is believed to be beneficial to one's sleep. at least. subjectively.

Sunlight Exposure Light. as a major synchronizer. can adjust phase and

amplitude of the circadian cycle (Czeisler, Kronauer, Mooney, Anderson and Allan, 1987; Campbell, et al., 1995b; Dijk, et al., 1995). Its entraining effect is stronger than that of the other synchronizers such as sleep-wake cycle, food availability cycle and social cues (Duffy, Kronauer and Czeisler, 1996). Possessing these characteristics, light may be helpful in promoting sleep. The effects of bright light on sleep are elaborated in the section following on "Bright Light Exposure".

Supper time and Snacks In one study, researchers have pointed out that a change in one's customary late evening eating pattern can affect one's sleep quality. For instance, the sleep quality is worse if one misses his or her usual bedtime snack. Or, if one has a bedtime snack which is not a habit, the related sleep quality will also be worse (Adam, 1980). A full meal near bedtime is not recommended as it stimulates digestive activity that can interrupt sleep. A desirable supper time is suggested to be several hours before bedtime (Lacks, 1987).

Sleeping Partner One study has demonstrated that sleep quality of sleeping with others and sleeping in separate beds is different. For couples sleeping together, they have more REM sleep and so dreamed more. In addition, the amount of delta sleep decreases and it does not develop unless sleep is not disturbed for at least ten minutes (Hauri and Linde, 1990). Therefore, sleep studies with experimental variables prefer to

recruit subjects who have no sleeping partner.

Illnesses and Drugs Some illnesses and drugs may cause disturbances in sleep. Hyperthyroidism, hypothyroidism, Alzheimer's disease, urinary tract infection (UTI), orthopnea, fever, alcoholism, intolerable pain, depression and anxiety were some conditions and illnesses related to sleep (Vitiello and Prinz, 1988; Bliwise, 1997). Drugs causing sleep disturbances are central nervous system stimulants, antimetabolites, cancer chemotherapeutic agents, thyroid preparations, anticonvulsants, major tranquillizers, sedating tricyclics, nonsteroidal anti-inflammatory drugs (NSAIDS), beta-blockers, calcium channel blockers, sleeping pills, anti-depressant, alpha-receptor blocker, anti-anxiety drugs and niacinamide (Fordham, 1988; Reiter and Robertson, 1995).

Other Factors Stress, environmental factors and pain are also thought to influence sleep. It has been suggested that stress may cause sleep disturbance (Hodgson, 1991). Environmental factors such as noise and light are considered to cause sensory overload in a person (Pulling and Seaman, 1993). Pain is reported to be strongly related to all types of insomnia especially early morning awakening (EMA) (Gislason, Reynisdóttir, Kristbjarnarson and Benediktsdóttir, 1993).

To summarise, smoking, caffeine consumption, having a full meal too close

to the bedtime and the change in the consumption of bedtime eating habits may interfere with one's sleep. Alcohol is not considered to be a good sleep-inducing agent while dairy products may promote a sweet sleep by shortening the time for sleep onset. Although doing exercise may not change one's polysomnographic results, it may improve the subjective sleep quality. Light may be helpful in achieving a good sleep while some illnesses and drugs will disturb it. Stress, environmental factors and pain are also a contributing factor to sleep disturbance.

Sleep disturbance

Sleep disturbance is defined as a subjective complaint of poor sleep (Nakra, Grossberg and Peck, 1991), which can be described objectively. Sleep disturbance is commonly classified as difficulty in initiating sleep (DIS), difficulty in maintaining sleep (DMS) and early morning awakening (EMA) (Bootzin and Engle-Friedman, 1981; Nakra, Grossberg and Peck, 1991; Gislason, Reynisdóttir, Kristbjarnarson and Benediktsdóttir, 1993). DIS is defined as having difficulty in getting to sleep. The sufferers complain of a long duration before the onset of sleep. Their sleep onset latencies (SOL) are long. DMS refers to disruption of sleep after sleep induction. The disruption is described according to the number of waking after sleep onset (WASOf), the duration of each waking after sleep onset (WASOd) and the total time of waking after sleep onset (WASOt). In

elderly people. DMS occurs mostly during the second half of the night. The complaints are mainly increased in WASOf and WASOt at night. EMA refers to the final awakening during the night in which the person cannot fall asleep again. The sleep offset time (SoffT) of the sufferers. the final waking time. is considered not to be the usual time for the person to awake (Espie. 1991).

When the possible causes of sleep disturbance are studied. there are several factors influencing one's sleep such as poor sleep habits (Nakra. Grossberg and Peck. 1991). physical pathology. physiological disturbances. drug. diet. circadian rhythm disturbances. psychopathology. anxiety and stress. cognitive intrusions. sleep environment factors. inappropriate stimulus control and reinforcement for sleeplessness (Bootzin and Engle-Friedman. 1981). In the case of physiological disturbances. noise. variations of environmental temperature. ventilation and light are the dominant causes (Kearnes. 1989).

Sleep management

To tackle poor sleep. different interventions are suggested which include pharmacological measures. psychotherapy and behavioral therapies (Rogers. 1997). Among these interventions. pharmacological measures are frequently employed (Orr. Altshuler and Stahl. 1982: Swift and Shapiro.

1993). The administration of sleep medication is risky especially when it is addictive (Halfens, Cox and Kuppen-Van Merwijk, 1994). Sleeping pill users frequently report difficulty in initiating sleep (DIS) and early morning awakening (EMA) (Gislason, Reynisdóttir, Kristbjarnarson and Benediktsdóttir, 1993). In elderly people, changes in liver and kidney functions intensify the effect of the sleeping pills and may also lead to the occurrence of hangover effects (Kearnes, 1989). When hypnotic drugs are administered to elderly people, risks of accentuated acute sedation and unwanted residual sedation may be present in the early stage of treatment. For regular users, an accumulating dose of hypnotic drugs may also impair their daytime performance, cognition, motor activity, and postural stability (Swift and Shapiro, 1993). Some hypnotic drugs, such as barbiturates and tricyclic antidepressants, cannot provide a natural sleep as they may suppress REM sleep (Sweeney, 1989). Zopiclone (Mamelak, Scima and Price, 1983) and zolpidem (Besset, Tafti, Villemin, Borderies & Billiard, 1995) are similar to benzodiazepines, which have no effect on REM sleep. These new generation hypnotics are effective in relieving sleep problems and will not affect sleep structure. They own different kinds of side effects. Bitter taste and dry mouth with a minimal incidence of central nervous system depressant effects are the main side effects presented by zopiclone (Musch and Maillard, 1990). Zolpidem may cause drowsiness, fatigue, headache, anxiety and irritability but these side effects will fade away quickly after awakening (Monti, 1989).

Sleep disturbance was not a serious concern for nurses even though they were convinced that it was their duty to deal with sleep problems (Halfens, Lendfers and Cox, 1991). Insufficient knowledge of sleep (Edéll-Gustafasson, Arén, Hamrin and Hetta, 1994) and unfamiliarity with effective nursing methods for tackling sleep problems (Halfens, Lendfers and Cox, 1991) were reported as obstacles in developing sleep management. In view of the risks of administering sleep medications, it is essential for nurses to make more effort to equip themselves with knowledge about sleep and to develop an efficient way to manage sleep disturbance.

With the repetition of NREM-REM sleep cycles, we sleep throughout the night. As the architectures of both NREM sleep and REM sleep change along the life span, our sleep conditions alter together. In elderly people, sleep architecture, both at night and in daytime, undergoes tremendous changes. It is not clear whether the increase in napping in elderly people is related with their nocturnal sleep. However, some findings have revealed that smoking, caffeine products consumption, alcohol consumption, dairy products consumption, exercise, sunlight exposure, supper time, snack, sleeping partner, some illnesses, certain drugs, stress, environmental factors and pain are associated with sleep quality. The changes in sleep architecture in elderly people cause sleep problems. Among the sleep complaints, DIS, DMS and EMA are the most common ones. To tackle sleep disturbance, sleeping pills are the most popular choice. In the light of the adverse effects of sleeping pills, especially in elderly people, the

investigator has recommended nurses to search for another efficient sleep management method.

Melatonin

Pierpaoli. Regelson and Colman (1995) claimed that melatonin could maintain youth. regulate sleep pattern. strengthen immune system. fight against diseases such as cancer. reduce cholesterol and decrease stress. Because of its powerful effects. melatonin has attracted the attention of many researchers. Dawson and van den Heuvel (1998) stated that changes in melatonin level were associated with certain physiological changes. When melatonin level was elevated. the core body temperature decreased and heat loss also increased. Both the cardiac output and alertness reduced and immune responsiveness was enhanced. They proposed that there were two physiological roles for melatonin. Firstly. it was involved in the self-regulation of the suprachiasmatic nucleus-pineal complex. The regulation power of melatonin on the biological timing system was classified as circadian effects. The second role of melatonin was to promote restorative or anabolic physiological processes. To understand more about melatonin. a description of "The nature of melatonin secretion" is presented on the following page. Similar to sleep. melatonin secretion changes along the life span. Thus. this discussion will also include "Age-related melatonin level changes".

Taking into account of circadian regulating power, endogenous melatonin rhythm has a fixed phase relationship with core body temperature (CBT) (Shanahan and Czeisler, 1991). Such relationship has implied its association with sleep. Exogenous melatonin used for jet lag (Arendt, Aldhous, English, Marks and Arendt, 1987) and insomnia (Wurtman and Zhdanova, 1995) has been found to be effective in relieving sleep problems. Therefore, it is reasonable to assume that the alteration in melatonin secretion level may, in turn, change the sleep-wake cycle. A section on "Melatonin as a sleep regulating agent" will further elaborate the investigator's viewpoint.

The nature of melatonin secretion

Melatonin, N-acetyl-5-methoxytryptamine, is a neurohormone (Delagrange and Guardiola-Lemaitre, 1997). It is the product of tryptophan metabolism. After tryptophan is taken up actively from the circulation in the pineal gland, it is firstly converted to 5-hydroxytryptophan and then to serotonin. Serotonin is then changed to N-acetylserotonin before melatonin is synthesized (Figure 3.2) (Axelrod, 1974; Reiter, 1988; Yu, Tsin and Reiter, 1993).

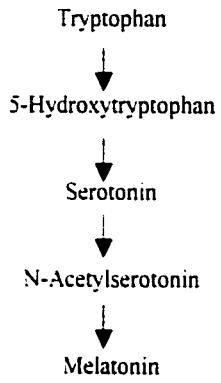


Figure 3.2 The synthesis of melatonin

Once melatonin is produced, it is not stored in the pineal gland even for a short time (Reiter, 1988). It diffuses into the blood stream quickly (Pardridge and Mietus, 1980; Reiter, 1988), and is metabolised mainly in the liver and excreted in urine as 6-sulphatoxymelatonin, aMT6s (Kopin, Pare, Axelrod and Weissbach, 1961; Kveder and McIsaac, 1961; Reiter, 1988; Yu, Tsin and Reiter, 1993). The time lag between nocturnal onset of melatonin and aMT6s is about an hour (Waldhauser, et al., 1984). The secretion of nocturnal melatonin is in an episodic pattern of 10-minute intervals (Weitzman, et al., 1978; Vaughan, Bell and De La Peña, 1979) but this pulsatile theory is not supported by some researchers (Trinchard-Lugan and Waldhauser, 1989). The half-life of plasma melatonin was reported to be less than 30 minutes (Weitzman, et al, 1978) though it was suggested that it should be 57 minutes (SD = 34 minutes) (Claustrat, Brun, Garry, Roussel and Sassolas, 1986). Iguchi, Kato and Ibayashi (1981), however, suggested that the half-life of plasma melatonin displayed a biphasic pattern

of first-order kinetics with the first half-life as 2 minutes and the second as 5 minutes. The secretion is spontaneous and its metabolism is quick. These characteristics facilitate the monitoring of melatonin secretion over short time periods.

The production of pineal melatonin depends on neural activity within the suprachiasmatic nuclei (SCN) of the hypothalamus. SCN is connected to the pineal gland by sympathetic fibers (Reiter, 1988). Neural activity of these sympathetic fibers is provoked during the daily dark period (Reiter, 1988; Weissbluth and Weissbluth, 1992) and is suppressed by light during the day (Reiter, 1988). The secretion of melatonin is, therefore, affected by light information. It is estimated that 80% of the total 24-hour melatonin production is secreted at night time (Matthews, et al., 1981). So, the nocturnal pineal melatonin contents are higher than those during the day (Laakso, Porkka-Heiskanen, Alila, Peder and Johansson, 1988). Although the changes of daylength by artificial light were found to have certain effects on one's duration of the nocturnal melatonin secretion (Wehr, 1991), in natural conditions, there was little difference in melatonin synthesis between summer and winter (Bojkowski and Arendt, 1988; Matthews, Guerin and Wang, 1991). Even for urbanised men, there is no difference in the duration of elevated nocturnal melatonin concentration between summer and winter. However, melatonin rhythm in winter is phase delayed by about 1.5 hours as compared with that of summer (Illnerová,

Zvolsky and Vaněček, 1985).

The onset of melatonin production normally occurs at about 2100 hours (Sack and Lewy, 1988). Laakso, Hätönen, Stenberg, Alila and Smith (1993) stated that the onset time should be from 2000 hours to 0030 hours. Nonetheless, it was claimed to be about one hour before the sleep onset time by other researchers (L'Hermite-Baleriaux, et al., 1989). The peak level of melatonin production time period was found to be around 0200 hours to 0400 hours (Arendt, 1988) while others suggested that it was 0300 hours to 0400 hours (Dawson and van den Heuvel, 1998; Geoffriau, Brun, Chazot and Claustrat, 1998). After the peak is reached, melatonin production decreases. The offset time is from 0330 hours to 0900 hours (Laakso, Hätönen, Stenberg, Alila and Smith, 1993). As concluded by Dawson and van den Heuvel (1998), the secretion period of melatonin was from 2100 hours to 0700 hours. Figure 3.3 summarizes the 24-hour cycle of melatonin production.

Melatonin production is not prevented or suppressed by any waking or sleep stages (Vaughan, Allen and De La Peña, 1979; Claustrat, Brun, Garry, Roussel and Sassolas, 1986; L'Hermite-Baleriaux, et al., 1989). However, it can be increased by the monoamine oxidase inhibitors and selective serotonin reuptake inhibitors such as fluvoxamine. Beta-blockers (for examples, propranolol and atenolol), reduce nocturnal melatonin secretion

(Wincor. 1998). Therefore. the evaluation of melatonin production should include the current information of drug taking.

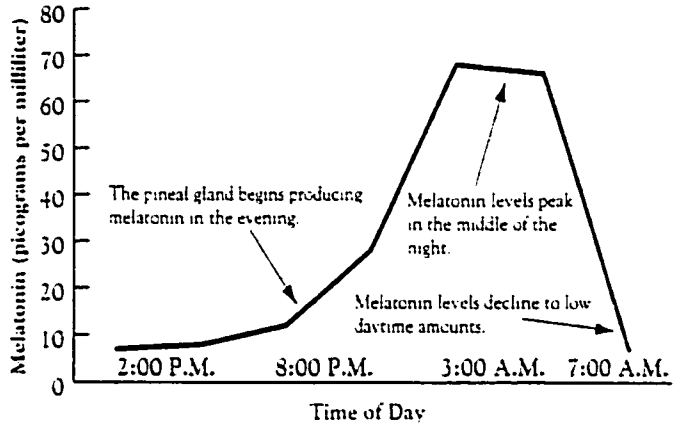


Figure 3.3 The 24-hour cycle of melatonin production (Reiter & Robinson. 1995)

Age-related melatonin level changes

Both melatonin secretion rhythm and melatonin levels change along the life span. Before babies are born. their melatonin production is initiated by their mothers' pineal glands. This condition is maintained until the babies are three months old. When they are three months old. the secretion rhythms maintained by the infant's pineal gland (Weissbluth and Weissbluth. 1992). The melatonin rhythms will not be mature until about five months old. Once the melatonin rhythm is well established. infants stay awake during most of the day time and sleep most of the night time (Geoffriau. Brun. Chazot and Claustrat. 1998). When people become old. their melatonin rhythms will undergo certain changes. Some researchers

found that there was no great difference in the melatonin secretion onset time between the young and elderly males (L'Hermite-Baleriaux. et al.. 1989). Dissenting from this. Reiter and Robinson (1995) claimed that the alteration of melatonin rhythm was mainly a matter of 'phase shifting' especially 'phase advance' in elderly people. As people get old. melatonin is produced earlier at night and the production stops earlier in the morning. As with melatonin rhythm. melatonin level changes throughout the life span (Figure 3.4). For newborn babies. aged from one to three months. their nocturnal melatonin levels are low. There is no difference in their levels at day time and night time. As the babies grow. their nocturnal melatonin levels increase and the highest level is reached at the age of one to three years. Then. their levels decrease continuously. Their levels can drop by 80% at the age of 15 to 20 years compared with those at one to three years (Waldhauser. et al.. 1988). In young male adults. the peak melatonin production level is 116.8 pg/ml (SD = 13.5 pg/ml) (Hajak. et al.. 1995) while it has been suggested to be 70.5 pg/ml in another study (L'Hermite-Baleriaux. et al.. 1989). In elderly people. the peak level has been identified as 36.8 pg/ml (L'Hermite-Baleriaux. et al.. 1989). Melatonin level is lower in elderly people (Iguchi. Kato and Ibayashi. 1982: L'Hermite-Baleriaux. et al.. 1989).

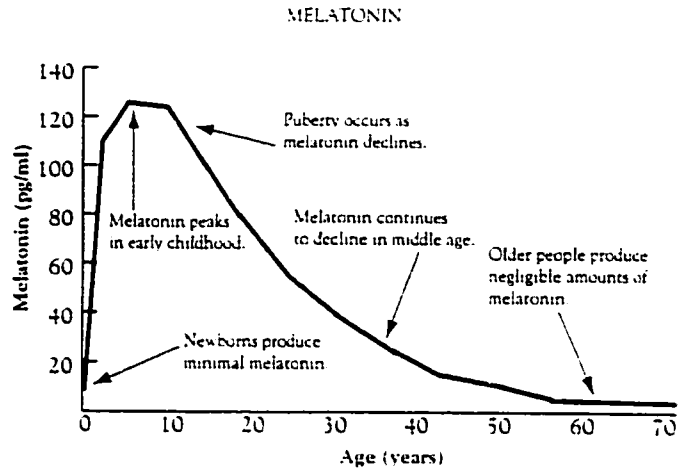


Figure 3.4 The age-related changes of melatonin level (Reiter & Robinson, 1995)

Melatonin as a sleep regulating agent

Core body temperature (CBT) is known of fixed phase relationship with melatonin (Shanahan and Czeisler, 1991). At the same time, it is also related to sleep. Endogenous melatonin rhythm and CBT are primary phase markers for circadian rhythm (Dijk and Cajochen, 1997) in which endogenous melatonin rhythm is believed to be a reliable phase marker (Arendt, 1988). When melatonin production is suppressed at night, CBT will rise (Reiter and Robinson, 1995). Apart from melatonin, CBT is also related to sleep. Dumont and Carrier (1997) have claimed that it is easier for an individual to fall asleep at his or her minimum body temperature. When body temperature is high, an individual can rarely initiate sleep. Campbell and Murphy (1998) have also suggested that the earlier the

timing of the fitted body temperature minimum (Tmin), the more fragmented the sleep is. As postulated, melatonin may have a role in sleep regulation.

Birkeland (1982) has found that the peaks of melatonin level are related to spontaneous waking at night while its nadirs (lowest points) are correlated with REM periods when an intra-subject control is employed. Repeating Birkeland's study, Claustrat, Brun, Garry, Roussel and Sassolas (1986) found that the nocturnal melatonin secretion pattern is not correlated with sleep stages. The inconsistent results may be due to the difference in the definition of the peak value of melatonin level. Similar situations were identified when different reference points were used in the measurement of melatonin. Vaughan, Allen and De La Peña (1979) claimed that melatonin secretion is not related to stages of sleep when mean peak-to-peak interval of melatonin is the reference of measurement. Morris, Lack and Barrett (1990) have found that total sleep time is not correlated with absolute nocturnal melatonin levels but is positively associated with the amplitude of the melatonin circadian rhythm when constant routine is included in the design of the study. Illustrated by the circadian rhythm of a 44-year-old totally blind man, it was found that sleep propensity raised with the increase in melatonin production and decreased when melatonin fell to its daytime level (Nakagawa, Sack and Lewy, 1992). The onset time of nocturnal 6-sulphatoxymelatonin was identified to be significantly

correlated with the timing of sleep gate (the timing of the steepest increase in nocturnal sleepiness) when an ultrashort sleep-wake paradigm was included with intra-subject comparison (Tzischinsky, Shlitner and Lavie, 1993). The hourly plasma melatonin concentrations of insomniacs was increased at an earlier time in the evening when compared with healthy subjects (Hajak, et al., 1995). As a conclusion, there may be an association between endogenous melatonin and sleep when the reference point of the measurement of melatonin is taken into consideration. Such association is further illustrated by the use of exogenous melatonin in sleep management.

Exogenous melatonin has been involved in sleep regulation. It was found to be effective in alleviating jet lag in 17 healthy subjects by advancing the sleep propensity and improving sleep quality (Arendt, Aldhous, English, Marks and Arendt, 1987). According to Wurtman and Zhdanova (1995), exogenous melatonin could decrease sleep onset latency and the number of waking at night in elderly people with insomnia. In addition, it could improve self-rated sleep quality (Folkard, Arendt and Clark, 1993; Wurtman and Zhdanova, 1995). Bearing these characteristics in mind, melatonin has been commended as an effective sleep aid with sleep-inducing effects (Reiter and Robinson, 1995; Pierpaoli, Regelson and Colman, 1996). Some researchers have even suggested using melatonin in elderly insomniacs especially for those with the problems of sleep initiation

and sleep maintenance (Haimov, et al., 1995; Wurtman and Zhdanova, 1995).

The availability of exogenous melatonin can facilitate effective sleep regulation but it has its shortcomings. It is claimed that exogenous melatonin does not bring with it any dependency or side effects that can occur with sleeping pills (Pierpaoli, Regelson and Colman, 1996). Repeated administration (7 days) of melatonin preparations has been related to daytime fatigue, headache and increase in irritability (Zhdanova and Wurtman, 1997). In addition, there is speculation that melatonin may impair one's mental processing, thus causing an increase in mental load (Folkard, Arendt and Clark, 1993). In response to the uncertainties of the side effects of exogenous melatonin, it is valuable to explore the using of endogenous melatonin in managing sleep.

Melatonin has been said to possess many powerful effects on human bodies. With its prompt release from the pineal gland, it enables researchers to study its properties within a short period. Its diurnal characteristics, and the change in its secretion level and rhythm with the advancing of age, has led the investigator to think about its relationship to sleep disturbance in elderly people. Studies have identified a relationship between melatonin and sleep. Exogenous melatonin has been recommended as an effective sleep aid.

Bright light exposure

Sunlight is such a crucial environmental factor in our lives that we cannot live without it. Sunlight not only provides us with light and heat. It also provides us with energy. Unfortunately, ozone depletion brings attention to its harmful effects on our health rather than its beneficial effects. We are now busily searching for methods of protect ourselves from solar radiation. At the same time, we are missing its advantages. It is undeniable that excessive sunlight exposure may lead to several skin problems and even worse. There is a high risk of skin cancer. Optimal exposure is essential for vitamin D production and maintaining one's well-being (Lillyquist, 1985). Apart from sustaining health, light is also helpful in improving one's alertness and performance (Daurat, Foret, Touitou and Benoit, 1996). In addition, it can be therapeutic for certain illnesses. Artificial bright light that simulates sunlight has been used in some clinical research.

Several studies have demonstrated that patients with depression, such as seasonal affective disorder, have their depressive symptoms reduced after artificial bright light exposure (Kripke, Risch and Janowsky, 1983; Meesters, Jansen, Beersma, Bouhuys and van den Hoofdakker, 1993; Partonen, 1994). For patients with dementia (Mishima, et al., 1994) or Alzheimer's disease (Satlin, Volicer, Ross, Herz and Campbell, 1992), artificial bright light also proved to be effective in

ameliorating sleep and behavioral disorders. Artificial bright light has been included in treatment programmes for instance delayed sleep phase syndrome (Akata. et al.. 1993) and sleep maintenance insomnia (Campbell. Dawson and Anderson. 1993). Further investigating the mechanisms involved. some researchers have suggested that bright light may be employed in sleep management (Czeisler. et al.. 1989: Campbell. Dawson and Anderson. 1993). Since the light-dark cycle is an effective synchronizer (Duffy. Kronauer and Czeisler. 1996) and its entraining power is stronger than that of the sleep-wake cycle or the melatonin secretion rhythm. it is expected that light can alter one's sleep and melatonin secretion. The way that bright light acts on sleep and melatonin secretion is described in the following sections. In addition. factors for synchronization and the side effects of bright light exposure are presented.

Light as a synchronizer

Since human circadian rhythms respond to external signals. the amplitude and phase of circadian cycle can be affected by light exposure (Czeisler. Kronauer. Mooney. Anderson and Allan. 1987: Campbell. et al.. 1995b). As a 'time giver' to human beings. the light-dark cycle is an effective synchronizer. Its entraining effect is stronger than that of other synchronizers such as the sleep-wake cycle. food availability cycle and social cues (Duffy. Kronauer and Czeisler. 1996). The entraining property of bright light has even been found in blind subjects (Czeisler. et al.. 1995).

As a major synchronizer for endogenous circadian cycles (Dijk. et al.. 1995). light is also thought to regulate the circadian system (Dawson and van den Heuvel. 1998) and thus the entrainment of the melatonin cycle. One study showed that daylength could influence both melatonin and sleep-wake cycles. A "summer" photoperiod for one week and a "winter" photoperiod for four weeks were introduced into a constant routine protocol. The durations of both nocturnal melatonin secretion and the nocturnal sleep period in the "winter" phototperiod were lengthened when compared with that in the "summer" period. Both melatonin and sleep-wake cycles were lengthened with the extension of the dark period (Wehr. 1991). It has been observed that if bright light is applied in the morning. it will phase advance (shorten) the circadian rhythm. If bright light is applied in the evening. it will phase delay (lengthen) the circadian rhythm. No phase change is found when bright light is applied in the afternoon (Honma. Honma and Wada. 1987: Sack and Lewy. 1988: Hyman. 1990: Regestein and Monk. 1995). There is abundant evidence to illustrate that light can be used to regulate the circadian system.

Effects of bright light on sleep-wake cycle

By employing the entraining property of light. artificial bright light can reset the sleep-wake rhythm. In combination with vitamin B_{12}. the sleep-wake rhythm of a 24-year-old man with delayed sleep phase syndrome

could be advanced (Akata, et al., 1993). Four elderly men and four elderly women with difficulty in maintaining sleep had their self-selected bedtime delayed by an average of 29 minutes after bright light exposure (Campbell, Dawson and Anderson, 1993). The delay in the time of the sleep gate (the steepest nocturnal increase in sleepiness) for nearly an hour after evening bright light exposure was also found in eight healthy males who had no sleep problems (Tzischinsky and Lavie, 1997). As a conclusion, light can induce phase shifting on everyone's sleep-wake cycle regardless of his or her age, gender and health status.

In addition to phase shifting, bright light is found to have effects on sleep-wake parameters. After bright light exposure, subjects with midwinter insomnia had some of their sleep parameters improved. For instance, sleep latency was modestly shortened (Hansen, Bratlid, Lingiärde and Brenn, 1987). Subjects, who complained of sleep disturbance for at least a year, had their average sleep efficiency increased from 77.5% to 90.1%. Their average wake after sleep onset (WASO) decreased from 102.8 minutes to 43.2 minutes and the number of waking after sleep onset reduced by 41.5% after bright light exposure (Campbell, Dawson and Anderson, 1993). Ten elderly women, who had several sleep complaints, showed an improvement in sleep quality by a reduction in sleep latency, an increase in both sleep time and sleep efficiency and by reporting less fatigue after bright light exposure (Cooke, Kreydatus, Atherton and

Thoman. 1998). Sighted subjects benefited from bright light which brought about a reduction in sleepiness and improving mood. The same phenomenon has also been found in some blind subjects (Partonen. Vakkuri and Lamberg-Allardt. 1995). Light can change some sleep-wake parameters and improve perceived sleep satisfaction not only in elderly insomniacs but also in some blind persons.

Effects of bright light on the melatonin secretion rhythm

Similar to sleep-wake cycle. bright light also has a phase shifting effect on melatonin secretion rhythm. Morning bright light was shown to provide a phase advance in the rise of plasma melatonin in eight male adults. who were free of sleep complaints (Dijk. Beersma. Daan and Lewy. 1989). Combined with vitamin B_{12}. the melatonin rhythm of a 24-year-old man was advanced by about one to two hours after bright light exposure (Akata. et al.. 1993).

Apart from phase shifting. bright light can suppress melatonin secretion (Daurat. Foret. Touitou and Benoit. 1996: Leproult. Van Reeth. Byrne. Sturis and Van Cauter. 1997). The suppressive effect in women seems to be much greater than that in men (Monteleone. Esposito. La Rocca and Maj. 1995). This suppression has also been observed in sightless people. As substantiated by Czeisler and associates (1995). when shielding the eyes.

the light-induced suppression of melatonin level was absent in subjects who had originally demonstrated positive results. It was concluded that blind people with the related sympathetic fibers remaining intact could react towards bright light. Moreover, the acute suppression of melatonin production was important in augmenting and fine tuning the entrainment of the circadian cycle by light (Arendt, 1988; Lewy, Ahmed and Sack, 1996). Bright light can both initiate phase shifting melatonin rhythm and suppress melatonin secretion.

Since bright light is said to be capable of augmenting circadian amplitude (Czeisler, Kronauer, Mooney, Anderson and Allan, 1987), melatonin production may increase after bright light exposure. According to a study conducted on a 57-year-old woman, who presented with seasonal affective disorder, 14 out of 17 blood samples showed an increase in melatonin level after exposing to bright light for two hours in 14 consecutive mornings. Collecting samples at the equivalent time before and after bright light exposure, the researchers found that the increase was not related to the phase shifting of the melatonin secretion rhythm (McIntyre, Norman, Burrows & Armstrong, 1990). A similar result was obtained in subjects with midwinter insomnia in a control group design study. Their mean evening melatonin levels increased after bright light exposure. Since no data on the 24-hour melatonin levels were available, further investigation was needed to support the findings (Hansen, Bratlid, Lingiärde and Brenn,

1987). In contradiction to the above findings. Shanahan and Czeisler (1991) found that the average amplitude of melatonin level in eight healthy male adults showed no significant change after bright light exposure. In another study. there was no significant change in the 24-hour melatonin output after subjects were exposed to green bright light (Horne. Donlon and Arendt. 1991). With reference to the above inconsistent findings. the effect of light on the melatonin level cannot be confirmed. Since melatonin level is lower in elderly people (Iguchi. Kato and Ibayashi. 1982: L'Hermite-Baleriaux. et al.. 1989) while people start to complain about their sleep as they grow old (Orr. Altshuler and Stahl. 1982: Borbély. 1986). the melatonin level is suspected to play a role in the sleep complaints of elderly people. Therefore. whether melatonin level can be increased after bright light exposure is worth further exploration.

The application of bright light in regulating sleep and melatonin secretion

Summarising from the light effects on sleep-wake cycle and melatonin secretion rhythm. the investigator found that bright light could induce changes in them. With the sleep-wake cycle. the changes could happen in everybody regardless of age. gender. health status and sleep condition. Even the blind could get benefit from light. Towards melatonin secretion rhythm. the phase shifting and suppressive effects of bright light were ensured but not the increase in melatonin secretion level. To alter the

sleep-wake cycle and the melatonin secretion rhythm in elderly people. light is considered to be a desirable synchronizer.

Factors for synchronization

By using light to synchronize our melatonin and sleep-wake cycles. we have to pay attention to the features of light. which include wavelength. intensity. duration. timing and position of the light sources. Side effects of light exposure should also be considered. When an appropriate light exposure schedule is chosen. a desirable rhythm of sleep together with an optimal change in melatonin secretion rhythm may be attained.

Wavelength In hamsters. the maximum spectral sensitivity of phase shifting response was found to be near 500 nm (blue-green range). The sensitivity decreased slowly along the shorter wavelength side but quickly on the longer side (Takahashi. DeCoursey. Bauman and Menaker. 1984). While blue-green range was the optimal wavelength to entrain melatonin rhythm in hamsters. white light including the full spectrum was commonly used in humans (Dijk. Beersma. Daan and Lewy. 1989: Shanahan. and Czeisler. 1991: Czeisler. et al.. 1995). For the suppressive effect. different wavelengths of light possessed different suppressive powers on the melatonin level. Healthy male adults irradiated with different wavelengths of monochromatic light illustrated that a wavelength of 509 nm (green

range) could maximally suppress their plasma melatonin levels (Brainard, et al., 1985). Light of other wavelengths can also exercise this suppression but to a minor extent. For instance, moderately red light could suppress melatonin secretion in three of seven subjects after 1.5 hours exposure (Zeitzer, Kronauer and Czeisler, 1997). Blue-green light could suppress melatonin level and induce phase shifting in melatonin rhythm efficiently. White light including the full spectrum and being the popular choice in light experiment was found capable of altering the melatonin secretion rhythm and improving sleep quality effectively (Bunnell, Treiber, Phillips and Berger, 1992; Campbell, Dawson and Anderson, 1993; Daurat, Aguirre, Foret and Benoit, 1997). Thus, it was considered to be the best and convenient choice for light experiment including the study of both sleep and melatonin.

Intensity According to Arendt (1988), the exact intensity for the entrainment of melatonin was undetermined. It was, however, observed that there was a reciprocal relationship between intensity and duration (Blehar, Rosenthal, Terman and Wehr, 1990). Hence, both intensity and duration should be considered at the same time during the formulation of a light treatment protocol. Dijk, Beersma, Daan and Lewy (1989) applied 2000 lux of bright white light to eight male adults. Their melatonin rhythms were then advanced by an hour. Higher intensities of 6000 lux and above were also used to cause phase shifting of melatonin for more

than an hour in adults (Budnick, Lerman and Nicolich, 1995; Dumont and Carrier, 1997). In spite of the uncertainty in the exact intensity, it was observed that the magnitude of phase shifting by each wavelength was increased with the intensity of light in hamsters (Takahashi, DeCoursey, Bauman and Menaker, 1984). Since light intensity was mostly a determining factor in the degree of melatonin suppression (Laakso, Hätönen, Stenberg, Alila and Smith, 1993), the design for phase shifting the melatonin level should take account of the light intensity used to suppress the melatonin level.

Light intensity of 500 lux failed to demonstrate suppression in one study (Lewy, Wehr, Goodwin, Newsome and Markey, 1980) but a different situation was identified in another study. McIntyre, Norman, Burrows and Armstrong (1989) concluded from their study that light intensity as low as 200 lux could slightly suppress nocturnal melatonin and 1000 lux could cause a suppression nearly to the daytime values. When light intensities were increased to 1500 and 2500 lux, light-induced suppressive effect on melatonin secretion was observed with the effectiveness of the latter being one better than that of the former one (Lewy, Wehr, Goodwin, Newsome and Markey, 1980). Dollins, Lynch, Wurtman, Deng and Lieberman (1993) found that the percentage of melatonin suppression by light was increased with the light intensity. Thus, a higher the light intensity would bring about a greater suppression on melatonin level and so a greater phase

shifting effect on melatonin secretion rhythm.

When bright light is influencing melatonin rhythm, the sleep-wake cycle is affected at the same time. Bright light of 2000 lux through a light visor could improve sleep qualities of the ten elderly women who had sleep complaints (Cooke, Kreydatus, Atherton and Thoman, 1998). Eight out of eleven healthy men had their sleep gate delayed after exposing them to 2500 lux of evening light (Tzischinsky and Lavie, 1997). Bright light of 2000 to 2500 lux was found to be capable of reducing sleep latency in subjects with midwinter insomnia complaint (Hansen, Bratlid, Lingiärde and Brenn, 1987). Eight subjects, who were troubled by sleep disturbance (advanced sleep phase syndrome) for at least a year, had their sleep qualities improved after bright light (4000 lux) exposure (Campbell, Dawson and Anderson, 1993). In summary, light intensity as low as 2000 lux could cause changes in the sleep-wake cycle.

Together with the information on the light intensity for suppressing and phase shifting of melatonin secretion rhythm, it was desirable to use high intensity of light in experiments studying both melatonin and sleep, as more prominent effects might be achieved. Nevertheless, the uncertainties arising from the light-induced reactions in eyes had made the investigator considering whether a high intensity or an optimal intensity of light should be used. The details of the harmful effects of light on eyes are described

in the "Side-effects of bright light exposure". In this study, 2000 to 2500 lux was identified to be the optimal range of light intensity for inducing changes in melatonin and sleep. To confirm the exact light intensity, the duration of light exposure would give some clues.

Duration Comparing with their previous work, Blehar, Rosenthal, Terman and Wehr (1990) suggested that, in their two-week treatment condition, there was a reciprocal relationship between intensity and duration. Their work illustrated that the remission rate of subjects with winter-depressed disorder receiving 30 minutes of 10000 lux morning light was equivalent to those receiving 2 hours of 2500 lux morning light. Based on this reciprocal relationship, the duration required for inducing changes in the melatonin secretion rhythm and the sleep-wake cycle using light intensity of 2000 to 2500 lux was explored.

One-hour light exposure is sufficient to induce suppressive effect on melatonin secretion regardless of the light intensity (McIntyre, Norman, Burrows and Armstrong, 1989). According to Lewy, Wehr, Goodwin, Newsome and Markey (1980), the melatonin level could be decreased to nearly the daytime level within an hour by bright light of 2500 lux. One-hour light exposure seems to be a desirable duration for inducing melatonin suppression when light intensity of 2500 lux is employed. To determine if the duration, one-hour, is long enough to induce phase shifting effect,

several light exposure schedules are examined.

In terms of phase shifting in the melatonin secretion rhythm, different schedules were planned to achieve various alterations. Dijk, Beersma, Daan and Lewy (1989) applied bright white light of 2000 lux for 3 hours in 3 consecutive days on eight healthy adults. Their melatonin rhythms had advanced by an hour. With the presence of constant routine, nine healthy subjects had their melatonin secretion rhythm delayed for 2 to 4 hours after exposing to light of 2500 lux for 4 hours in 2 days (Lack and Wright, 1993). For those with midwinter insomnia, researchers had employed light intensity of 2000 – 2500 lux on the patients for one hour in 5 days (Hansen, Bratlid, Lingiärde and Brenn, 1987). As shown by the above studies, the duration needed to induce phase shifting effect is dependent on, at least, the characteristics of the subjects and the degree of phase shifting. During the formulating of the light exposure schedule, these factors should be taken into consideration.

Investigating the bright light effects on the sleep-wake patterns, Dijk, Cajochen and Borbely (1991) observed a significant increase in sleep onset latencies in subjects exposed to bright light (approximately 2500 lux) for 3 hours immediately prior to nocturnal sleep. Dumont and Carrier (1997) obtained a similar result in their study. In another study, Daurat, Aguirre, Foret and Benoit (1997) reported that after exposure to bright light of 1000

to 2000 lux for three hours, decrease in sleep onset latency, the number of waking after sleep onset and increase in total sleep time were found. Nine patients with midwinter insomnia (mean age = 40.7 years) had their sleep onset latency decreased, total sleep time increased and sleep quality improved after being exposed to 2000 to 2500 lux of bright light for 1.5 hours in five days (Hansen, Bratlid, Lingiärde and Brenn, 1987). Sleep disturbances in patients with Alzheimer's disease were reduced after two-hour (1900 hours – 2100 hours) with light exposure of 1500-2000 lux for a week (Satlin, Volicer, Ross, Herz and Campbell, 1992). It was also found that 2000 lux of evening bright light through a light visor half an hour a day for two weeks could improve sleep quality in ten elderly women who had sleep complaints (Cooke, Kreydatus, Atherton and Thoman, 1998). Similar to the mentioned situation in the phase shifting of melatonin secretion rhythm, the duration needed to induce alterations in sleep-wake patterns is partly determined by the nature of the subjects. Melatonin is suppressed promptly by light but needs time to initiate phase shifting. Sleep-wake cycle will demonstrate light-induced effects after at least 3 hours bright light exposure (> 1000 lux). With reference to the findings of the above studies, to induce effects on both sleep and melatonin by a 2500 lux white light, the exposure time should be around 3 hours for 2 to 3 days. Regarding the exact duration (2 or 3 days), it can be determined by the feasibility of the study.

Timing According to Czeisler, Kronauer, Mooney, Anderson and Allan (1987), there was no therapeutic difference between morning bright light and evening bright light in depressed patients. In fact, findings on patients with seasonal affective disorder also supported this idea. Researchers found that there was no difference in efficacy ratings between light treatment in both morning and evening, morning only and evening only (Oren, Shannon, Carpenter and Rosenthal, 1991). However, some researchers have found differences. To obtain a maximal phase shifting effect, Lewy, Ahmed and Sack (1996) proposed to have the bright light exposure period scheduled at the time it was not normally present. Thus, bright light during the day would not be a good choice. Twilight transitions were the most desirable time for causing phase shifting effect. A similar schedule was also suggested by Czeisler and associates (1989) in earlier years. They proposed that when bright light was applied at about 2 to 3 hours before habitual wake time, a largest phase shift could be obtained. When there is a great contrast between light and dark, there will be a stronger coupling strength (a function of the range of its oscillation) of the time giver (Moore-Ede, Sulzman and Fuller, 1982). Hence, greater light-induced effects can be attained if bright light is applied during twilight transitions. In elderly people, the sleep-wake cycle will mostly advance with aging (Swift and Shapiro, 1993). For those with phase advance, bright light should be scheduled in the evening (Campbell, et al., 1995a). Therefore, evening bright light at the twilight transition is recommended to

be used in elderly people with phase advance problem.

Position of the light sources Suprachiasmatic nuclei (SCN) are suggested to be one of the important pacemakers in human beings and is located in the hypothalamus. It is directly connected to the retina through the retinohypothalamic tract. The light-dark signals being transmitted from the retina to SCN through the tract are then sent to the other parts of the brain and body (Reiter. 1988: Hyman. 1990). Whenever the photic pathway used by the circadian system remains functionally intact. entrainment can be achieved even in blind subjects (Czeisler. et al.. 1995). Eyes are suggested to be a medium for light to induce effects on our circadian rhythm (Dijk. Cajochen and Borbely. 1991). In the case of melatonin synthesis. the eye is. therefore. the major site for receiving light stimulus.

The synthesis of melatonin takes place mainly in the eye but it can also be found in other parts of the body. Several studies have demonstrated that pinealectomy only causes a reduction in melatonin level but does not completely eliminate the source. Ralph (1981) believed that the pineal gland was the main but not the unique source of melatonin production. Verified by different studies on the detection of melatonin. some researchers have accepted that the synthesis of melatonin can take place in the retina. Harderian gland of mammals. rabbit blood platelets and the

gastrointestinal tract (Ralph. 1981: Delagrange and Guardiola-Lemaitre. 1997). Receptors or affinity sites for melatonin are found in different parts of the human body such as the brain. retina. intestine. granulosa cells. kidney. lymphocytes. platelets. spermatozoa and malignant melanoma cells (Pang. et al.. 1996). In view of the availability of different synthetic sites of melatonin. some researchers try to identify the sites which can react to light stimulus. After the popliteal region was exposed to light. Campbell and Murphy (1998) observed a phase delay in both core body temperature and the melatonin cycle. Repeating the same experiment with a similar protocol. Lockey and associates (1998). however. could not detect any light-induced suppressive effect on the subjects' nocturnal melatonin levels. Thus. extraocular transduction of light does not have a strong role in altering melatonin synthesis. In addition. another study has illustrated that greater antidepressant effects can be obtained by applying light to the eyes rather than to the skin (Wehr. Skwerer. Jacobsen. Sack and Rosenthal. 1987). In conclusion. the eye is the preferred site for receiving light stimulus though it is not the only site for melatonin synthesis.

Side effects of bright light exposure

It is undeniable that light treatment has benefits for the patient but. at the same time. it possesses some side effects. The common side effects mentioned are headache and eye problems (Oren. Shannon. Carpenter and

Rosenthal, 1991; Levitt, et al., 1993; Rosenthal, et al., 1993; Budnick, Lerman and Nicolich, 1995; Kogan and Guilford, 1998). Eye problems include eye strain (Levitt, et al., 1993; Rosenthal, et al., 1993; Kogan and Guilford, 1998), increased sensation of glare (Terman, Reme, Rafferty, Gallin and Terman, 1990; Budnick, Lerman and Nicolich, 1995; Gallin, et al., 1995; Kogan and Guilford, 1998), seeing spots (Kogan and Guilford, 1998), and blurring and irritation (Gallin, et al., 1995; Kogan and Guilford, 1998). In addition, other side effects have also been identified such as fatigue (Rosenthal, et al., 1993), insomnia (Oren, Shannon, Carpenter and Rosenthal, 1991; Labbate, Lafer, Thibault and Sachs, 1994; Budnick, Lerman and Nicolich, 1995), heat (Budnick, Lerman and Nicolich, 1995), feeling "wired" and nausea (Levitt, et al., 1993) and mania in two patients with major mood disorders (Schwitzer, Neudorfer, Blecha and Fleischhacker, 1990).

It seems that there are many light-induced side effects but some of them may be reduced or may disappear after bright light exposure and some are not reported in other studies. Mania and insomnia are examples of the side effects. In the study conducted by Rosenthal and colleagues (1993), there was no record related to mania in patients with seasonal affective disorder after bright light exposure. Other studies have shown that even if bright light is applied immediately before bedtime, it will not cause or aggravate insomnia (Campbell, et al., 1995a). Kogan and Guilford (1998)

also reported that no insomnia was identified after light treatment in their study. In fact, one study conducted on 17 patients with seasonal subtype depression and 19 patients with no seasonal pattern depression, using a similar experimental protocol (two hours for a week 2500 lux, full spectrum), found only one patient with seasonal affective disorder who complained of headache. No more side effects were reported by the other patients (Özkan and Arik, 1994). Apart from the low rate of occurrence, a large proportion of subjects suffering from eye irritation, photophobia, swollen eyes and blurred vision during light exposure had decreased in reporting the complaints after light exposure (Gallin, et al., 1995). Similarly, Kogan and Guilford (1998) observed that during and after bright light exposure, the side effect report rate declined from 34.3% on Day 1 to less than 10% on Days 4 and 5. Therefore, light-induced side effects did not occur in all studies using light exposure. Even though side effects occur, they occur transiently. They reduce or disappear after the light exposure.

In reality, light therapists are also concerned about damage to eyes connected with bright light exposure. Vanselow, Dennerstein, Armstrong and Lockie (1991) claimed that light intensity of 2000 lux might cause damage to the retina of susceptible eyes and worsen the condition of retinopathy. Dissenting from this, Waxler and colleagues (1992) asserted that a light intensity of 2000 lux only corresponded to the situation during

sunset and sunrise. According to their estimation, the threshold for inducing photoreceptor damage in the human retina would be at least 10800 lux bright light applied for over 6400 half-hour sessions. Using fluorescent lamps of 10000 lux, which emitted negligible ultraviolet radiation, for 2 to 6 weeks, Blehar, Rosenthal, Terman and Wehr (1990) stated that no ocular pathological changes were found and no findings of such changes were received even after two full seasons. Similarly, no opthalmological abnormalities were detected after 10000 lux bright light exposure in another study (Terman, Reme, Rafferty, Gallin and Terman, 1990). For the sake of convenience and increasing the effectiveness of the therapy, Kogan and Guilford (1998) even suggested that light therapy using 2500 lux might be replaced by 10000 lux. Consolidating the ideas from these researchers, the investigator finds a light intensity of 2500 lux does not do harm to our eyes.

Light treatment will not induce damage to normal eyes, it also will not worsen the abnormal ones. A patient diagnosed with idiopathic preretinal fibrosis was exposed to bright light of 10000 lux for 30 minutes each day in the treatment. The patient's mild red-green colour vision defect and his altered Amsler grid perception secondary to the preretinal fibrosis were not worse after bright light exposure. Two patients with pre-existing retinal scars had reported no clinical change after being exposed to 10000 lux bright light for 30 minutes each day. Similarly, no change in colour

perception and visual fields after exposure to bright light of 10000 lux for 30 minutes each day was observed by Gallin and associates (1995). With reference to their findings, there were no clinically significant abnormalities identified by visual acuity, ocular motility, intraocular pressure, Amsler grid perception and slit lamp and fundus examinations after light treatment for other side effects. Light exposure is, therefore, confirmed not to worsen abnormal conditions of the eyes.

In the case of glaucoma, the increase in intraocular pressure (IOP) is responsible for the damage in the optic nerve (Kitazawa, 1989). Thus, any dramatic change in IOP may worsen the condition of glaucoma. Similar to melatonin, IOP possesses a diurnal nature but with its maximum during the day and minimum in the early morning. This effect is so weak that sleep can override its fluctuation. With the presence of sleep, IOP increases and remains low when awake (Frampton, Da Rin and Brown, 1987). IOP is significantly increased in the first 30 minutes of sleep in normal subjects (Brown, Morris, Muller, Brady and Swann, 1988) but returns to the baseline within 20 minutes after waking (Brown, Burton, Mann and Parisi, 1988). During bright light exposure, the sleep parameters may be altered quickly which, in turn, may induce a sudden alteration in the IOP. Such dramatic change in IOP has led some researchers to worry about the effects on people with glaucoma. A study had shown that people with 'high-normal' IOP, who had no visual field

defects, only slightly increased their maximum IOPs after sleep compared to subject with 'low-normal' IOP (Wildsoet, Eyeson-Annan, Brown, Swann and Terry, 1993). As evidenced by the narrow range of change in IOP, the change of sleep-wake parameters in those with glaucoma may not have any harmful effects on them.

Regarding the concern about the alteration in the melatonin level, Brown, Burton, Mann and Parisi (1988) stated that the increase in IOP is most probably related to a reduction in the pumping of aqueous humor from the eye during sleep but not the secretion of melatonin. It has been found that melatonin production begins earlier at night but stops earlier in the morning (Reiter and Robinson, 1995). The nocturnal melatonin level is higher than that during the day (Laakso, Porkka-Heiskanen, Alila, Peder and Johansson, 1988) and the melatonin production is not prevented or suppressed by any waking at night (Vaughan, Allen and De La Peña, 1979; Claustrat, Brun, Garry, Roussel and Sassolas, 1986; L'Hermite-Baleriaux, et al., 1989). IOP is, however, decreased while staying awake until midnight (Frampton, Da Rin and Brown, 1987). As a conclusion, the change in melatonin level may not have a direct effect on the IOP. It is known that a lower IOP has been detected during bright light exposure. After exposing to light and then dark conditions, there is a significant increase in IOP with dark condition influential (Wildsoet, Eyeson-Annan, Brown, Swann and Terry, 1993). The fluctuation in IOP, therefore, should not do harm to those with

glaucoma through the changes in melatonin production. Since the alterations in both sleep-wake parameters and melatonin levels will not induce a harmful change in IOP of those with glaucoma, it is worth trying light treatment with patients having glaucoma when necessary (Gallin, et al., 1995).

Leaving aside glaucoma, light intensity is still a concern during bright light exposure as side effects have been discovered in a study using 400 lux bright light (Rosenthal, et al., 1993). To investigate the side effects of light therapy using different light intensities (60 lux, 600 lux and 3500 lux), Levitt and colleagues (1993) reported that side effects were independent of the illumination level. This has been supported by Gallin and associates (1995). They stated that no ocular abnormalities were found in seasonal affective disorder patients, who were exposed to artificial light in the morning or evening for 30 minutes at 10000 lux, neither after short-term light treatment (two to eight weeks) nor after three to six years of usage. Kogan and Guilford (1998) had even said that if side effects were present, the effects caused by bright light using 10000 lux were much the same as those caused by the much lower light intensity (2500 lux) and with longer exposure hours (4 hours). To achieve a more effective and convenient light therapy, they suggested that patients might consider using higher intensity instead of 2500 lux in their light treatments. Therefore, light intensity would not be a focus when discussing the side effects of bright

light exposure.

There is a lot of evidence shown that bright light exposure is safe. Nevertheless, measures should be taken to ensure safety. Vanselow, Dennerstein, Armstrong and Lockie (1991) firmly held the belief that ophthalmological examination should be conducted before bright light exposure. They insisted that patients should take an examination even though they had no history of eye complaint because they thought that artificial bright light could exacerbate any existing retinopathy. Waxler and colleagues (1992) recommended screening out ultraviolent rays during bright light exposure. Patients with aphakic eyes, actively degenerating retinal disorders and those treated with hematoporphyrin or any highly light-sensitive compounds should not receive light therapy. With reference to these suggestions, researchers should consider incorporating these preventive measures in their studies with bright light exposure.

Sunlight can be our friend when we enjoy it in the proper way. But, it can also do harm to us when we are exposed to it excessively. In order to explore its therapeutic effects, artificial bright light that simulates sunlight has been used in some clinical studies. Since light is a strong synchronizer, it can entrain many circadian cycles including sleep-wake cycle and melatonin cycle. It can adjust their phases and amplitudes. Therefore, it is possible to induce changes in both sleep-wake cycle and melatonin cycle using light. To initiate such changes,

researchers should pay heed to the features of the bright light being used in the experiment so as to choose an optimal light exposure schedule. The features of exposure include wavelength, intensity, duration, timing and position of the light sources. In addition, the possible side effects should not be neglected. Among the bright light exposure schedules that have been mentioned, 2500 lux white light applied for 3 hours for 2 to 3 days is considered to be effective in inducing changes in both the sleep-wake cycle and the melatonin secretion rhythm. This schedule is regarded as a safe protocol for creating light-induced effects.

The measurement of bright light effects on sleep and melatonin secretion level

The bright light effects on sleep and melatonin secretion level were illustrated by reported sleep quality, recorded sleep-wake parameters and excreted 6-sulphatoxymelatonin (aMT6s) level in this study. The quality of sleep was presented both qualitatively and quantitatively because it could be defined by the subject's own feeling. At the same time, it could be measured using specific instruments. Unlike the quality of sleep, secreted melatonin level was determined in an indirect and quantitative way. Radioimmunoassay technique was used to decide the excreted aMT6s level.

The measurement of the quality of sleep

The quality of sleep can be presented both qualitatively and quantitatively. Qualitatively, only the individual can judge whether his or her sleep is good or not (Closs, 1988). Quantitatively, fragmentation, length, delay and depth of sleep are suggested to be the main factors associated with sleep (Snyder-Halpern and Verran, 1987). Sleep efficiency (dividing total sleep time by total time in bed and multiplying by 100) is an index recommended for the investigation of sleep disturbance in elderly people (Morin and Gramling, 1989). To measure the quality of sleep, both subjective and objective tools can be employed. As subjective tools, self-report methods such as interview, visual analogue scale, subjective rating scales, questionnaire and sleep log are commonly used. The responses of the subjects are recorded either by the subjects themselves or by the researchers. Since the chances of subjective responses, bias and inaccuracy, may not be avoided (Webster and Thompson, 1986; Portney and Watkins, 1993), objective tools are adapted. In sleep studies, observation, polysomnography, static charge sensitive bed and wrist actigraphy are the commonly used objective tools. To decide the suitability of these subjective and objective tools for the study, the investigator had evaluated them with reference to the design of the study.

Interview In the interview, the interviewer can make any necessary

clarification at once. It allows the respondents' behaviour or opinion to be analysed in a deeper way (Portney and Watkins. 1993). In addition. the interview can enable the interviewer to avoid missing data. This method is more appropriate for subjects who have difficulty in reading or writing (Closs. 1988) and is more effective for establishing rapport (Portney and Watkins. 1993). Nevertheless. it requires a lot of time. It is also costly to employ (Closs. 1988; Portney and Watkins. 1993).

Visual analogue scale (VAS) Unlike the interview. VAS is an economical way to evaluate a person's sleep quality. It is the simplest and most effective subjective method for sleep assessment. Many sleep researchers find it useful in examining the effects of different kinds of hypnotics (Roden. Harvey & Mitchard. 1977; Aantaa. Salonen & Nyrke. 1990; Parrino. Boselli. Spaggiari. Smerieri & Terzano.1997). The design of the Verran and Snyder-Halpern (VSH) Sleep Scale used VAS to measure self-reported sleep patterns (Snyder-Halpern and Verran. 1987). VAS allows the raters greater freedom in conveying their feelings as compared with the forced-choice formatted Likert-type scale (Snyder-Halpern and Verran. 1987; Nyren. 1988). However. the raters may find it difficult to grasp the principles in using the scale since they have to create their own scales (Closs. 1988). It was difficult to use the scale without a numerical value and detailed description. so VAS was not employed in this study.

Subjective rating scales Subjective rating scales are inexpensive, simple and useful means of assessing sleep quality (Closs, 1988). The Stanford Sleepiness Scale (SSS) quantifies subjective sleepiness levels by using a 7-point scale (Hoddes, Dement and Zarcone, 1972). Although these scales are easily administered (Closs, 1988), there are several points that should be considered. In contrast to the interview, the scales can serve the purpose of preliminary screening but they may not be precise enough for examining any treatment effects. A study of agoraphobic subjects found exaggerated treatment effects when a subjective rating scale was used (Williams, 1985). Since the items on subjective rating scales can only be described in general terms, no detailed information can be obtained, only a rough picture. The scales, however, are considered to be superior to VAS as they can provide consolidated choices for the subjects. A five-point scale from very good to very poor was included in the study to evaluate the subjective quality of sleep.

Questionnaire Different from VAS and subjective rating scales, questionnaires have their questions set in a more specific way so that the researchers can obtain a more precise answer (Closs, 1988). Questionnaires can be designed in a simple and general way to investigate a phenomenon epidemiologically. Alternatively, they can be designed in a more detailed way with the focus mainly on the quantitative measures for the sake of clinical exploration (Buysse, Reynolds III, Monk, Berman and

Kupfer. 1989). For example. the Pittsburgh Sleep Quality Index (PSQI) was originally designed for clinical purpose. so it is more empirical than statistical. It allows direct comparisons between individuals or groups (Buysse. Reynolds III. Monk. Berman and Kupfer. 1989). The St. Mary's Hospital Sleep Questionnaire (SMH) is designed specifically for hospitalised adults. It tests both the subconcepts of sleep disturbance and sleep effectiveness (Richardson. 1997). Although being simple and useful. the questionnaire does have its disadvantages. There is potential for misunderstanding or misinterpreting questions (Portney and Watkins. 1993). To counteract this shortcoming. the researchers can fill in the questionnaire by themselves. Since the sleep habits and life style of the subjects had to be examined before the commencement of the experiment. a questionnaire was designed accordingly.

Sleep log This is a daily. written record of an individual's sleep-wake pattern (Closs. 1988). Compared with the retrospective questionnaire. the sleep log seems to be more reliable (Lacks. 1988). It contains parameters such as bedtime. rising time. sleep onset latency. number and duration of waking. time of last waking. naps. medication intake and some indices of sleep quality (Morin. 1993). Factors which will influence sleep are also included coffee. alcohol and cigarette consumption (Sweeney. 1989).

As a self-report instrument. the sleep log of elderly people is not as accurate

as that of electroencephalogram (EEG) (Webb, 1982). Rogers, Caruso and Aldrich (1993) also found the self-report data inaccurate in subjects with frequent short naps or disorders of excessive daytime sleepiness. Regardless of these inaccuracies, Chambers (1994) stated that sleep log could provide a more detailed view of the insomniac's sleep patterns over an extended period of time. Bootzin and Engle-Friedman (1981) considered sleep log superior to EEG as it could detect any perceptual or cognitive distortions related to the disorders. Concerning the discrepancies between sleep log and other sleep measuring instruments, Lacks (1988) had pointed out that, for sleep onset latency, a different definition of sleep onset would contribute different results. If sleep onset was defined as the first 15 minutes of stage 2 sleep, reports from insomniacs would be very accurate. In addition, the discrepancies between sleep log and EEG's recordings were consistent and constant to 10 to 25 minutes. The determining factors in using the sleep log are how to motivate subjects to record their daily sleep condition (Closs, 1988) and how to avoid data loss caused by forgetfulness (Bootzin and Engle-Friedman, 1981). As suggested by Rogers, Caruso and Aldrich (1993), the sleep log will be more reliable if subjects can fill out it immediately after waking. Thus, the sleep log is concluded to be a trustworthy instrument to measure sleep quantity when the recruitment of subjects is made with caution. Being an economical and reliable method of measuring sleep (Bootzin and Engle-Friedman, 1981; Rogers, Caruso and

Aldrich, 1993), the sleep log is helpful in exploring the experiential component of any sleep disorders. Therefore, it was employed in the study to detect the light effects on sleep quality of those complaining of sleep disturbances or who had the desire to improve sleep.

To sum up, an economical, efficient and reliable way to measure an individual's sleep quality was preferred by the investigator. A five-point subjective rating scale was used to evaluate the subjective quality of sleep while questionnaire and sleep log were employed to get the preliminary information about the subjects' sleep and to investigate any changes in sleep-wake pattern after an experimental variable was applied. Nonetheless, the self-report data of the subjects was, to some extent, subjective. A comparatively accurate and objective method should be used in addition to these sleep measuring instruments.

Observation As one of the objective methods, observation is a non-intrusive way to measure sleep. It can be conducted intermittently by the observer or continuously using video camera or closed circuit television. By observation, we can roughly discriminate between the sleeper's wakefulness and sleep. In this way, sleep duration can be estimated. Nevertheless, observation limits the further study of one's sleep quality and quantity (Closs, 1988). Using the Observational Sleep Assessment Instrument (OSAI) to observe different variables related to sleep and

breathing pattern. Cohen-Mansfield. Waldhorn. Werner and Billig (1990) claimed that OSAI was a reliable and valid tool to measure sleep in elderly people living in nursing homes. The same is not the case for polysomnographic measures. When compared with the related somnographic recording. nurse reports were found to consistently over-estimate sleep time (Aurell and Elmqvist. 1985). Observation can only outline the sleep conditions of the subjects but cannot provide a detailed description of sleep.

Polysomnography (PSG) In order to study sleep at a detailed level. polysomnography is considered to be the best method for small scale studies (Closs. 1988) but not large ones (Webster and Thompson. 1986). Compared with other methods. it is rather intrusive. expensive (Friedman. Brooks III. Bliwise and Yesavage. 1993) and time-consuming (Webster and Thompson. 1986). By using recordings from electroencephalogram (EEG), electro-oculogram (EOG) and electromyogram (EMG). the onset. progress and depth of sleep can be estimated (Closs. 1988). In addition. examination of both sleep stages and consciousness level can be achieved. Although it is considered to be the gold standard for studying sleep (Sadeh. Hauri. Kripke and Lavie. 1995). it does have some shortcomings.

Interpretation of EEG recordings is considered to be one of the shortcomings. It can be observed in an EEG track that stage changes are

slow and each non-rapid eye movement (NREM) stage is merged with another. Such unclear illustrations not only cause difficulties for scorers to interpret stage changes, but also reflect the fact that the interpretation of EEG recordings is scorer dependent. The presence of first night effects is also factors affecting the objectivity of EEG (Le Bon, et al., 2000). In addition, sleep-wake patterns of high variability and effects of the environment on sleep quality tend to increase the difficulties of assessing sleep through EEG (Sadeh, Hauri, Kripke and Lavie, 1995). In terms of the effects of the environment, portable telemetry techniques allow sleep studies to be carried out at home, thus alleviating the effects that are brought about in the laboratory. It traces polysomnographic data on to audio cassettes which may be played back and decoded through a visual display unit. However, the employment of portable telemetry techniques is very expensive (Closs, 1988).

The static charge sensitive bed This includes a thin, pressure-sensitive pad, which is placed under the bed sheet or mattress of the subject's bed. After signals are amplified, they are recorded in a small data recorder. The generation of signals is mainly dependent on potential difference produced by respiration and body movements. Compared with polysomnogram, the static charge sensitive bed is a nonintrusive and natural method in studying sleep, because the subjects need not attach any cables or instruments and the study can be conducted in their homes. In

addition, they are allowed to engage in many activities in bed according to their habits (Alihanka and Vaahtoranta, 1979; Cooke, Kreydatus, Atherton and Thoman, 1998). In Hong Kong, the limitation in space restricts the activities of many elderly people in their beds. It is very important in studying sleep that subjects do not change any habits during recording. The static charge sensitive bed is a favoured instrument for sleep study but only a few subjects can be involved at any one time. Since it is not a low-priced product, its application is limited to small scale studies.

Wrist actigraph As an unobtrusive and easily implemented tool, the wrist actigraph is another instrument recommended for use in sleep studies. Wrist movements are used as indicators of restlessness or sleep (Closs, 1988). Similar to the static charge sensitive bed, it allows subjects to sleep in their usual and familiar environment so that disturbances in sleep pattern and habits can be minimized (Beck-Little and Weinrich, 1998). Compared to the static charge sensitive bed, the actigraph can record the subjects' information about napping during the daytime when they do not go to bed (Tryon, 1996). Owing to its comparatively reasonable price, it is more economical to have it as a measurement tool in a large scale sleep study. Nevertheless, it has its disadvantages.

When sleep occurs, muscles will relax and body movements will diminish (Closs, 1988; Tryon, 1996). Body movement occurs about 20 to 60 times

per night (Kleitman, 1963). Since wrist actigraph uses motility measurement as an indicator of sleep, we can only estimate the duration of sleep but not sleep quality. In addition, any interferes with movement will affect the interpretation of sleep. In the case of patients suffering from pain, body movements are decreased and this may be misinterpreted as the presence of sleep (Closs, 1988). Similar conditions were found in those with psychophysiologic insomnia. The total nocturnal sleep time was overestimated by the actigraph in these subjects because they tended to lie on the bed relatively motionless even when awake. For people suffering from movement disorders, tremors, or other forms of activity or inactivity patterns, the validity of actigraphic sleep-wake scoring might also be significantly compromised. Periodic limb movement disorder (PLMD) was one of the examples. There was a greater discrepancy in accuracy between PSG and wrist actigraph. The percentage agreement between these two instruments could be as low as 41.3% when used for severe PLMD cases (Sadeh, Hauri, Kripke and Lavie, 1995).

The misinterpretation of sleep due to inactivity causes errors in scoring but the related minute-to-minute agreements and correlation between actigraph and PSG is very high. Of 102 subjects in which there were 39 patients, nearly all of them who reported a certain degree of insomnia, revealed a low correlation ($r = 0.25$) between actigraph and PSG in the measurement of number of midsleep waking (Mullaney, Kripke and Messin, 1980).

However, the associated correlations on total sleep period, total sleep time and minutes of wakefulness after sleep onset were very high ($r > 0.70$). High correlation ($r = 0.79$) on sleep efficiency between PSG and actigraphic data was also found in the study conducted by Sadeh, Alster, Urbach and Lavie (1989). Correlations between PSG and actigraphic data are not high in all the sleep-wake parameters because the actigraph cannot record the exact amount of sleep (Hauri and Wisbey, 1992). Nevertheless, the considerably high minute-to-minute agreements and correlation between actigraph and PSG make the data acceptable (Sadeh, Hauri, Kripke and Lavie, 1995). In addition, the consistency of the actigraphic data from night to night is good (van Hilten, et al., 1993; Chambers, 1994). Because of this, any inaccuracy will remain constant throughout the study. Such consistency also suggests that there will be no first night effects when using the actigraph (van Hilten, et al., 1993). When employed in longitudinal studies or in evaluating sleep pattern changes throughout a treatment, the wrist actigraph is considered to be a reliable tool (Hauri and Wisbey, 1992; Chambers, 1994).

Apart from the validity and reliability of the actigraph, researchers should also pay attention to the issue of artifact. The common artifacts cited by previous researchers are breathing artifact and artifact caused by bed partner or any unusual mattress or bed. Placing the actigraph on wrists or under the head or stomach during sleep will influence the recordings.

Similarly, an active bed partner or an unusual mattress or bed such as a waterbed, or a rocking instrument for a crib may also induce artifact occurrence (Sadeh, Hauri, Kripke and Lavie, 1995). Concluding the issues of validity, reliability and artifact of actigraph, the investigator would not apply actigraph on those with movement disorders. With those sleeping with a partner and sleeping on an unusual mattress or bed, actigraph would not be the preferred sleep measuring instrument. In view of the fact that high correlations between PSG and actigraphic data were not found in all the sleep-wake parameters, the investigator suggested that wrist actigraph should not be used alone.

Combined use of subjective and objective tools To get a clearer picture of an individual's sleep-wake pattern throughout the experiment, it is necessary to include both subjective and objective tools in the measurement of sleep. It has been suggested that actigraphy and sleep log can complement each other (Sadeh, Hauri, Kripke and Lavie, 1995). Both sleep log (Closs, 1988) and actigraphy (Hauri and Wisbey, 1992; Chambers, 1994) were described as most useful in longitudinal or long-term studies. Actigraphy providing objective rest-activity information can report activities in detail. These activities may be sometimes ignored by the subjects (Sadeh, Hauri, Kripke and Lavie, 1995). Sleep log can supplement the actigraphic motility data by introducing perceived sleep information. Combining the characteristics of actigraphy and sleep log,

researchers have found that they can clearly display the sleep-wake patterns of their subjects.

Actigraphy and sleep log can complement each other because they are measuring different dimensions of sleep. Because of this, discrepancies have been found in data collected by actigraphic and sleep log measures. For instance, in a study conducted on patients with insomnia associated with chronic musculoskeletal pain, the sleep onset latencies recorded by actigraph were shorter than those recorded by a sleep log. The average number of waking recorded by actigraph was much more than that recorded by sleep log (Wilson, Watson and Currie, 1998). Reanalysis of the data of the study conducted by Hauri and Wisbey (1992), Chambers (1994) revealed that the total sleep time obtained from a sleep log was often underestimated but, for actigraph, it was either under- or overestimated. Based on his observation, Chambers (1994) claimed that the sleep log could provide more reliable information than the actigraph whereas Hauri and Wisbey (1994) insisted that actigraphic measurement was more exact than that of the sleep log. Facing these discrepancies, researchers can choose actigraphy as the major source of sleep information when subjects are considered not to recall details as accurately as young adults do. In response to the inadequacies of the actigraphy, researchers can employ the sleep log to supplement the motility recording with perceived sleep information in the hope of figuring out the details of a person's sleep-wake

pattern.

The measurement of 6-sulphatoxymelatonin (aMT6s) level

In order to detect light-induced alterations in melatonin secretion level, we can study the level directly through blood and saliva or indirectly through its main metabolite, urinary 6-sulphatoxymelatonin (aMT6s). To determine the mode of monitoring, the investigator had considered these three media independently. There seems to be no doubt that serum can reflect the amount of melatonin secreted but the insertion of a cannula is found to be invasive. According to Vitiello and associates (1996), periodic blood sampling through indwelling catheter could affect sleep in elderly people, particularly in elderly women. Since the sleep conditions of the subjects were investigated in this study, it was not appropriate to involve invasive measures that might disturb the subjects' sleep. Besides, most Chinese elderly people dislike blood tests. Hence, blood was not chosen as a source of data on secreted melatonin in this study.

Saliva is another relatively direct medium for the measurement of melatonin secretion. The collection of saliva samples is not as invasive as blood sampling. According to Sack, Lewy, Blood, Stevenson and Keith (1991), the serum dim light melatonin onset (the onset of melatonin production), DLMO, was 10 pg/ml. For salivary DLMO, it was 4 pg/ml

which was lower by a factor of 2.5 (Nagtegaal. et al.. 1998). In view of the association between serum melatonin level and salivary melatonin level and the convenience in collecting samples. saliva is a desirable collection medium. Nevertheless. residue food such as cheese and potato chips (McIntyre. Norman. Burrows and Armstrong. 1987) and the use of toothpaste and coffee too near the collection time of saliva samples (Reiter. 1988) can interfere with the results of the melatonin radioimmunoassay. Most importantly. this sampling method has to wake up the subjects and that will interfere their sleep (Nagtegaal. et al.. 1998). For these reasons. it was not chosen as a collection medium in this sleep study.

Urine sample collection. being a non-invasive. convenient and natural sampling method. is superior to blood sampling and the collection of saliva samples in sleep studies because urine samples can be collected whenever the subjects urinate. so that sleep is not disturbed. After melatonin is secreted. about 92-97% of melatonin is cleared by the liver (Pardridge and Mietus. 1980). Before being excreted through the kidney. 70-80% of melatonin is hydroxylated and conjugated with sulphate by liver microsomes. Urinary 6-sulphatoxymelatonin (aMT6s) is the major melatonin metabolite and it is considered to be a reliable index of melatonin production (Matthews. et al.. 1981). The time lag between nocturnal onset of melatonin and aMT6s is about an hour (Waldhauser. et al.. 1984). Referring to Arendt. Bojkowski. Franey. Wright and Marks (1985). aMT6s

was stable in urine for at least 24 hours at 4°C and at least 6 months at -20°C. In addition, the amount can be revealed by the most popular technique, radioimmunoassay (RIA). In view of the short time lag and long storage period of aMT6s and the availability of a good method of analysis, urine is the most desirable medium for estimating melatonin levels in sleep studies.

Evaluating the strengths and the limitations of the sleep measuring instruments, the investigator found the subjective rating scale was the most suitable tool to determine the subjective quality of sleep in this study. Before the commencement of the experiment, a questionnaire was needed to investigate the sleep histories and current sleep conditions of the subjects. The combined use of sleep log and actigraphy was reliable enough to measure the sleep-wake parameters of the subjects throughout the experiment. The bright light effects on sleep were determined both subjectively and objectively by these sleep measuring instruments. To examine the light-induced effects on melatonin secretion, urinary aMT6s level was considered to be the best choice, as the collection of urine samples would not disturb the subject's sleep. In view of it being the major metabolite of melatonin and the availability of RIA technique, urinary aMT6s level was used to estimate any changes in the melatonin secretion pattern.

Summary

Sleep architecture in human beings will change with the advancing of age. Along with aging, sleep disturbance appears. It is not clear if sleep deprivation can be compensated by a nap or by modifying some sleep-related factors. The commonest disturbances reported are difficulty in initiating sleep (DIS), difficulty in maintaining sleep (DMS) and early morning awakening (EMA) of which DMS is the most common sleep complaint. Insomnia is one of the commonest health complaints amongst elderly people and the administration of sleeping pills is the major way to manage sleep disturbances. Owing to the disadvantages in administering sleep medications, there is some incentive to find alternative approaches to sleep management.

The diurnal rhythm of melatonin changes with age too. Melatonin is a phase marker for circadian rhythm and its synchronizing power is stronger than that of core body temperature (CBT). Since CBT is related to sleep and some studies also demonstrates a correlation between melatonin and sleep, it is possible that alterations in the melatonin level may induce changes in the sleep-wake cycle. In addition, exogenous melatonin has been found to be effective in dealing with jet lag and insomnia. Therefore, melatonin should have a role in sleep regulation.

Light is a strong synchronizer for circadian cycles. Its entraining power is even stronger than that of the sleep-wake cycle and melatonin secretion rhythm. It is observed that an appropriate bright light exposure schedule (2500 lux white light for 3 hours for 2 to 3 days) can induce changes in both the melatonin cycle and the sleep-wake cycle. Although side effects occur during bright light exposure, these effects will fade during the experimental period. The schedule of 2500 lux for 3 hours for 2 to 3 days is supposed to be a safe protocol for light exposure. Employing this schedule, the investigator queried whether the sleep-wake pattern could be regulated using light-induced melatonin alteration.

To investigate the relationships between melatonin, bright light and sleep, both subjective and objective tools have been used together to measure sleep quality. Among the quoted self-reported methods, questionnaire and sleep log were considered to be the most economical and effective way to check a person's sleep-wake pattern and sleep satisfaction. Considering the factor of feasibility, the investigator decided to employ wrist actigraph as an objective method to collect data on sleep-wake patterns. Along with the sleep log, wrist actigraphic recording was found to be a desirable method for determining sleep-wake patterns. In order to measure the changes in the melatonin level, urine was found to be the most favourable medium. Urinary aMT6s level can be analysed by the RIA technique. Having made these decisions, the investigator formulated the method of the study accordingly in Chapter 4.

Chapter 4

The Method of Study

Introduction

After reviewing the studies on sleep, melatonin and bright light, the need to explore the bright light effects on an individual's sleep and melatonin secretion in a real world situation was revealed. In formulating the method of this field study, feasibility should be taken into consideration. This chapter describes the related research design, sampling, instruments, equipment and techniques for data collection. Followed by data analysis, it also outlines the process of data collection that does not disturb the daily routine of the subject. In addition, the ethical consideration is presented.

Research design

This was a quasi-experimental study with intra-subject comparison. Perceived quality of sleep was a major dependent variable in this study. One's quality of sleep is best determined by oneself (Closs, 1988); therefore, intra-subject comparison was adopted. Aging likely brings cataract, hypertension, asthma,

arthritis and diabetic mellitus. One advantage of this design is to minimise the possible confounding effects due to their health conditions. This strategy, in addition, is not a concern on the issue of random assignment because the subjects have to undergo both the control and experimental conditions. Being the most efficient method to control inter-subject differences, intra-subject control can ensure the highest possible degree of equivalence across experimental conditions. Intra-subject control appreciating the uniqueness of each subject and allowing the measurement of subjective feelings is the best way to control extraneous variables (Portney and Watkins, 1993). In view of the reporting of significant experimental effects in studies with intra-subject control (Byerley, et al., 1989; Lack and Wright, 1992; Lemmer, et al., 1994; Tzischinsky and Lavie, 1997; Cooke, Kreydatus, Atherton and Thoman, 1998), the control group was replaced by the intra-subject control in this study.

Apart from intra-subject control, this quasi-experimental study was characterised with the use of convenience sampling technique in subject recruitment. Subjects were recruited on the basis of availability. Unlike random sampling, convenience sampling is limited by the potential bias of self-selection (Portney and Watkins, 1993). Nevertheless, the limitation had shown that there was an urge to seek improvement in the quality of sleep as only those who were not satisfied with their quality of sleep would participate into this study. The convenience sampling technique was a preferred method to recruit subjects for the investigation of sleep management.

This study was comprised of three stages: the pre-bright light exposure stage, the bright light exposure stage and the post-bright light exposure stage. Each stage lasted two days. To determine the two-day duration in each stage, maturational effects and motivational influence were considered. Maturation effect causes alterations in the dependent variable as time passes by. This effect will have an impact on the internal validity (Partney and Watkins, 1993). Tiredness was one of the possible maturation effects in this study. Motivational influence related to the effect on a person's motivation to complete this study. A long phase length (at least four days per stage) can detect the maturation effect or any erratic pattern changes (Partney and Watkins, 1993) before and after bright light exposure; however, it may induce the motivational influence. Therefore, to balance the advantage and disadvantage of these two factors, the investigator had dealt with the motivational influence first. Thus, a short phase length (2 days per stage) was adopted. To minimise the maturation effect or any erratic pattern changes, home, instead of sleep laboratory, was chosen to be the place for conducting the experiment. Home is the usual sleeping place of the subjects. Subjects did not need to spend extra energy on adapting to a new environment. The influences of the extraneous variables were already constantly acting on the subjects, so the confounding effects of the extraneous variables would remain constant. Any maturational trends related to tiredness might be minimised because travelling between home and the sleep laboratory was avoided. Home providing a stable environment for sleep study can retain the internal validity of the study. Together with the consistency of actigraphic recording (van Hilten, et al., 1993; Chambers, 1994) and the absence of the first night effect

in melatonin (Claustrat, Brun, Garry, Roussel and Sassolas, 1986), a two-day phase length per stage was adequate to demonstrate the experimental effects in a home setting environment. A detailed description of the determination of the study design is presented in the "Factors for synchronization" in the Chapter 3.

White bright light was applied to the subjects in the bright light exposure stage. Red dim light used as a placebo was applied to the subjects in both pre- and post-bright light exposure stages. In the pre-bright light exposure stage, the first day was set for adaptation while the second day was used in the establishment of baseline. Data collected on Day 2 served as control data whereas data collected in the bright light exposure (Day 3 and Day 4) and post-bright light exposure stages (Day 5 and Day 6) served as experimental data (Table 4.1). Using the method of intra-subject, changes induced by the experimental variable were observed by comparing the control and experimental data. Data collected before, during and after bright light exposure acted as a pseudocontrol condition. In this way, the relationship between bright light, sleep-wake parameters, excreted 6-sulphatoxymelatonin (aMT6s) level and sleep satisfaction level of the subjects could be determined.

Table 4.1 The Outline of the Experiment

Day and Stage	Intervention	Data Collected*
Day 1 - Day 2 Pre-bright light exposure stage	Red dim light exposure	Day 1: served as adaptation Day 2: served as control data (Baseline)
Day 3 - Day 4 Bright light exposure stage	White Bright light exposure	Day 3: Data served as experimental data Day 4: Data served as experimental data
Day 5 - Day 6 Post-bright light exposure stage	Red dim light exposure	Day 5: Data served as experimental data Day 6: Data served as experimental data

* The types of data included sleep satisfaction level, sleep-wake parameters and 6-sulphatoxymelatonin level.

Sampling

To deal with a sleep disturbance in a real situation, home, instead of sleep laboratory, was chosen to be the experimental environment for the study even though most of the variables interfering with sleep could be controlled in a laboratory. Regestein and Rechs (1980) suggested **home** as the best place to study sleep while Lemkin (1996) claimed home as a relatively low-cost and more comfortable environment for subjects. According to Edinger and associates (1997), polysomnography recordings in the laboratory demonstrated greater first night effects than those recorded at home. Hence, the home seems to be a better place to study sleep. Factors such as travelling between home and the sleep laboratory may change one's sleep quality. As such the investigator decided to have the whole study, including the bright light exposure, conducted in the subjects' homes.

Elderly people were invited to join this study. As aging progresses, sleep architecture undergoes certain changes (Swift and Shapiro, 1993). Elderly people begin to complain about their sleep (Orr, Altshuler and Stahl, 1982). Insomnia has been reported as one of their common health complaints (Morin and Gramling, 1989). Because of the reported correlation between sleep disturbance and increasing with age (Karacan, Thornby and Williams, 1983), sleep quality in elderly people should be a cause of concern. As mentioned before, home is a favourable environment to study sleep. It is more realistic and practical to help elderly people at home than in the laboratory. Nevertheless, the variables interfering with sleep, which cannot be well-controlled in a field setting, may confound the results. To minimize the confounding variables, subjects were recruited from elderly care homes. Sleeping in an equivalent environment and living under a similar daily routine, they were expected to be of high homogenity. Taking these factors into consideration, the investigator decided to recruit subjects from **elderly care homes**.

Female residents were preferable to male residents in this study. For people of 65 years old and above in Hong Kong, more than a half (55%) of the population in this age group is formed by women (Department of Health, 1996-1997). In addition, insomnia has been more frequently reported in elderly women than in elderly men (Karacan, Thornby and Williams, 1983; Morgan, Dallosso, Ebrahim, Arie and Fentem, 1988; Schechtman, et al., 1997; Chiu, et al., 1999) as such this study focuses on **sleep in elderly women**.

Data collection started from early March to the end of May in 1997 and from the early November to late March in 1998. The difference in temperature within these periods was not great so that variability due to weather change could be eliminated. Female subjects living in elderly care homes were recruited by the convenience sampling method within the stated time period.

Sample size

Since this study is the first of its kind in Hong Kong, no relevant data can be referred. The effect size index (d) of the study, therefore, could not be determined easily. To find out the sample size of this study, the investigator referred to similar studies on sleep, melatonin and phototherapy in the recent years. Through the review of these studies (Table 4.2), the sample size of each experimental group ranged between 7 and 18. Studies with this sample size demonstrated the experimental effects significantly. As a result, doubling the upper limit of the range (N = 36) was considered to be sufficient for the study.

Table 4.2 The summary of the studies on sleep, melatonin and phototherapy

Author & Year	Subjects	Aim(s) of the Study	Method	Results
Byerley, et al. (1989)	N = 8 (8 males with mean age of 27) *Intra-subject control*	To investigate the effect of five minutes bright light exposures on melatonin and ACTH secretion	This was a 2-night study in which the subjects were kept awake during the experiment. They were exposed to bright light (> 2500 lux) for 5 minutes at 0200 on one night while another night was presented with dim light (< 500 lux). Blood samples were collected according to schedule to monitor the change in melatonin and ACTH secretion in plasma.	The plasma concentration of melatonin was reduced ($p = 0.04$) whilst there is no significant changes in ACTH concentration in blood ($p = 0.69$).
Lack & Wright (1993)	N = 9 (4 females, 5 males; mean age = 53.4 years; early morning awakening insomniacs) *Intra-subject control*	To ascertain the effect of evening bright light in delaying the circadian rhythms and lengthening the sleep of early morning awakening insomniacs	Subjects were exposed to bright light (2500 lux) from 2000 to 2400 hours on two consecutive evenings. Their sleep was evaluated with wrist actigraphy and their temperature and melatonin circadian rhythms were measured in constant routine procedures.	Subjects' temperature phase marker and melatonin phase marker were delayed 2-4 ($p < 0.05$) and 1-2 hours ($p = 0.0027$) respectively. Their final wake-up time was delayed by an average of 1 hour 12 minutes ($p < 0.01$).
Lemmer, et al. (1994)	N = 18 (9 females, 9 males; mean age = 23.9 years) *Intra-subject control*	To investigate whether or not circadian variation of the parameters was influenced by bright light applied either in the morning or in the evening in healthy volunteers	Subjects were divided into two groups with application of bright light (2500 lux for 3 hours over 6 days) from 0500-0800 hours or 1800-2100 hours. Blood samples were collected every 3 hours over a 24 hours period and plasma cAMP, cortisol and melatonin were determined on day 1 and on day 8.	There is a significant phase advance in the circadian rhythms of melatonin ($p < 0.05$) and cortisol ($p < 0.05$) when bright light was given in the morning but not when given in the evening. Whilst, plasma cAMP was not affected by light treatment.

Table 4.2 The summary of the studies on sleep, melatonin and phototherapy (Continue)

Author & Year	Subjects	Aim(s) of the Study	Method	Results
Mishima, et al. (1994)	N = 24 (14 inpatients with dementia showing sleep & behavior disorders, 10 control elderly people; mean age: demented = 75 years, control = 75 years) *Control group available*	To investigate the effects of bright light therapy on sleep time, behavioral disorders and melatonin secretion levels among the elderly patients of dementia	3000-5000 lux of full-spectrum bright light was administered on the subjects each morning for 2 hours for a 4-week period. Sleep-wake patterns of the subjects were closely monitored by nurses in the form of a sleep diary along with other behavioral disorder. Serum melatonin level was measured from collected blood samples.	Morning light therapy improved sleep ($p < 0.05$) and behavioral disorders ($p < 0.05$) in the dementia group. In terms of melatonin, no significant change in the level during bright light exposure.
Partonen, Vakkuri & Lamberg-Allardt (1995)	N = 18 (7 blind subjects, 11 sighted controls; mean age: blind = 51.7 years, sighted = 44.3 years) *Control group available*	To investigate the effects of bright light on melatonin secretion into the saliva, body temperature, subjective sleepiness and on mood in blind subjects and sighted controls and to investigate the effect of bright light therapy on vitamin D status in the body	Subjects were exposed to 3300 lux cool white light for either 1 hour or 15 min in the morning for 2 weeks during the winter. Salivary samples, body temperature, subjective sleepiness and mood assessment were being collected and closely monitored according to schedule.	Significant increase in melatonin concentration was observed among the blind subjects at 2300 ($p < 0.05$) but it was at 2100 among the controls ($p < 0.02$). The body temperature were increased in the controls but decreased in the blind in the morning. Subjective sleepiness was decreased and mood was improved. However, there was no impact on the vitamin D levels.

Table 4.2 The summary of the studies on sleep, melatonin and phototherapy (Continue)

Author & Year	Subjects	Aim(s) of the Study	Method	Results
Tzischinsky & Lavie (1997)	N = 12 (12 healthy men with mean age of 23.5 years) *Intra-subject control*	To investigate the effects of evening bright light compared to dim light on next day sleep propensity as well as the acrophase of oral temperature and mood scores	Subjects were exposed to dim light for 2 hours in the evening or bright light (2500 lux) for 30 minutes after sunset in 5 consecutive days. After light exposure, subjects remained awake in sleep laboratory until 0700 hours when they began the 7/13 ultrashort sleep-wake paradigm, which continued for 24 hours until 0700 hours the next day. Temperature was measured hourly.	Compared with the dim light condition, bright light exposure could delay the next day sleep gate ($p < 0.01$) as well as the acrophase of the oral temperature curve ($p < 0.01$) and the acrophase of negative mood ($p < 0.02$). Bright light also caused increase of stage 2 sleep ($p < 0.008$).
Cooke, Kreydatus, Atherton & Thoman (1998)	N = 10 (10 community-residing women with mean age of 79.4 years) *Intra-subject control*	To address the typical phase advanced, disturbed sleep of the elderly	Evening light (2000 lux) was provided for 30 mins to each eye by means of a "visor" during the experimental period (pretreatment – 7 days, treatment - 14 days, posttreatment – 7 days). The entire experiment was carried out in the subjects' home. Sleep was recorded using the Home Monitoring System.	There was a significant change during and even after the intervention: decrease in sleep latency ($p < 0.05$), increase in sleep time ($p < 0.05$) and sleep efficiency ($p < 0.10$). Subjects also reported less fatigue during treatment ($p < 0.001$).

Selection criteria

Inclusion criteria The experiment was conducted in elderly care homes. Only female residents were recruited. They had no sleep partner. They either complained of sleep disturbance and/or had a desire to improve their sleep quality. They could perform normal limb movement. According to Hauri and Linde (1990), there were differences in the quality of sleep between sleeping alone and sleeping with another. Thus, potential subjects with a sleep partner were excluded. The desire to improve sleep quality was an indication of the need to seek better sleep. Voluntarily participation could illustrate the desire. Any abnormalities in limb movement can affect the actigraphic recording of the sleep-wake pattern. Hence, potential subjects with restrictions in movement were not recruited.

Exclusion criteria Owing to their effects on sleep or melatonin secretion, potential subjects with certain physical conditions, psychological illnesses or, taking some kinds of medications were not invited to join the study.

Physical conditions include (i) hyperthyroidism and hypothyroidism; (ii) Alzheimer's disease; (iii) urinary tract infection (UTI); (iv) orthopnea; (v) fever; (vi) alcoholism; (vii) intolerable pain; (viii) blindness (both eyes); (ix) known case of glaucoma; (x) cerebrovascular accident (CVA) with residual signs such as muscle weakness and poor range of

movement: and (xi) liver diseases. These physical conditions either irritate an individual's sleep (i – vii) (Vitiello and Prinz. 1988: Bliwise. 1997) or influence the effects of bright light (viii and ix). In terms of the items (i) and (x), they interfere with the recording of actigraphic data while item (xi) will affect the metabolism of melatonin (Iguchi. Kato and Ibayashi. 1982).

Psychological illnesses refer to depression and anxiety. As for ***medications***. potential subjects taking drugs such as hypnotics and antihistamines (Kales and Vgontzas. 1995) were not recruited because these drugs might induce changes in their sleep pattern. Although antihypertensives and bronchodilators (Kales and Vgontzas. 1995) would also disturb one's sleep. subjects with hypertension or asthma were recruited because these illnesses were common in elderly people. Nevertheless. any changes in dosage or frequency of the prescription during the experimental period would lead to the disqualification of the subjects. In addition. subjects with exacerbation of asthma or with severe shortness of breath were disqualified.

Apart from the above mentioned conditions. potential subjects with *sleep disorders* were excluded from joining the study. The disorders include obstructive sleep apnea. narcolepsy. restless legs syndrome. periodic limb movements. gastro-esophageal reflux and parasomnias.

Instruments for data collection

To identify the eligibility of the subjects, screening was performed by the use of a screening tool - the screening assessment (Appendix 1). The preliminary sleep histories of the subjects were collected. The potential subjects were further examined for sleep habits and life style using a questionnaire (Appendix 2) before the experiment was conducted. Both the screening assessment and the questionnaire were filled in by the investigator.

These two instruments were designed by the research team in Chinese. They were subsequently translated into English. The items were derived from the Sleep Questionnaire and Assessment of Wakefulness (SQAW) designed by Miles in 1979 (cited in Guilleminault, 1982, Appendix I), the self-assessment questionnaires cited by Regestein and Rechs (1980), the Sleepiness Scale and History of Disorders of Excessive Sleepiness and History of disorders of Initiating and Maintaining Sleep cited by Orr, Altshuler and Stahl (1982), the Current Health and Life Style Assessment, Sleep History cited by Sweeney (1989) and the Insomnia Interview Schedule designed by Morin (1993).

To monitor the changes in the sleep-wake pattern and to establish the baseline formulation, the sleep log (Appendix 3) was filled in each day by the investigator. Similar to the screening assessment and the questionnaire, this sleep log was also developed by the research team in Chinese first, then translated into English. In addition to the instruments stated above, the Sleep

Diary cited by Sweeney (1989) and the Sleep Diary suggested by Morin (1993) were reviewed too. Therefore, the content of the sleep log was equivalent to that of the questionnaire except that detailed description of the sleep-wake parameters and questions for the purpose of monitoring any changes were included. The sleep log should be capable of illustrating a more detailed sleep-wake pattern of the subjects as compared with that of the questionnaire (Hauri, 1982; Morin, 1993).

The detailed description of the screening assessment, the questionnaire and the sleep log are presented in the following sections.

Screening assessment

Before the commencement of the experiment, potential subjects, complaining of sleep disturbance or with a desire to improve their sleep quality, were screened. The screening assessment allowed the investigator to identify eligible subjects exactly. This assessment included two parts: Part I - Demographic Information and Part II - Sleep History. Potential subjects went to Part II only if they were not disqualified in Part I.

In Part I, the investigator would examine the health and sleep status of each potential subject. There were seven questions covering health aspects including the body mass index (BMI) (Q3 and Q4). Potential subjects with certain physical or psychological illnesses, or taking some

kinds of drugs (refer to the selection criteria) would be disqualified. The last four questions of Part I (Q8 to Q11) illustrated aspects of sleep. These four questions reflected the perceived sleep quality of the potential subjects (Q8 and Q9) and displayed their sleep habits (Q10 and Q11). If the potential subjects were not disqualified in this part of assessment, they were further assessed on their sleep history.

The focus of Part II was to investigate each potential subject's sleep history so that the nature of the sleep disturbance would be clarified. Besides this, the investigator could explore whether the sleep disturbance was related to any sleep disorders (Appendix 4 – the instruction sheet), psychological factors, environmental factors and medical factors. The development of this part of the assessment was based on the Insomnia Interview Schedule designed by Morin (1993). During the assessment, both the onset time of the sleep disturbance (Q1) and the severity of the disturbance (Q2) were recorded. The development of the pattern of the sleep disturbance was also described (Q3 and Q4). Factors that worsen the disturbance were identified (Q5). Several questions (Q6, Q11 - Q15) were designed to discover if the disturbance was related to other factors. These factors were focused on sleep disorders and included medical aspects (Q11) and psychological aspects (Q12 - Q15). Since question 6 might arouse some emotional responses, four questions (Q7 - Q10) were inserted in the assessment to relieve the tense or defensive atmosphere. In addition, the disturbances claimed by the potential subjects were initially classified by these

questions. After the sleep nature of the potential subjects was outlined by the use of the screening assessment. further investigation on their sleep-wake patterns was performed using the questionnaire.

Questionnaire

If the potential subjects were qualified in the screening assessment. the investigator assessed their sleep again by questionnaire. The questionnaire was particularly designed for the establishment of the sleep history in more defined terms. Factors related to sleep were studied at the same time so that the investigator could know the usual sleep nature of the potential subjects. Data collected with the questionnaire were important for the discrimination of Hawthorne effect. which might lead to inaccurate results. The main intention of the questionnaire was to get further information on the sleep of the potential subjects. When one or more of these sleep-related factors were suspected to be dominant in causing the disturbance. the potential subjects were also disqualified.

Three experts were invited to test the content validity of the questionnaire. The experts included a nurse who had experience in sleep management. a clinical nurse specialist who had experience in geriatrics and a geriatrician. A four point rating scale - not relevant. somewhat relevant. relevant and very relevant - was used in the test. The results are shown in Table 4.3. Twenty-two items were rated as relevant or very

relevant. There were two items considered by both the nurse and geriatrician as somewhat relevant. The two items were related to dairy product consumption and the supper time. Dairy products were not popular among elderly people but the special price, which was offered by manufacturers to institutionalized elderly people, might have some effects on the consumption rate. Many elderly care homes have their supper time set at 1700 hours to 1800 hours. Such arrangement might interrupt sleep because of hunger. Facing these uncertainties, the investigator decided not to eliminate this item from the questionnaire. Therefore, they were retained in the questionnaire. After collecting the validation results from the experts, the content validity index (CVI) was computed. The CVI was the percentage of total agreement to which the items in the questionnaire adequately reflect the content domain being measured (Portney and Watkins, 1993). It was the proportion of items that were given a rating of relevant or very relevant by the three experts. The CVI for the questionnaire was 0.92 (22/24) which was considered to be an acceptable level of content validity.

Table 4.3 The ratings of the relevance of 24 items in the questionnaire by the three experts

Relevance	Number of items
Relevant / Very Relevant	22*
Irrelevant / Somewhat Relevant	2**

Note: * *items which had been chosen by all three experts*
** *items which had been chosen by two experts*

Apart from CVI. the reliability of the questionnaire was also established. The test-retest reliability of the questionnaire was tested at a two-week interval using ten elderly people. Correlation between the scores of these two tests was calculated. The related coefficient of reliability. Pearson r. was 0.87. It was an acceptable level of reliability.

Similar to screening assessment. there were two parts in the questionnaire: Part I - Sleep Habits and Part II - Life Style. In Part I. the questions explored sleep-wake parameters. The related questions were arranged in chronological order. It was hoped that such arrangements might facilitate the potential subjects to recall their memories. The chronological order was set according to the design of the experiment - from 1800 hours to the same time on the next day. Thus. sleep-wake parameters involved in this questionnaire were arranged in the order of bedtime. sleep onset latency (SOL). wake after sleep onset (WASO). sleep offset time (SoffT). rising time and napping. For questions concerning WASO and nap. the causes. frequency. duration of the waking and napping. the reactions towards the waking and the timing of the napping were also investigated. In addition. napping was divided into two categories. They were intentional napping and unintentional napping.

Part II of the questionnaire looked into the habitual life styles of the potential subjects. It mainly reviewed sleep-related factors which might affect sleep. In this questionnaire. sleep-related factors referred to

smoking, caffeinated food or drink consumption, alcohol consumption, dairy products consumption, doing exercise, outdoor sunlight exposure, supper time and snack consumption. In the case of the first four items, they also included the usual amount and the usual last consumption time. For the fifth and sixth items, time and duration were identified. Combining Parts I and II, the questionnaire could provide a well-defined sleep history and the associated sleep factors of the subjects.

Sleep log

Similar to the questionnaire, sleep-wake parameters and sleep-related factors were examined but in a more detailed mode in the sleep log. Some questions for monitoring possible changes during the experiment were embodied in the sleep log so that the sleep log not only could reveal the current sleep status of the subjects in more defined terms but also could display any modifications of the sleep-wake patterns of the subjects.

The sleep log was divided into two parts with 17 questions (Q1 – Q13, Q22 - Q25) focused on sleep-wake parameters and 8 questions (Q14 – Q21) emphasized sleep-related factors. All the questions concerning the sleep-wake parameters were arranged in chronological order from 1800 hours to the same time on the next day. The sleep log began with the questions concerning napping in the evening. Napping was divided into intentional and unintentional naps. Then, the questions were arranged in

the sequence of light off time, bedtime, sleep onset latency (SOL), wake after sleep onset (WASO), sleep offset time (SoffT) and rising time in which the light off time was specifically set for the investigation of melatonin secretion. Several questions (Q6, Q12, Q13 and part of Q7) allowed the investigator to explore the causes of and the reactions to the disturbances. This was followed by the sleep-related questions, sleep satisfaction level (Q14) and refreshment level upon rising (Q15). For the sleep-related questions (Q14 – Q21), the factors referred to smoking, caffeinated food or drink consumption, alcohol consumption, dairy products consumption, doing exercise, outdoor sunlight exposure, supper time and snack consumption. The amount and last consumption time existed in the first four items (Q14 – Q17) while time and duration were identified in the fifth and sixth items (Q18 – Q19). After the investigation of sleep-related factors, the sleep log ended with the study of napping in the morning and in the afternoon (Q22 – Q25). The organization of the sleep log hoped to minimize inaccuracy in the retrospective estimates, especially in elderly people (Rogers, Caruso and Aldrich, 1993) as the investigator filled in the sleep log during both the morning and evening sessions of the experiment instead of just in one session. In the morning session, the investigator completed questions 1 to 21. In the evening session, the investigator completed questions 22 to 25.

In addition to the questionnaire, the sleep log could provide more detailed information about the sleep-wake patterns. The sleep onset time

(SOT) of a subject could be obtained from the data provided by bedtime and SOL at night. Total bed time (TBT) could be determined from the data provided by bedtime and rising time. Total sleep time (TST) could be determined from the data provided by bedtime. SOL, the total time of waking after sleep onset (WASOt) and rising time. Sleep efficiency (SE) could be calculated from the information illustrated by TBT and TST and sleep-wake ratio (SWR) could be obtained by including the information related to TST and WASO parameters. Apart from sleep-wake patterns, the desirable duration for sleeping at night was crucial in the evaluation too. Therefore, a related question (Q26) was set on the last day of the sleep log and it was also the last question of the sleep log. This arrangement was adopted to avoid any preconception before the commencement of the experiment.

Equipment for data collection

To determine the sleep-wake patterns of the subjects in an objective way, a wrist actigraph was employed in this study. Its validity and reliability has been mentioned in Chapter 3 – Literature Review. This Chapter describes the nature of the actigraph precisely. Acting as the source of the independent variables, light boxes will also be described.

Wrist actigraphy

Performing an objective measurement of sleep-wake parameters, wrist actigraphy measuring wrist movements, was adopted in this study. A watch-like Mini Motionlogger actigraph was used (Figure 4.1). Its size was 4.5×3.3×1.2 cm^3 and its weight including battery was 35 g. Manufactured by Ambulatory Monitoring Incorporation, this actigraph was waterproof so that the subjects did not have to take it off while they were bathing or washing their dishes or clothes. Indeed, they should wear the actigraph throughout the experiment.

Figure 4.1 The watch-like Mini Motionlogger actigraph

When the actigraph is placed on different parts of the body, it can record different degrees of movement. At the waist, it can record integrated generalized movements such as postural shifts. At the wrist, not only generalized movements but also small movements occurring at the distal extremities can be detected. In addition, there are no significant differences between the dominant and non-dominant wrist recordings

among the right- or left-handed subjects (van Hilten, Middelkoop, Kuiper, Kramer and Roos, 1993). Owing to the popularity of the non-dominant placement among many studies, the actigraph was worn on the non-dominant wrist rather than on the dominant one. Thus, the investigator might compare the results with those of other studies.

The actigraph designated as the Basic Model Actigraph, BMA-32, was programmed by a Motionlogger Operational Software, Act 5.10 in which the header file of 10SECOND.HDR was chosen to initialize the actigraph. Through this header file, the actigraph was operated in a zero crossing mode (ZCM) and data was collected in a sampling rate of tenths of a second with epoch length as 10 seconds. To be specific, the actigraph recorded the number of times when the signal voltage crossed the reference voltage, owing to the movement being accelerated or decelerated (Tryon, 1991), at the rate of 10 Hz and stored the data temporarily in a 10-second interval. Apart from setting the method of data collection, the function of event mode was also activated so that subjects might record any napping or waking after sleep onset by pressing the event button on the actigraph.

After actigraphic data was collected, the data was transferred to a portable computer through the Actigraphic Interface Unit (AIU). To minimize the loss of data owing to device failure, the investigator downloaded the data for every morning session. She also checked the actigraph by listening for the beeping sound during every evening

session. Afterwards, the data was analysed by a computerised sleep scoring programme, Action 1.32. By tagging the appropriate interval, the investigator could identify the sleep onset time (SOT), sleep offset time (SoffT), total sleep time (TST), information about wake after sleep onset (WASO) at night, sleep onset latency (SOL), total bed time (TBT), napping and sleep-wake ratio directly from the interval statistics results.

Since the correlation coefficient between the polysomnographic and actigraphic data was highly significant in several studies (Mullaney, Kripke & Messin, 1980; Sadeh, Alster, Urbach & Lavie, 1989), no correlation test between polysomnography (PSG) and actigraphy was done in this study (Sadeh, Hauri, Kripke and Lavie, 1995). Instead, the correlation between actigraphy and sleep log was calculated.

Light boxes

Being the independent variable, white bright light was deployed in this study. White bright light was produced by four light boxes. Each light box contained a 250-watt lamp (Osram, made in Germany) which could emit white light. The distance between the subjects and the light boxes were adjusted so that a light intensity of 2500 lux at a subject's face could be established. To minimize the Hawthorne effect, white bright light was replaced by red dim light in both the pre- and post-bright light exposure stages. Red dim light was produced by two light boxes. Each contained three incandescent tungsten filament 15-watt red globes. Six

red globes together could emit light intensity equivalent to 150 lux at one metre away from the light sources. The light intensity at each subject's face was measured with an illuminance meter (Minolta, TL-1).

Techniques for the collection and analysis of urine samples

Urinary 6-sulphatoxymelatonin (aMT6s) was used to monitor any alterations in melatonin secretion. To measure the aMT6s level, the radioimmunoassay (RIA) technique was applied. Detailed description of the methods for the monitoring of melatonin secretion has been mentioned in Chapter 3 - The measurement of 6-sulphatoxymelatonin (aMT6s) level. This Chapter justifies the using of urinary aMT6s as the monitoring medium. Following the justification, the collection of the urine samples and use of RIA kit are described.

Urinary 6-sulphatoxymelatonin, instead of melatonin, was used to monitor the changes in melatonin level during the experiment. Since the investigator had observed that most Chinese elderly people disliked blood tests and it was an intrusive measure, blood was not used as a medium of data collection in this study. Urine possessing a non-invasiveness nature is an alternative medium frequently employed by the researchers to monitor melatonin secretion (Ando, Kripke, Cole and Elliott, 1999; Benhaberou-Brun, Lambert and Dumont, 1999; Lockley, Skene and Arendt, 1999). Being the primary urinary

metabolite of the pineal hormone melatonin. urinary aMT6s was measured instead.

As urine served as a collection medium in this study. clean. wide-mouth and labelled specimen bottles were prepared. The bottles needed to be the wide-mouth ones because such design could facilitate the female subjects to urinate directly into the bottles. Apart from the design. the bottles were labelled and placed in a tray with partitions so that the subjects could get the bottles in the correct order. The collection time of the urine samples could be marked accordingly.

With reference to the manual provided by CIDtech Research Incorporation (Appendix 5). urinary aMT6s is stable for at least two days when being stored at room temperature and at least two years when being stored at -20°C. In view of the information provided. fresh urine samples were stored temporarily in a polyurethane icebox which was packed with ice pads when the samples were stored in the elderly care home or on the way to the laboratory. To maintain the stability of aMT6s. the investigator collected the urine samples in the morning session and took them to the laboratory as soon as possible. After being centrifuged at 2000 g for 20 minutes at 4°C. the urine samples were stored in a refrigerator at -20°C until assayed.

The urine samples were analysed using the radioimmunoassay (RIA) technique in a radio-isotope laboratory. RIA kits. CIK104H. were purchased from CIDtech Research Incorporation in Canada for the assay. The concentration of

aMT6s was finally determined by counting the charcoal pellet using a Packard Cobra II gamma counter which had been input with an appropriate dose-response curve. Figure 4.2 presents the process of urine collection and analysis using the RIA technique. The associated crossreactivity and parallelism are reported in the following sections. All the laboratory work was carried out in compliance with the guidelines set by the University Health and Safety committees.

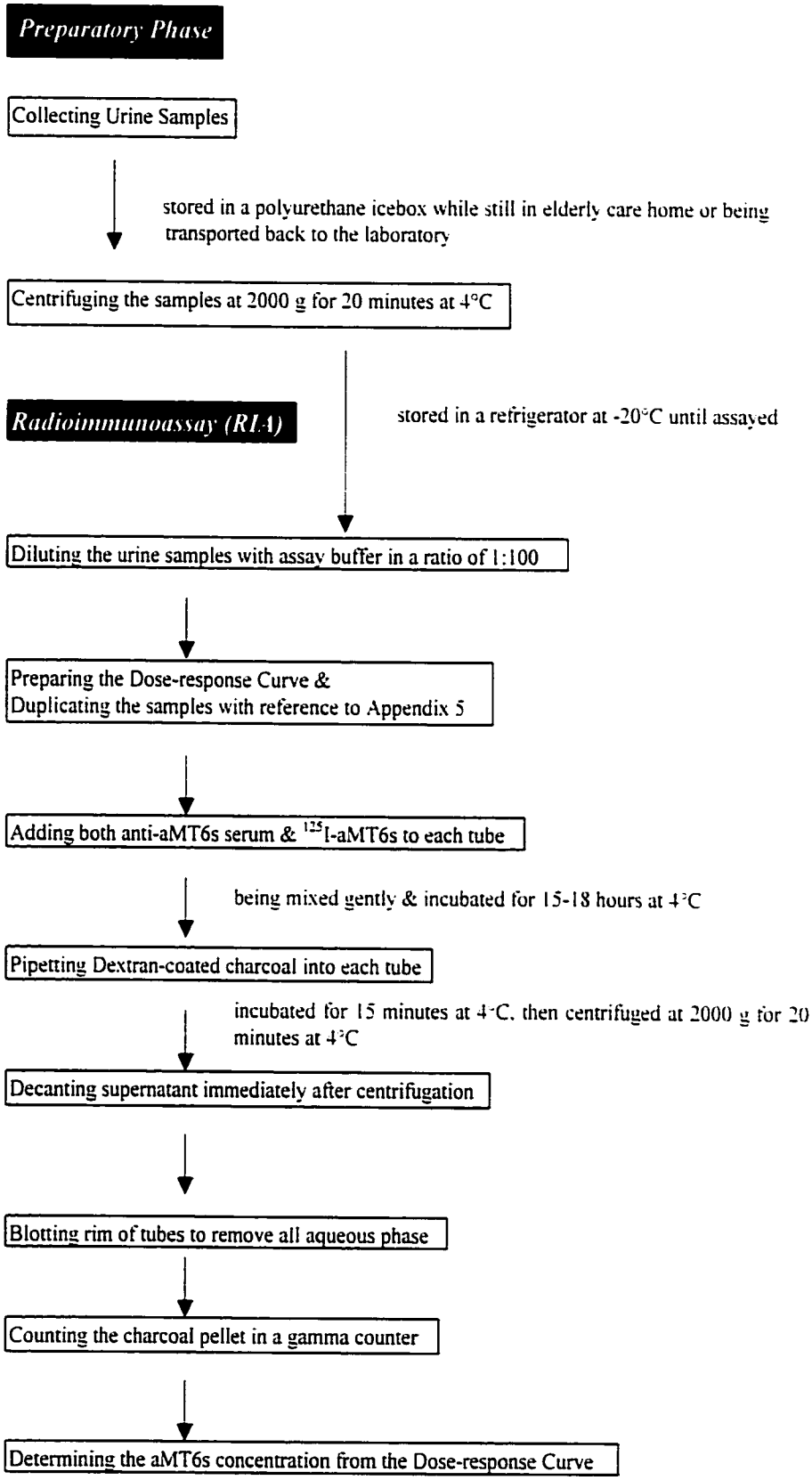


Figure 4.2 Process of the urine collection and analysis using the radioimmunoassay (RIA) technique

Crossreactivity and parallelism

According to the radioimmunoassay (RIA) kit instructions provided by the CIDtech Research Incorporation. crossreactivity was negligible in many tested compounds. 6-sulphatoxymelatonin was the most important cross-reactant. CIDtech ultraspecific antiserum was highly specific as determined by crossreactivity studies. Table 4.4 shows the related crossreactivity of the compounds. Apart from crossreactivity. the CIDtech RIA kit instructions also state that the within assay variation is 9.6. the between assay variation is 12.5 and the sensitivity of the assay is 1 pg/tube.

Table 4.4 Crossreactivity data

Compound	% Crossreactivity
6-sulphatoxymelatonin	100.0
N-acetylserotonin sulphate	2.0
N-acetylserotonin glucuronide	1.4
6-hydroxymelatonin glucuronide	0.5
6-hydroxymelatonin	<0.11
Melatonin	<0.11
5-methoxyindole acetic acid	<0.11
5-hydroxyindole acetic acid	<0.11
N-acetyltryptamine	<0.11
N-acetylserotonin	<0.11
5-hydroxytryptophan	<0.11
N-methyltryptamine	<0.11
5-methoxytryptamine	<0.11
5-methoxytryptophan	<0.11
5-hydroxytryptamine	<0.11
5-methoxytryptophol	<0.11
5-hydroxytryptophol	<0.11
Tryptophan	$<1.1 \cdot 10^{-3}$

Note: Crossreactivity is based on mass required for 50% displacement of ^{125}I-aMT6s.

Parallelism was assessed by comparing the displacement of a aMT6s standard curve with another aM16s standard curve in which an urine

sample was added. The urine sample was diluted to 1:250 and 10 µl of the sample was added in a standard curve to make up a displacement curve. Parallelism was established by superimposing the displacement curve with the urine sample added onto the aMT6s standard curve. Figure 4.3 demonstrates that the displacement curve is parallel with the aMT6s standard curve.

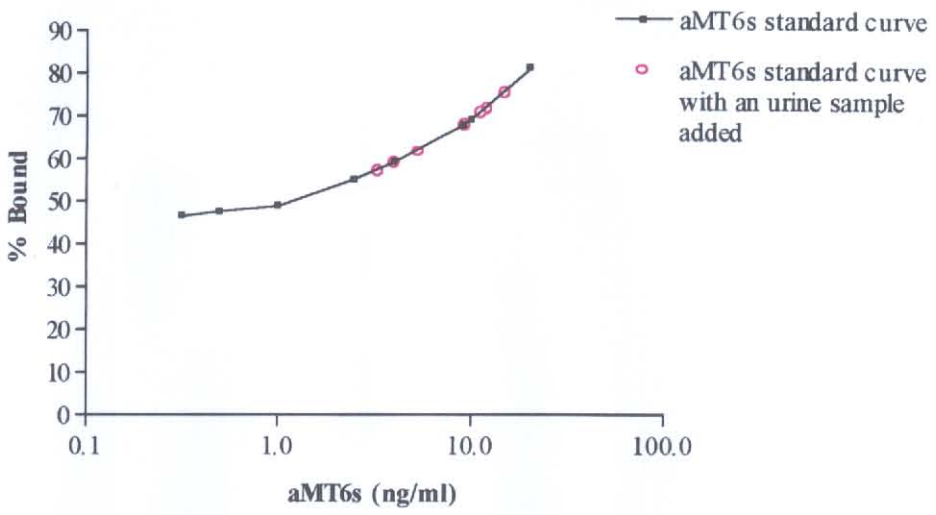


Figure 4.3 Parallelism between the aMT6s standard curve and the aMT6s standard curve with an urine sample added

Data collection

There were **three phases** in the data collection. Firstly, the investigator had to contact the elderly care homes and their residents in the Preparatory Phase. After access was approved, eligible subjects were identified in the Screening Phase. Then, the qualified subjects proceeded to the Experimental Phase. The setting of the experiment is described in the last part of this phase.

Preparatory phase

To conduct an experimental study in a field setting, the investigator undertook part of the preparatory work before the experiment was commenced. All the subjects approached by the investigator were living in elderly care homes. Before making contact with them, the investigator explained the purposes of the study, the nature of the experiment, equipment and the instruments being used to the superintendents or the related associations of the elderly care homes. After approval was granted, the investigator gave a 15-minute talk in the elderly care homes to explain the whole project directly to the residents. Residents, who complained of sleep disturbance or had a desire to improve their sleep quality, were invited to join the study. After verbal consent was obtained, the screening assessment was conducted.

Screening phase

Through the screening assessment, most of the ineligible subjects were screened out. For the remaining potential subjects, they were further assessed in terms of their sleep histories and factors related to sleep using the questionnaire. Both screening assessment and questionnaire were completed by the investigator. After the completion of the questionnaire, the investigator explained to them once again the purposes of the study, the nature of the experiment, and the equipment and instruments being used during the experiment. Those who agreed to

take part in the experiment were requested to sign a consent form (Appendix 6). A study procedure from the screening phase to the data analysis is demonstrated in Figure 4.4.

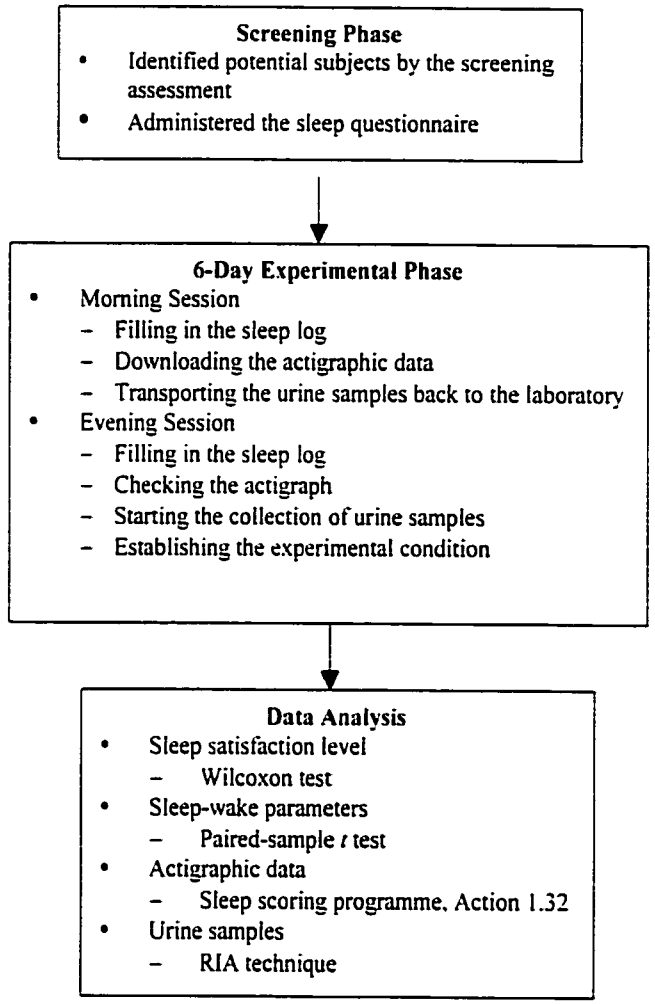


Figure 4.4 Study procedure

Experimental phase

The 6-day experiment was divided into **three stages** with each lasting two days. The three stages were pre-bright light exposure stage, bright light exposure stage and post-bright light exposure stage. Data collected

in the pre-bright light exposure stage served as control data whereas data collected in both the bright light exposure and post-bright light exposure stages served as experimental data. The subjects were exposed to white bright light for two days during the bright light exposure stage whereas red dim light was used as a placebo during the pre- and post-bright light exposure stages. Throughout the experimental period, each subject wore a wrist actigraph on her non-dominant hand without taking it off. The investigator documented their everyday sleep information in a sleep log during these six days. In addition, the subjects saved urine samples whenever they urinated between 1800 hours and their rising times in the following morning. First morning urine was also included.

To minimize retrospective estimates in the sleep log, to reduce the loss of actigraphic data and maintain the stability of 6-sulphatoxymelatonin (aMT6s) in the urine samples, the investigator decided to divide the data collection into **two sessions** - the morning session and the evening session. In the morning session, information related to nocturnal sleep was recorded in the sleep log as soon as the subjects woke up. At the same time, actigraphic data was downloaded to the computer though the memory of the actigraph could store data for more than three days. The urine samples stored temporarily in the polyurethane icebox were transferred to another freshly prepared icebox when they were carried back to the laboratory. In the evening session, only the parts in the sleep log concerning daytime sleep and activities were filled in. For the actigraph, the investigator checked whether it was functioning by

listening for the start up beep. Freshly prepared polyurethane iceboxes and clean bottles were delivered to the subjects for collecting urine samples starting at 1800 hours. The main focus in the evening session was to maintain the experiment condition rather than data collection.

In this **6-day** study, each experimental day started from 1800 hours and finished at the same time on the following day. The 6-day period always began on Monday evening and was completed on Sunday morning. This enabled some subjects to go out for dinner with their relatives on Sunday evening. Days 1 and 2 were defined as the pre-bright light exposure stage in which Day 1 was designed for adaptation and Day 2 for baseline observation. Although it was claimed that there was no first-night effect among elderly subjects when their mobility was measured by wrist actigraph on their non-dominant hands for six consecutive days (van Hilten, et al., 1993), no local investigation had yet been done, to re-affirm their findings. In addition, the investigator could not confirm if the experiment itself had effects on the subjects. As psychological preparation, the investigator decided to allow a one-day adaptation period for the subjects to be familiar with the actigraph, the light sources (only the red dim light), the experimental routine and the urine saving procedure.

Day 3 and 4 were defined as the bright light exposure stage in which the subjects were exposed to white bright light instead of red dim light. Since it was difficult to accommodate bright light in a few seconds, the

investigator turned on the light sources only when all the subjects arrived. The slow illumination of the lights allowed time for the subjects to adapt. After the lights were turned off, the subjects were advised to stay in the experimental place for 15 minutes in order to prevent a fall which might be caused by slow adjustment to the relatively "darker" outside environment.

The situation in Days 5 and 6, the post-bright light exposure stage, was the same as that of Day 2. The main difference was that the completion of data collection on Day 6 was not at 1800 hours but at 1000 hours. Day 6 originally started from Saturday 1800 hours to Sunday 1800 hours. It was suggested that there was no day-of-week effect on activity and immobility among retired subjects (van Hilten, et al., 1993). However, Sunday was the day the subjects' family members would come to visit them or take them out. This day was considered to be different from the other weekdays. Therefore, the day-of-week effect might emerge. To minimize the chance of diversifying the results and not to disturb the subjects' family lives, the investigator terminated the data collection on Sunday morning.

Setting

White bright light was applied to the eyes to alter the pineal secretion of melatonin. To achieve the most desirable effect, the investigator set the light sources near the television. The subjects were asked to sit in front

throughout the experimental period so that the results would not be affected.

It was a hard task for the subjects to complete the three phases of data collection. It was also very difficult to achieve a variable-free field setting. Although the investigator could not absolutely control the experimental environment, she made every effort to maintain a stable setting. She tried to incorporate bright light into the subjects' daily routine without disturbing their usual night time sleep schedules and daytime activities. Any changes in the weather, sleeping environment, daily routines and even the subject's physical and emotional status during data collection were recorded. To ensure the smoothness of the experiment, a detailed protocol (Appendix 7) and an instruction sheet were prepared.

Data analysis

The data collected in this study were demographic data, sleep-related factors, sleep satisfaction level, actigraphic sleep-wake parameters, and urinary 6-sulphatoxymelatonin (aMT6s) level. Demographic data were presented in the form of frequency, mean, mode, range and standard deviation using descriptive statistics. As for the sleep-related factors, only frequency count was conducted. Sleep satisfaction levels were analysed using Wilcoxon test. Actigraphic sleep-wake parameters were obtained from the analysis using the

software Action 1.32. The parameters were further analysed using *t* test. To determine the aMT6s levels, radioimmunoassay (RIA) technique was employed.

Using the RIA technique, the determination of aMT6s level depends on the competition between the aMT6s in urine (the urine samples) and the known amount of ^{125}I-labelled aMT6s (provided by the RIA kit) for a limited number of high affinity binding sites on the ultraspecific antiserum (also provided by the RIA kit).

aMT6s + ^{125}I-aMT6s + antiserum ⇌ aMT6s-antiserum + ^{125}I-aMT6s-antiserum + aMT6s + ^{125}I-aMT6s

The amount of radioactive-labelled aMT6s bound to the antiserum is inversely proportional to the amount of the unlabelled urinary aMT6s. When the amount of urinary aMT6s increases, the amount of ^{125}I-labelled aMT6s bound to the antiserum decreases. Conversely, when the amount of urinary aMT6s decreases, the amount of ^{125}I-labelled aMT6s bound to the antiserum increases. Since the binding process is a reversible reaction, urinary aMT6s, ^{125}I-labelled aMT6s and the bound complex would present together after equilibrium is achieved. To separate the mixture, charcoal is used to absorb the unbound aMT6s. The unknown amount of unlabelled urinary aMT6s can be determined by counting the radioactivity of the charcoal in a gamma counter and referring to the response curve prepared using known standards.

The aMT6s level was presented in the unit of pmol/ml. Since it was expected that there might be some changes in the level after bright light exposure, the aMT6s results on Day 2 (pre-bright light exposure stage) were compared with that on Day 5 and Day 6 (post-bright light exposure stage). Therefore, not only descriptive data analysis was conducted but also paired-sample *t* test was employed to detect the effects of bright light on the melatonin secretion. For the relationships between bright light, excreted melatonin (aMT6s) level, sleep-wake parameters and sleep satisfaction level, they were studied using Spearman's Correlation Test.

Ethical consideration

The research proposal was submitted to the Ethics Committee of The Hong Kong Polytechnic University, the elderly care homes or the related associations before the study was commenced. After approvals were granted by The Hong Kong Polytechnic University Ethics Committee and the elderly care homes, data collection then began.

Before any screening and history-taking commenced, the investigator thoroughly explained the nature and purposes of the study to the potential subjects. Verbal consent was then sought from them. After the eligible subjects were identified, they were requested to sign a consent form that they were willing to participate in the experiment. Detailed explanation about the

study. the protocol. and the equipment were explained again to them. The wrist actigraph, light boxes and urine collection bottles were shown to them. The method of urine collection was explained as well as the protocol of the study. The subjects were encouraged to raise any questions or to clarify any uncertainties throughout the study. They were allowed to withdraw from the study at any time.

Personal information and opinions were kept confidential and anonymous. A code number was assigned to each subject instead of using their own names. Data collected could only be accessed by the investigator. and co-investigators such as the supervisor and the co-supervisors. All raw data would be destroyed after the thesis was completed.

Summary

It is undeniable that conducting experiments in a field setting brings about many difficulties. Measuring changes caused by the experimental variable in a real situation is much meaningful than in any well-equipped laboratory. Knowing the limitations of performing the study in elderly care homes – the customary sleep place for the subjects, the investigator had designed a feasible method to assess the bright light effects on the subjects. To test the feasibility of the design of the experiment and the setting, a pilot study was carried out.

The description of the process and the evaluation of both the design and setting of the experiment are presented in Chapter 5.

Chapter 5

The Pilot Study

Introduction

Before the actual study was commenced, a pilot study was conducted to test the feasibility of the study (Portney and Watkins, 1993). It provided a chance for the investigator to experience the process of study in action so that refinements could be made if necessary. All steps or procedures of the pilot study were the same as that of the actual study. This pilot study was focused on the use of the instruments and equipment. The safety and comfort of the experimental setting were the other concerns. Basically, the pilot study was evaluated according to the study procedure stated in Figure 4.4 except the relevant communication skill with the elderly people was assessed with reference to the Preparatory Phase. Prior to the presentation of the evaluation of this pilot study, the method of the study is described first.

Method of the study

Same as the actual study, a quasi-experimental design with intra-subject

comparison was employed in the pilot study. The potential subjects were recruited by the convenience sampling method. The eligibility of the subjects was determined by a screening assessment while the questionnaire was used to further investigate their sleep histories and sleep-wake patterns. The selected subjects went through a 6-day study. The 6-day study was divided into three stages. Each stage lasted two days. The stages were pre-bright light exposure stage, bright light exposure stage and post-bright light exposure stage. White bright light was applied on the bright light exposure stage while red dim light was applied on the other two stages. All the procedures of the experiment including sleep log, actigraphic recording and urine samples collection were the same as that of the actual study except the sample size in the pilot study was smaller than that of the actual one. Six subjects were recruited in the pilot study. They were all from the same elderly care home.

The preparatory phase

There were three phases in the study. They were the preparatory phase, the screening phase and the experimental phase. In the preparatory phase, it was important for the investigator to be equipped with the required communication skills in explaining the study to the staff of the related association, the superintendent, the staff of the elderly care home and the elderly residents. Effective communication skills were crucial for recruiting subjects.

To gain the cooperation of the staff in the elderly care home, the investigator explained the study in detail to them. Most of the superintendents were concerned about the safety and effectiveness of applying bright light to the subjects. Concern over a possible electrical overload affected their thinking in granting access. The experimental routine was another critical aspect for them to assess the related impact on their staff. Whether the subjects could participate in the study on a voluntary basis or not was the most important thing for them to decide. In response to their concerns, the investigator had to clarify the above mentioned issues while seeking access. During the 15-minute recruitment talk, the emphasis was put on voluntary participation. In addition, the investigator spoke slowly and concisely to the residents to assist their understanding.

The screening phase

In the screening phase, the eligibility of all potential subjects was tested by the screening assessment. Hence, the effectiveness of the screening assessment for filtering out ineligible subjects was examined. The questionnaire was used to further investigate the sleep histories and the sleep-wake patterns of the eligible subjects. Its organization was checked so that the related information could be documented clearly.

After the pilot study, it was found that both the screening assessment and the

questionnaire could effectively identify ineligible subjects and could record the sleep histories and sleep-wake patterns smoothly. The outline of the sleep-wake patterns of the subjects could be made out within a short period of time. On the whole, the subjects could understand the contents of the instruments. There were two questions which required further clarification. The questions related to the nocturnal bedtime and the sleep offset time (final waking time). In the pilot study, the investigator observed that the recorded bedtime might not be equivalent to the time the subjects wanted to sleep but might be just equal to the time they went to bed. Institutionalized elderly people have limited personal space. They usually rest on their bed when they have nothing to do. To obtain the real bedtime of the subjects, the investigator set apart the lying time from the reported bedtime. Apart from bedtime, the subjects also confused the sleep offset time with the rising time. Since some subjects might be reluctant to get up once they were awake, a time lag existed. Hence, the investigator needed to clarify the reported sleep offset time. As a whole, both the screening assessment and the questionnaire were considered to be clear and systematic. These two instruments were used in the actual study with the two questions being further clarified.

The experimental phase

In this phase, the smoothness and feasibility of the experimental procedures was examined with reference to the morning and evening sessions. As with

the questionnaire. the organization of the sleep log in collecting sleep-wake parameters was assessed. In terms of wrist actigraph. it was evaluated not only by recording the sleep-wake parameters but also by the comfort of wearing the wrist actigraph. the usage of the event button to record special events and the running duration of the battery. The collection of urine samples was checked as well. In addition. the safety and comfort of the experimental setting were investigated.

To minimize retrospective estimates in sleep log. to reduce the loss of actigraphic data and to maintain the stability of 6-sulphatoxymelatonin (aMT6s) in the urine samples. the data collection was divided into two sessions - the morning session and the evening session. Following the schedules of the morning and evening sessions. most of the subjects could complete the sleep log without data missing. Nonetheless. malfunction of the actigraph had been found. The downloading and function checking schedules of the actigraph were retained in the actual study. To preserve the urine samples in a good way. the polyurethane boxes used in the pilot study were found to be sufficiently cold to store the urine samples temporarily when the freshly prepared iceboxes were available in each session. As a conclusion. it was essential to divide the data collection into two sessions.

Apart from the smoothness of experimental procedures. the feasibility of the data collection was considered. At the end of the experimental phase. it was Day 6 (Sunday). The investigator identified that morning was the most favourable time for data collection as Sunday was the day the subjects' family

members would come to visit them or take them out. To avoid disturbing their usual family gathering, data collection on Day 6 was set in the morning during the actual study. In the pilot study, there was no great fluctuation in the emotional state of the subjects on Saturday night (Day 6 night). Therefore, the data on Day 6 was included in the actual study.

In terms of instruments and equipment, the sleep log using to record subjective data was found to be organized enough to assess the sleep-wake pattern and sleep habits. It was feasible to use it according to the way described in Chapter 4. To record sleep-wake parameters in a relatively objective mode, a wrist actigraph was employed. Basically, it could perform well in recording the sleep-wake patterns of the subjects. Some subjects believed that the wrist actigraph could relieve their sleep disturbances even though lucid explanation was given. To correct this misunderstanding, the investigator cited the example of using sphygmomanometer to measure blood pressure in which the role of actigraph was the same as that of sphygmomanometer. Apart from this misunderstanding, the investigator also noted that there were several points to pay attention to while the subjects were wearing the actigraph. First, the actigraph might damage the jade bracelet by the frequent contact between them when the wrist was moving. Second, even when fast-dry wrist band was used, discomfort remained a problem because it needed ample time for the moisture to evaporate. Third, the subjects said that they found it embarrassing to wear the actigraph as they did not know how to explain its existence to others. Tackling these difficulties, the investigator had suggested that they twisted a handkerchief round their jade bracelets to

minimize damage to their bracelets from hitting other objects. As the subjects were instructed to wear the actigraph throughout the study, they could not prevent the wetting of the wrist band of the actigraph. To minimize the irritation induced by the wet wrist band, the investigator recommended that the subjects absorbed the water from the wet band with a towel so as to accelerate the drying process. Concerning the embarrassment, the investigator taught the subjects the way to respond to inquiries from others. For instance, when doctors asked about the actigraph, the subjects could tell them that they had joined a study. If the question came from their friends, the subjects could introduce the actigraph as a watch-like instrument to them. Although the above misunderstanding and problems might not affect the results, the investigator added these instructions to the actual study. Nonetheless, the use of the event button and the close monitoring of the voltage of the battery were not included. The availability of the event button on the actigraph allows a more accurate recording of any napping or waking at night. In the pilot study, the subjects were unable to use the button. The activation of the event button was not necessary for the actual study. Since the battery was found reliable throughout the pilot study, there was no need to monitor the voltage of the actigraph closely in the actual study.

Considering the urine collection procedure in the pilot study, the investigator observed that there were several things that needed attention in the actual study. To keep the urine samples in the right order, a tray with partitions was used. A label was stuck on the front of the tray and each bottle was labelled in sequence. Although every effort was made to achieve a correct order of

the samples. some subjects either got the bottles in a reverse order or left a bottle empty before proceeding to another one. Therefore. the investigator was reminded that she should reinforce the instructions for collecting urine samples. Apart from this. some subjects were unable to screw the cap on the bottle tightly. This discovery made the investigator alert in collecting the samples. She screwed the cap again if necessary. In the actual study. emphasis was also placed on screwing the cap on the bottle.

Finally. the focus was placed on the safety and comfort of the experimental setting in which issues related to the arrangement of electrical supply and the light exposure were evaluated. In view of the low consumption of electrical power of the lights. it was considered safe to employ the light boxes in the elderly care home. With the help of a illuminance meter. the intensity of light was well-controlled. A comfortable distance between the light boxes and the television was maintained (more than one metre). The wires and extension boards were organized so that safety was ensured. As a whole. the setting was safe and comfortable. Having a different perspective from their superintendents. the subjects mainly focused on whether the red dim light or white bright light would have any effect on them. Following the suggestion from Dollins. Lynch. Wurtman. Deng and Lieberman (1993). the investigator requested the subjects to postpone their questions till the end of the study. Otherwise. random errors might be introduced to the findings of the actual study.

Assessing the issues of the slow illumination of light. the investigator found it

helpful for the subjects to adapt to the brightness of the light. Similarly, the presence of an adaptation period after light termination could also help the subjects to adjust back to the environment. A 15-minute time period was found to be sufficient for adaptation. During the bright light exposure period, it was appreciated that it was difficult for subjects to tolerate the brightness. It was noticed that the subjects might turn away from the bright light. To ensure that the subjects kept their eyes open, the investigator chatted continuously with them during the exposure period. Such a strategy was applied in the actual study. In addition, a comfortable chair was prepared to minimize the physical discomfort of the elderly people as they had to sit for at least three hours a day. For the room temperature, the investigator adjusted it according to the comfort of the environment. In the actual study, the investigator tried these methods to increase the compliance of the subjects.

Data analysis

The purpose of this pilot study was to test the feasibility of the experimental procedures. The data analysis in the pilot study was confined to the ability of the analytical tests or techniques in detecting the experimental effects. There were three sets of data available for the study of bright light effects on the subjects. They were the sleep log, actigraphic data and urine samples.

Analysed by the paired-sample *t*-test and Wilcoxon test, the sleep log could

demonstrate the reported effects of bright light on the subjects. The analysis of the actigraphic data using the programme Action 1.32 confirmed that the data was sufficient for outlining the sleep-wake patterns of the subjects. Concerning the radioimmunoassay (RIA) procedure, the investigator observed that the dilution factor (1:250) was not sensitive enough to detect the low level of the aMT6s level. Therefore, a more concentrated factor (1:100) in the actual study was used. Summarizing the findings of the sleep log, actigraphic data and 6-sulphatoxymelatonin level, it was ensured that the one-day adaptation period was long enough for the subjects to get used to the experimental routines and environment. Apart from the analysis procedures, the pilot study had provided experience for the investigator in handling the radioactive waste. Thus, a better preparation before the actual study was achieved.

In summary, the pilot study was conducted smoothly. The investigator did not need to question the feasibility of the study. Combining the experience of using the sleep log, wrist actigraph and urine samples collection, the investigator confirmed that the one-day adaptation period was long enough for the subjects to get used to the experimental routines and environment. In view of the achievement of a safe and comfortable experimental environment in the pilot study, the investigator only changed the dilution factor from 1:250 to 1:100 in the actual study.

Implications of the pilot study for the main study

The results of this pilot study indicated that the three phases of the study were feasible and effective. The setting of the experiment was safe and comfortable for the subjects participating for three hours a day. Apart from the following enhancements, the procedures of the pilot study were replicated in the actual one as described in Chapter 4.

1. Since the subjects tended to misunderstand the questions about bedtime and sleep offset time, special attention was given to them in the actual study.

2. The misinterpretation of the function of wrist actigraph was avoided by the citation of the example of sphygmomanometer. For the management of the actigraph especially the wet wrist band, the investigator gave recommendations to the subjects before the commencement of the experiment. Because the wearing of the actigraph might induce embarrassment, the investigator also suggested some proper responses to the subjects.

3. Since the handling of urine sample collecting bottles was not satisfactory in the pilot study, the investigator emphasized the relevant instructions in the actual study.

Chapter 6

Results (I) – The characteristics of the subjects

Introduction

Data collected in the study is presented in Chapters 6 to 9. The analysis of data was driven by the research questions stated in Chapter 1. The investigator mainly focused on the two aspects of the results: the characteristics of the subjects and the effects of bright light exposure on the subjects. This chapter deals with the characteristics of the subjects. For Chapters 7 to 9, the effects of bright light exposure on the subjects will be explored.

In response to the research questions 1 to 3, this chapter emphasizes the sleep history and the latest sleep conditions of the subjects. The demographic information of the subjects and sleep-related factors are available to capture their characteristics. In addition, the correlation between the sleep log and actigraphic recording is presented. Since sleep quality will not be the same throughout the week, no consistency of the sleep log and the actigraph is investigated. The detection of first night effect on the aMT6s excretion was shown. All the data presented in the parts of demographic information, sleep history and sleep-related

factors are extracted from the screening assessment and the questionnaire. To formulate the recent sleep state of the subjects, actigraphic data and the results of radioimmunoassay of Day 2 (baseline of the pre-bright light exposure stage) of the experiment are integrated.

Demographic information

Fifty-five institutionalized elderly women participated in the study and all of them wanted to improve their sleep qualities. Eight of them quit the experiment. The drop-out rate was 14.6%. Fifty percent of these subjects (n = 4) claimed that they could not tolerate the brightness of the light during the experiment. Twenty-five percent of them (n = 2) found it too tiring to sit for a long time (3 hours per day). For the remaining twenty-five percent (n = 2), they would rather do something else. Apart from the withdrawal cases, two subjects were disqualified because they had taken medications which would affect their sleep. In addition, seven subjects were also disqualified for the failure in completing actigraphic data collection, urine samples collection or sleep log. Therefore, there were only 38 subjects eligible for the study.

These 38 subjects came from 9 elderly care homes situated in Kowloon or the New Territories. Their mean age was 79.84 years old (SD = 6.17 years). Their

mean body mass index (BMI) was 22.62 kg/m^2 (SD = 4.31 kg/m^2). Most of them (92.1%, n = 35) had their BMIs less than 27 kg/m^2. More than a half (78.9%, n = 30) of the subjects accepted or were satisfied with their health status. 60.5% of them (n = 23) considered their sleep as bad or very bad and 15.8% of them (n = 6) found themselves still tired or sleepy just after a night of sleep. For those who slept bad or very bad, there were 26.1% (n = 6) not satisfied with their health condition. As revealed by the Spearman correlation coefficient (r = 0.11, p = 0.522 for self-rated sleep quality), the association between self-rated health status and sleep quality did not exist.

Sleep history

Among these 38 subjects, 92.1% of them (n = 35) had experienced sleep disturbances for a year or more. The mean duration for the occurrence was 8.70 years (SD = 8.65 years). There were 13.2% (n = 5) of the 38 subjects whose rate of sleep disturbance occurrence was not fixed. Excluding these 5 subjects, 63.6% of the subjects (n = 21) claimed their sleep disturbances occurred every night. The mean occurrence rate was 5.46 times per week (SD = 2.20 times per week). Apart from the rate of occurrence, both the pattern and mode of the occurrence should also be considered in the assessment of sleep disturbance. There were 18.4% of the 38 subjects (n = 7) describing the disturbance as never stopping

while 73.7% of them (n = 28) stated no fixed mode. All of their disturbances were gradual. There were 65.8% of the subjects (n = 25) with sleep disturbance starting between the ages of 65 and 84. Their mean age of onset of the sleep disturbance was 71.14 years old (SD = 11.58 years). Facing such gradual but non-fixed changes, four subjects tried to relieve their disturbances by listening to radio (n = 1), taking sleeping pills regularly (n = 1) or irregularly (n = 1), or taking Piriton (n = 1) whenever necessary.

There were many different kinds of sleep disturbances. According to the selection criteria of the study, some disturbances were excluded. For these 38 subjects, the most popular complaints were difficulty in initiating sleep, DIS (50.0%, n = 19), difficulty in maintaining sleep, DMS (57.9%, n = 22) and early morning awakening, EMA (36.8%, n = 14). Compared with the other two disturbances, the ones with EMA seemed to have the worst sleep. In DIS cases (n = 19), there were 78.9% of the subjects (n = 15) reporting their sleep as bad or very bad. For DMS cases (n = 22), 63.6% of the subjects (n = 14) were unsatisfied with their sleep. Among those complaining of EMA (n = 14), 92.9% of the subjects (n = 13) claimed their sleep as bad or very bad.

Difficulty in initiating sleep (DIS)

For those complaining of DIS (n = 19), the mean sleep onset latency (SOL) was 152.50 minutes (SD = 90.33 minutes) with a range between 15.00 and

360.00 minutes except one subject who could not determine her SOL. The mode of their SOLs was 180.00 minutes. Among those without this complaint (n = 19), one subject could not determine her SOL. The mean SOL of this group was 66.00 minutes (SD = 62.57 minutes) with a range between 2.50 and 210.00 minutes. The relevant mode was 60.00 minutes. A great gap was revealed between the complaint and non-complaint groups. In view of similar mean bedtime (08:30 PM for the ones with the complaint and 08:38 PM for the ones without the complaint), the subjects suffering from DIS were really in need of improvement.

Difficulty in maintaining sleep (DMS)

Looking into the 37 reasons for waking at night, the investigator found that nocturia was a major one (64.9%, n = 24) although some subjects could not identify the reason (24.3%, n = 9). Micturition was claimed as their main activity (80.0%, n = 32) after waking at night. However, none of them reported nocturia as a factor worsening their sleep disturbances. In fact, one third of them (34.2%, n = 13) thought that there was no contributing factor towards their sleep disturbances. For the 22 subjects with the DMS complaint, the mean number of waking after sleep onset (WASOf) was 3.14 times (SD = 1.21 times) with a range of frequency between 1.00 and 6.50 times except one subject had very frequent waking at night. Compared with those without the complaint (n = 16), the mean WASOf was 1.81 times (SD

= 1.11 times) with a range of frequency between 0 and 4.00 times. The sleep of the subjects with DMS complaint seemed to be more fragmented. In addition, 45.5% of them (n = 10) had the duration for each waking after sleep onset (WASOd) lasting for a long time and 4.5% of them (n = 1) could not fall asleep again once they woke up at night. Among the subjects not complaining of DMS (n = 16), there were 12.5% of the subjects (n = 2) with their WASOds lasting for a long time while 25.0% of them (n = 4) were unable to fall asleep again.

Early morning awakening (EMA)

There were 13.2% of the 38 subjects (n = 5) who found themselves unable to fall asleep again once they woke up at night. All of these 5 subjects complained of EMA. There were 36.8% of the 38 subjects (n = 14) complaining of EMA. Their mean sleep offset time (SoffT) was 05:28 AM (SD = 311 minutes) with a large range between 11:00 PM and 06:35 AM. Among the sufferers, only one of them (7.1%) claimed to be still tired after getting out of bed. All of them were content with their refreshment level after a night of sleep. For those without this complaint (N = 24), the mean SoffT was 05:17 AM (SD = 52 minutes) with a range of SoffT from 03:30 AM to 06:45 AM. When the rising time of both groups were reviewed, the mean rising times were 05:34 AM for the complained group and 05:57 AM for the non-complained group. Getting up at similar time, the subjects who

woke up too early in the morning ought to find a silent way to spend the time as others were still sleeping.

Napping

Since napping can be divided into intentional napping and unintentional napping, the investigator looked into them separately.

Intentional napping Although 23.7% of the 38 subjects (n = 9) had the habit of an intentional nap and 77.8% of these 9 subjects (n = 7) claimed tiredness as the reason to nap, only two of them could actually fall asleep. Their mean lying time was 81.67 minutes (SD = 27.16 minutes). The mean asleep time was 45.00 minutes (SD = 21.21 minutes). Among the 23 subjects, who considered their sleep as bad or very bad, 21.7% of them (n = 5) had the habit of intentional napping. Tiredness remained as the dominant reason for an intentional nap as reflected by all of the 5 subjects. Nevertheless, only one out of these 5 subjects could fall asleep during an intentional nap with both the lying time and the asleep time at 60 minutes. Regardless of the sleep quality of the subjects, 77.8% of the 9 subjects (n = 7) napped regularly in the afternoon. Intentional napping did not seem to be common among the subjects.

Unintentional napping Many subjects would not like to sleep regularly in the daytime but they could not avoid an unintentional nap. Sixteen subjects (42.1%) had the habit of an unintentional nap. Most of these 16 subjects (93.8%, n = 15) dozed for a moment each time. More than half (56.3%, n = 9) of them dozed in the afternoon. For the 23 subjects who considered their sleep as bad or very bad, 52.2% of them (n = 12) had the habit of unintentional napping. They mostly dozed for a moment (91.7%, n = 11). About half of them (41.7%, n = 5) napped in the afternoon.

The actigraphic sleep-wake parameters and 6-sulphatoxymelatonin levels of the subjects

The actigraphic sleep-wake parameters and 6-sulphatoxymelatonin (aMT6s) levels were described according to the grouping of good and poor sleepers. The latest sleep conditions of the subjects were dependent on the actigraphic data collected on Day 2 – the pre-bright light exposure stage of the experiment. For those reported to have bad or very bad sleep, they were grouped as poor sleepers; otherwise, all were grouped as good sleepers. The sleep-wake parameters included sleep efficiency (SE), sleep-wake ratio (SWR), total sleep time (TST), total bed time (TBT), sleep onset latency (SOL), sleep onset time (SOT), wake

after sleep onset (WASO) and sleep offset time (SoffT). The magnitude of the parameters is shown in Table 6.1.

Table 6.1 The sleep-wake parameters of the subjects (N = 38)

Sleep Parameters	mean	SD	maximum	minimum
SE	82.34	10.07	96.59	57.46
SWR	7.36	6.13	28.34	1.35
TST	418.51	58.38	529.00	274.67
TBT	509.11	48.16	615.33	420.17
SOL	12.38	15.96	66.33	0.00
SOT	09:50 PM	31.53	11:39 PM*	09:08 PM**
WASOf	7.74	3.87	15.00	2.00
WASOd	8.79	6.85	43.29	2.24
WASOt	63.35	41.66	173.17	10.17
SoffT	05:52 AM	45.97	07:19 AM*	04:13 AM**

Note: SE – Sleep Efficiency (%)
SWR – Sleep Wake Ratio
TST – Total Sleep Time (minute)
TBT – Total Bed Time (minute)
SOL – Sleep Onset Latency (minute)
SOT – Sleep Onset Time (time): SD is measured in minute
WASOf – Number of waking after sleep onset (times)
WASOd – Duration of each waking after sleep onset (minute)
WASOt – Total time of waking after sleep onset (minute)
SoffT – Sleep Offset Time (time): SD is measured in minute
* – the time for the last subject to fall asleep in SOT cases or the time for the last subject to wake up in SoffT cases
** – the time for the first subject to fall asleep in SOT cases or the time for the first subject to wake up in SoffT cases

When the mean actigraphic sleep-wake parameters of the good sleepers (n = 15) were compared with that of the poor ones (n = 23), the sleep of the latter might not be very poor when it was measured in a relatively objective and quantitative way (Table 6.2). In fact, sleep-wake parameters of the poor sleepers seemed to show a better sleep than that of the good ones.

Table 6.2 The comparison of the mean actigraphic sleep-wake parameters between the good (n = 15) and poor sleepers (n = 23)

Sleep Parameters	Good sleepers (n = 15)	Poor sleepers (n = 23)
SE	78.69	84.73
SWR	5.32	8.69
TST	395.39	433.59
TBT	504.05	512.41
SOL	18.61	8.32
SOT	10:00 PM	09:43 PM
WASOf	6.73	8.39
WASOd	10.13	7.92
WASOt	69.44	59.39
SoffT	05:45 AM	05:56 AM

Note: SE – Sleep Efficiency (%)
SWR – Sleep Wake Ratio
TST – Total Sleep Time (minute)
TBT – Total Bed Time (minute)
SOL – Sleep Onset Latency (minute)
SOT – Sleep Onset Time (time)
WASOf – number of waking after sleep onset (times)
WASOd – Duration of each waking after sleep onset (minute)
WASOt – Total time of waking after sleep onset (minute)
SoffT – Sleep Offset Time (time)

When the reported desirable sleeping duration was examined, two subjects could not determine it and another two stated they had no preference. For the remaining 34 subjects, their mean desirable duration for sleeping was 5.13 hours (SD = 1.27 hours) with a range between 3.50 and 9.00 hours. When the subjects were grouped into either good or poor sleepers, the mean desirable duration for sleeping of the good sleepers was 5.15 hours (SD = 1.16 hours) with a range between 3.50 and 7.00 hours. For the poor sleepers, their mean desirable duration for sleeping was 5.12 hours (SD = 1.36 hours) with a range between 3.50 and 9.00 hours. For the aMT6s levels of the subjects, the mean was 15.02 pmol/ml (SEM = 2.08 pmol/ml) with a range between 1.90 and 58.28 pmol/ml. The aMT6s levels of these two groups of sleepers were almost the same. For the good sleepers, their

mean aMT6s level was 15.36 pmol/ml (SEM = 2.63 pmol/ml) with a range between 2.27 and 35.63 pmol/ml, while the poor sleepers, their mean aMT6s level was 14.80 pmol/ml (SEM = 3.03 pmol/ml) with a range between 1.90 and 58.28 pmol/ml.

Sleep-related factors

Though not as popular as caffeinated and dairy products, smoking (2.6%, n = 1) and alcohol (none of the subjects) consumptions were low in Hong Kong institutionalized elderly people. There were 31.6% of the 38 subjects (n = 12) consuming caffeinated products regularly. Among the caffeinated products consumption, 64.3% of their consumption (n = 9) was mainly Chinese tea while 35.7% (n = 5) was coffee. As part of the Chinese culture, the high consumption rate of Chinese tea was expected. There was no significant correlation between sleep quality and caffeinated food consumption ($r = 0.04$, $p = 0.791$). For those who considered their sleep as bad or very bad (n = 23), seven of them consumed caffeinated food regularly while it was five for the good sleepers. Among the seven poor sleepers, five mainly consumed Chinese tea. Just more than half of them (57.1%, n = 4) consumed the caffeinated products in the morning while the remaining (42.9%, n = 3) consumed the products either in the afternoon (n = 2) or in the evening (n = 1). Similar to caffeinated products, 34.2% of the 38 subjects

(n = 13) consumed dairy products regularly. There was also no significant correlation between the self-rated sleep quality and the dairy product consumption habit (r = 0.28, p = 0.090). Among the 23 subjects claiming their sleep as bad or very bad, 26.1% of them (n = 6) consumed dairy products regularly and 73.9% (n = 17) did not have such habit. Nearly half of the good sleepers (n = 7, 46.7%) consumed dairy products frequently.

Both exercise and outdoor activities were very common among the subjects. There were 78.9% of the 38 subjects (n = 30) doing exercise each day. Morning was found to be the most favourable time (97.1%, n = 33) for this. The mean duration for doing exercise was 33.53 minutes (SD = 16.86 minutes). The mode of the duration was 30 minutes. There was no preference for indoor (44.1%, n = 15) or outdoor (55.9%, n = 19). Although doing exercise was not significantly correlated with the sleep quality (r = 0.13, p = 0.430), there were 73.9% (n = 17) poor sleepers (n = 23) and 86.7% (n = 13) good sleepers did exercise regularly. For outdoor activities, only 60.5% of the 38 subjects (n = 23) went outside regularly. Morning remained as the most favourable time (84.6%, n = 22) for them. The mean duration for outdoor activities was 44.58 minutes (SD = 28.81 minutes). Similar to exercise, the mode of the duration for outdoor activities was 30 minutes. No significant correlation (r = -0.06, p = 0.724) was identified between self-rated sleep quality and outdoor activities. More than half (65.2%, n = 15) of those who were dissatisfied with their sleep quality (n = 23) had the habit of outdoor activities. In terms of good sleepers, 53.4% (n = 8) had this habit.

Correlation between the sleep log and the actigraphic recording

Among the sleep-wake parameters. all but three were not significantly correlated. The three parameters were the total bed time (TBT). the total time of waking after sleep onset (WASOt) and the sleep offset time (SoffT). Looking into the paired mean difference of the parameters. the investigator had observed that the reported sleep-wake parameters in the sleep log except sleep onset latency (SOL). tended to be underestimated when compared with that of the actigraphic recording. The details of the correlation coefficients are shown in Table 6.3.

Table 6.3 The correlation coefficients and the paired mean differences of the sleep-wake parameters between the sleep log and the actigraphic recording

Sleep-Wake Parameters	Pearson, *r*	Significance (2-tailed)	Paired Mean Difference*	Significance (2-tailed)
SE	0.048	0.782	-7.79	0.062
TST	0.042	0.806	-55.00	0.012
TBT	0.796	0.000	-20.00	0.001
SOL	-0.054	0.747	23.00	0.000
SOT	-0.257	0.119	-49.82	0.332
WASOf	0.010	0.950	-5.87	0.000
WASOt	0.382	0.022	-9.00	0.363
SoffT	0.380	0.019	-39.00	0.000

Note: SE – Sleep Efficiency (%)
TST – Total Sleep Time (minute)
TBT – Total Bed Time (minute)
SOL – Sleep Onset Latency (minute)
SOT – Sleep Onset Time (minute)
WASOf – Number of waking after sleep onset (times)
WASOt – Total time of waking after sleep onset (minute)
SoffT – Sleep Offset Time (minute)
* – Paired mean difference = [log] – [actigraph]

First night effect

When the aMT6s level was considered, the level on Day 1 was significantly correlated ($r = 0.644$, $p = 0.000$) with that on Day 2. In addition, no significant change in the level ($p = 0.556$) was identified within these two days. Hence, the first night effect was not detected in the aMT6s level.

Summary

These 38 insitutionalized elderly women were comparatively thin and healthy. All of them would like to improve their sleep quality. More than half of them considered their sleep as bad or very bad. Most of their disturbances had occurred for more than a year. The disturbance developed in a gradual and non-fixed mode. Among their complaints, the most popular ones were difficulty in initiating sleep (DIS), difficulty in maintaining sleep (DMS) and early morning awakening (EMA). More than 90.0% of the subjects complaining of EMA claimed their sleep was bad or very bad.

For those complaining of DIS, a big gap in the sleep onset latency was revealed between the complaint and non-complaint groups, though their mean bedtime was

similar. The sleep of those complaining of DMS was more fragmented than those who did not complain. Nearly half of them would wake for a long time once they woke at night. Nocturia. was reported as the main reason for mid-night waking by all the 38 subjects. This was not considered as a contributing factor to their sleep disturbance. It was interesting to note that the sleep offset time of the subjects complaining of EMA could be as early as 11:00 PM and as late as 06:45 AM. In addition. their mean rising time was closed to that of the non-complaint subjects. In the case of daytime sleep. intentional napping was not common but unintentional napping was habitual in more than 40.0% of the subjects. Sleeping during daytime was mainly because of tiredness. Some subjects who were not satisfied with their sleep might sleep during daytime.

When reviewing the latest actigraphic sleep-wake parameters of the subjects. the investigator found that the mean sleep efficiency was only 82.34%. It was therefore not surprising when they said they were not satisfied with their sleep. They spent more than eight hours in bed but. in return. could only sleep for about seven hours. The fragmentation of sleep had further augmented their frustration. Thus. when the subjects were grouped into either good or poor sleepers. there was no dominant difference between these two groups in actigraphic sleep-wake parameters. 6-sulphatoxymelatonin levels and the desirable duration for sleeping.

About one third of the subjects consumed caffeinated or dairy products regularly. Chinese tea was the major choice among the caffeinated products. The sleep

quality was not significantly correlated with the consumption of caffeinated and dairy products. Similarly, it was also not significantly correlated with exercise and outdoor activities. There were more than 60.0% of the subjects doing exercise or going outside regularly. The usual duration for these two kinds of activities was about half an hour.

In terms of the correlation between the sleep log and the actigraphic recording, the correlation was strong in TBT, WASOt and SoffT. Except SOL, the sleep log tended to be underestimated as compared with the actigraphic recording. Following the correlation between the aMT6s level of Day 1 and Day 2, the investigator concluded that there was no first-night effect.

Since the subjects wanted to improve their sleep quality and many of them considered their sleep to be bad or very bad, the investigator hoped that their desires might be fulfilled by bright light exposure. The effects of bright light on the subjects' sleep satisfaction level, actigraphic sleep-wake parameters and 6-sulphatoxymelatonin level will be reported in the following chapters.

Chapter 7

Results (II) - The Effects of Bright Light Exposure on the Subjects: The Changes in Sleep Satisfaction Level (SSL)

Introduction

This chapter includes results for the fourth research question. It also partly answers the fifth and sixth research questions. During the time period 1800 hours to 2100 hours, subjects were exposed to white bright light (2460 – 3990 lux) on Days 3 and 4. For the other four experimental days, they were exposed to red dim light with light intensity not exceeding 450 lux. Throughout the experimental period, a stable environment was maintained with the mean room temperature as 25.0°C and the mean bedroom temperature as 23.5°C. A five-point subjective rating scale ranging from very good to very poor was used to evaluate the subjective quality of sleep. The sleep satisfaction levels (SSLs) of the subjects on Day 5 and 6 (post bright light exposure stage) were compared with those of Day 2 (pre-bright light exposure stage). Those with their SSLs increased were classified as the increase group, decreased as the decrease group and unchanged as the unchanged group. The corresponding changes in the actigraphic sleep-wake

parameters and 6-sulphatoxymelatonin (aMT6s) levels were explored according to the changes in the SSL.

The change in the sleep satisfaction level (SSL)

With reference to the subjective reporting of the subjects (N = 38), many of them indicated that their sleep qualities improved after bright light exposure. Wilcoxon test showed that the mean of the sleep quality of post-bright light exposure stage was lower than that of the pre-bright light exposure stage (mean of sleep quality = 2.61 on Day 2; 2.50 on Day 5; 2.34 on Day 6). Therefore, subjects found better sleep quality after bright light exposure (p = 0.631 on Day 5; 0.069 on Day 6) though the insignificant results rejected the first alternative hypothesis stated in Chapter 1. On Day 5, there were 34.2% (n = 13) of the subjects with their SSLs increased, 26.3% (n = 10) decreased and 39.5% (n = 15) unchanged. On Day 6, 28.9% (n = 11) of the subjects claimed to have their SSLs increased while 13.2% (n = 5) decreased and 57.9% (n = 22) were unchanged. The evaluation of their sleep qualities throughout the experiment is presented in Figure 7.1.

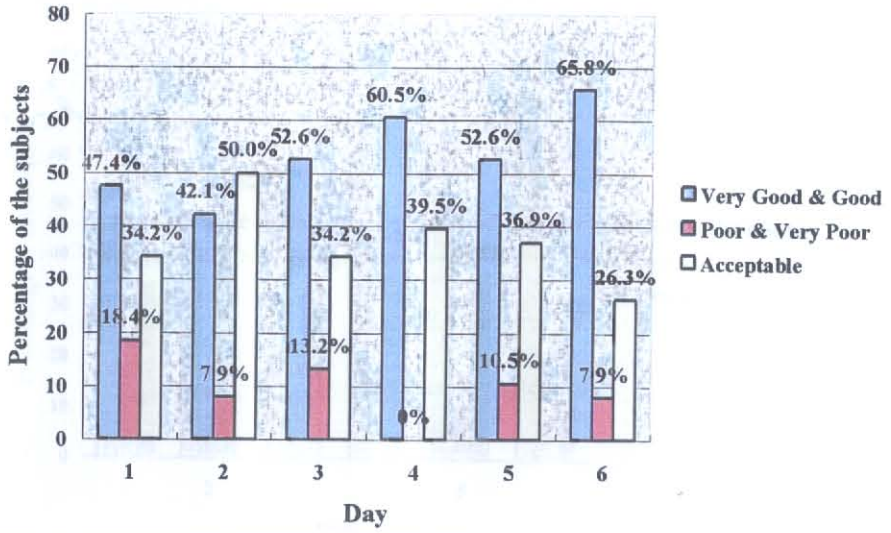


Figure 7.1 Sleep satisfaction level of the subjects throughout the experimental period (N = 38)

When the changes of the sleep efficiency (SE) and 6-sulphatoxymelatonin (aMT6s) level were examined with reference to the sleep satisfaction level (Table 7.1 – Table 7.3), subjects had significant differences in their sleep efficiencies on Day 5. For the increase group, the difference between the SE means on Day 2 and Day 5 was 6.33%, 95% confidence interval –10.54% to –2.12% (t = -3.27, df = 12, p = 0.007). It was 7.31%, 95% confidence interval 2.77% to 11.85% (t = 3.64, df = 9, p = 0.005) for the decrease group and 4.42%, 95% confidence interval –8.61% to –0.22% (t = -2.26, df = 14, p = 0.040) for the unchanged group. Except for those reporting poor or very poor sleep, more than half of the subjects had their sleep efficiencies increased. Poor sleepers mainly reported a decrease in SE after bright light exposure. In terms of aMT6s level, no prominent

trend of change in the level was observed regarding the SSL. As a result, alternative hypothesis 3 was supported while the hypothesis 4 was rejected.

Table 7.1 The change of the corresponding sleep efficiency and 6-sulphatoxymelatonin level on Day 5 with respect to the sleep satisfaction level

Sleep Satisfaction Level	Sleep Efficiency (SE)		6-sulphatoxymelatonin (aMT6s) Level	
	Increase	Decrease	Increase	Decrease
Very Good & Good (n = 20)	70.0%	30.0%	60.0%	40.0%
Poor & Very Poor (n = 4)	25.0%	75.0%	100.0%	0%
Acceptable (n = 14)	57.1%	42.9%	28.6%	71.4%

Table 7.2 The change of the corresponding sleep efficiency and 6-sulphatoxymelatonin level on Day 6 with respect to the sleep satisfaction level

Sleep Satisfaction Level	Sleep Efficiency (SE)		6-sulphatoxymelatonin (aMT6s) Level	
	Increase	Decrease	Increase	Decrease
Very Good & Good (n = 25)	56.0%	44.0%	56.0%	44.0%
Poor & Very Poor (n = 3)	33.3%	66.7%	33.3%	66.7%
Acceptable (n = 10)	60.0%	40.0%	30.0%	70.0%

Table 7.3 The change of the corresponding sleep efficiency and 6-sulphatoxymelatonin level after bright light exposure with respect to the change in sleep satisfaction level

Sleep Satisfaction Level	Sleep Efficiency (SE)		6-sulphatoxymelatonin (aMT6s) Level	
	Day 5	Day 6	Day 5	Day 6
Increase group	-	-	-	-
Decrease group	-	-	-	-
Unchanged group	-	-	-	-

Note: "+" = $p < 0.05$
"-" = $p > 0.05$

The change in the sleep-wake parameters

After bright light exposure. SSL was changed along with the related actigraphic sleep-wake parameters. As shown by the Spearman test. significant correlations between the change in the SSL and the changes in the actigraphic sleep-wake parameters were identified on Day 5 but not on Day 6. Among the parameters. the changes in sleep efficiency (SE). sleep-wake ratio (SWR). total sleep time (TST). sleep onset time (SOT) and total time of waking after sleep onset (WASOt) were significantly correlated with the changes in SSL (Table 7.4). According to the increase or decrease in SSL. the corresponding changes in the sleep-wake parameters will now be discussed.

Table 7.4 The correlation coefficients and significant levels between sleep satisfaction level and sleep-wake parameters

Correlation Items	Day 5		Day 6	
	r	*p*	r	*p*
SSL - SE	0.42	0.008	0.03	0.845
SSL - SWR	0.42	0.008	0.04	0.802
SSL - TST	0.63	0.000	0.16	0.353
SSL - TBT	0.12	0.460	0.26	0.114
SSL - SOL	-0.29	0.079	0.22	0.183
SSL - SOT	-0.37	0.021	0.08	0.626
SSL - WASOf	-0.23	0.169	0.01	0.961
SSL - WASOd	-0.23	0.169	0.01	0.961
SSL – WASOt	-0.58	0.000	0.01	0.961
SSL – SoffT	0.09	0.610	0.08	0.627

Note: SE – Sleep Efficiency
SWR – Sleep Wake Ratio
TST – Total Sleep Time
TBT – Total Bed Time
SOL – Sleep Onset Latency
SOT – Sleep Onset Time
WASOf – number of waking after sleep onset
WASOd – Duration of each waking after sleep onset
WASOt – Total time of waking after sleep onset
SoffT – Sleep Offset Time
SSL – Sleep Satisfaction Level

Sleep Efficiency (SE) and Sleep-Wake Ratio (SWR)

After bright light exposure, the changes of SE and SWR were significantly correlated with the change in SSL on Day 5 ($r = 0.42$, $p = 0.008$). However, the correlations were negligible and insignificant on Day 6 ($r = 0.03$, $p = 0.845$ for SE: $r = 0.04$, $p = 0.802$ for SWR).

The increase group on Day 5 For those with their SSLs increased on Day 5 ($n = 13$), SE and SWR changed significantly after bright light exposure (Table 7.5). These two sleep-wake parameters were increased in 76.9% ($n = 10$) of the subjects but decreased in 23.1% ($n = 3$) of them. The *mean*

increase of SE was 8.35% (SD = 6.71%) with a range of increase between 0.03% and 20.92%. The *mean decrease of SE* was 0.41% (SD = 0.35%) with a range of decrease between 0.04% to 0.72%. For SWR, the *mean increase of SWR* was 3.66 (SD = 2.30) with a range of increase between 0.01 and 8.39. The *mean decrease of SWR* was 1.34 (SD = 1.09) with a range of decrease between 0.09 and 2.00.

Table 7.5 The results of paired-sample *t* test of the changes in sleep efficiency, SE, and sleep-wake ratio, SWR, after bright light exposure with respect to the increase groups of the sleep satisfaction level

	Paired Mean Differences	*t*	*p*
Day 2 - Day 5: SE (n = 13)	-6.33	-3.27	0.007
Day 2 - Day 5: SWR (n = 13)	-2.51	-3.02	0.011
Day 2 - Day 6: SE (n = 11)	-3.04	-1.01	0.337
Day 2 - Day 6: SWR (n = 11)	-0.14	-0.08	0.939

Note: Paired mean differences of SE was measured in percentage.
Paired mean differences of SWR was a ratio.

The increase group on Day 6 For those with their SSLs increased on Day 6 (n = 11), there was no significant change in their related SEs and SWRs (Table 7.5). These two sleep-wake parameters were increased in 45.5% (n = 5) of the subjects but decreased in 54.5% (n = 6) of them. The *mean increase of SE* was 5.65% (SD = 2.16%) with a range of increase between 3.35% and 8.16%. The *mean decrease of SE* was 10.28% (SD = 7.57%) with a range of decrease between 1.51% and 23.91%. For SWR, the *mean increase of SWR* was 5.21 (SD = 2.50) with a range of increase between 1.00 and 7.44. The *mean decrease of SWR* was 4.61 (SD = 4.08) with a range of decrease between 1.60 and 11.77.

The decrease group on Day 5 For those with their SSLs decreased on Day 5 (n = 10), their related SEs and SWRs changed significantly (Table 7.6). These two sleep-wake parameters were increased in 20.0% (n = 2) of the subjects but decreased in 80.0% (n = 8) of them. The *mean increase of SE* was 1.21% (SD = 1.34%) with a range of increase between 0.26% and 2.15%. The *mean decrease of SE* was 9.43% (SD = 5.07%) with a range of decrease between 2.34% and 18.67%. In the case of SWR, the *mean increase* was 0.43 (SD = 0.26) with a range of increase between 0.24 and 0.61. The *mean decrease of SWR* was 3.69 (SD = 3.17) with a range of decrease between 0.31 and 8.19.

Table 7.6 The results of paired-sample *t* test of the changes in sleep efficiency, SE, and sleep-wake ratio, SWR, after bright light exposure with respect to the decrease groups of the sleep satisfaction level

	Paired Mean Differences	*t*	*p*
Day 2 - Day 5: SE (n = 10)	-7.31	-3.64	0.005
Day 2 - Day 5: SWR (n = 10)	-2.87	-2.76	0.022
Day 2 - Day 6: SE (n = 5)	-8.25	-1.90	0.131
Day 2 - Day 6: SWR (n = 5)	-5.26	-1.03	0.363

Note: Paired mean differences of SE was measured in percentage.
Paired mean differences of SWR was a ratio.

The decrease group on Day 6 For those with their SSLs decreased on Day 6 (n = 5), no significant change in their SEs and SWRs was identified (Table 7.6). These two sleep-wake parameters were increased in 20.0% (n = 1) of the subjects but decreased in 80.0% (n = 4) of them. Increases in SE and SWR were 6.37% and 6.11 respectively. The *mean decrease of SE* was 11.91% (SD = 6.09%) with a range of decrease between 3.82 % and

17.54%. The *mean decrease of SWR* was 8.10 (SD = 11.01) with a range of decrease between 1.73 and 24.57.

Total Sleep Time (TST)

The change in SSL was significantly and positively correlated with the change in TST on Day 5 ($r = 0.63$, $p = 0.000$). However, the same phenomenon could not be applied on Day 6 ($r = 0.16$, $p = 0.353$).

The increase group on Day 5 These 13 subjects showed significant TST change after bright light exposure (Table 7.7). There were 92.3% (n = 12) of the subjects with TST increased while the remaining 7.7% (n = 1) decreased. The *mean increase of TST* was 47.17 minutes (SD = 30.47 minutes) with a range of increase between 7.00 and 110.00 minutes. For the subject with her TST decreased, the decrease in TST was 35.00 minutes.

Table 7.7 The results of paired-sample *t* test of the changes in total sleep time after bright light exposure with respect to the sleep satisfaction level

	Paired Mean Differences (min)	*t*	*p*
Increase group on Day 5 (n = 13)	40.85	-3.98	0.002
Increase group on Day 6 (n = 11)	-7.09	-0.31	0.765
Decrease group on Day 5 (n = 10)	-43.35	-2.70	0.025
Decrease group on Day 6 (n = 5)	-55.17	-1.98	0.119

The increase group on Day 6 Eleven subjects had reported a SSL increase on Day 6. Their related TSTs changed insignificantly (Table 7.7). Among

them. there were 54.5% (n = 6) of subjects with TST increased and 45.5% (n = 5) decreased. The *mean increase of TST* was 52.83 minutes (SD = 22.82 minutes) with a range of increase between 25.00 and 84.00 minutes. The *mean decrease of TST* was 79.00 minutes (SD = 47.08 minutes) with a range of decrease between 27.00 and 130.00 minutes.

The decrease group on Day 5 There were 10 subjects with their SSLs decreased on Day 5. Their TSTs changed significantly after bright light exposure (Table 7.7). Only 10.0% (n = 1) of them showed a TST increase while 90.0% (n = 9) a decrease. For the subject with a TST increase. the increase in TST was 27.17 minutes. The *mean decrease of TST* was 51.19 minutes (SD = 47.08 minutes) with a range of decrease between 3.00 and 132.00 minutes.

The decrease group on Day 6 There were 5 subjects with their SSLs decreased on Day 6. The change in their TSTs was not significant (Table 7.7). 20.0% (n = 1) of the subjects showed a TST increase but 80.0% (n = 4) a decrease. For the subject with a TST increase. the increase was 37.17 minutes. The *mean decrease of TST* was 78.25 minutes (SD = 40.58 minutes) with a range of decrease between 28.00 and 124.00 minutes.

Sleep Onset Time (SOT)

On Day 5, the change in SSL was significantly correlated with the change in SOT ($r = -0.37$, $p = 0.021$). However, there was no significant correlation identified on Day 6 ($r = 0.08$, $p = 0.626$). The advancement of the SOT was described as a forward shift. The delay of the SOT was stated as a backward shift.

The increase group on Day 5 For those with a SSL increase on Day 5 (n = 13), the significant shift in SOTs was shown (Table 7.8). There were 15.4% (n = 2) of the subjects with SOT shifted backwards while 84.6% (n = 11) had shifted forwards. The *mean duration for SOT of backward shift* was 14.9 minutes (SD = 17.37 minutes) with a range of duration of shift between 2.62 and 27.20 minutes. The *mean duration for SOT of forward shift* was 15.18 minutes (SD = 9.82 minutes) with a range of duration of shift between 2.00 minutes and 26.50 minutes.

Table 7.8 The results of paired-sample *t* test of the changes in sleep onset time after bright light exposure with respect to the sleep satisfaction level

	Paired Mean Differences (min)	*t*	*p*
Increase group on Day 5 (n = 13)	-10.55	-2.49	0.028
Increase group on Day 6 (n = 11)	-1.17	-0.15	0.883
Decrease group on Day 5 (n = 10)	-15.22	-1.46	0.178
Decrease group on Day 6 (n = 5)	-13.87	-1.90	0.130

The increase group on Day 6 There were 11 subjects with SSL increased on Day 6. Unlike Day 5, their related SOTs showed no significant shift after bright light exposure (Table 7.8). Among them, 45.5% (n = 5) of subjects had SOT shifted backwards but 54.5% (n = 6) shifted forwards. The *mean duration for SOT of backward shift* was 21.88 minutes (SD = 22.08 minutes) with a range of duration of shift between 3.88 and 58.00 minutes. The *mean duration for SOT of forward shift* was 16.08 minutes (SD = 11.40 minutes) with a range of duration of shift between 3.50 and 33.72 minutes.

The decrease group on Day 5 These 10 subjects had their SOTs shifted insignificantly after bright light exposure (Table 7.8). There were 60.0% (n = 6) of the subjects with SOT shifted backwards and 40.0% (n = 4) shifted forwards. The *mean duration for SOT of backward shift* was 34.38 minutes (SD = 28.32 minutes) with a range of duration of shift between 9.28 and 73.67 minutes. The *mean duration for SOT of forward shift* was 13.52 minutes (SD = 9.15 minutes) with a range of duration of shift between 5.08 and 26.48 minutes.

The decrease group on Day 6 There were 5 subjects with their SSLs decreased on Day 6 and their related SOTs shifted insignificantly after bright light exposure (Table 7.8). Among them, 20.0% (n = 1) of the subjects showed SOT backward shift and 80.0% (n = 4) a forward shift.

The duration of the SOT backward shift was 12.78 minutes. The *mean duration for SOT of forward shift* was 20.53 minutes (SD = 7.68 minutes) with a range of duration of shift between 13.15 and 29.48 minutes.

Total time of waking after sleep onset (WASOt)

The change in SSL was significantly and negatively correlated with the change in the total time of waking after sleep onset ($r = -0.58$, $p = 0.000$) on Day 5. Nevertheless, the correlation was negligible and insignificant on Day 6 ($r = 0.01$, $p = 0.961$).

The increase group on Day 5 For those with their SSLs increased on Day 5 (n = 13), their related WASOts changed significantly (Table 7.9). There were 15.4% (n = 2) of the subjects with WASOt increased while 84.6% (n = 11) showed a decrease. The *mean increase of WASOt* was 15.50 minutes (SD = 17.68 minutes) with a range of increase between 3.00 and 28.00 minutes. The *mean decrease of WASOt* was 25.18 minutes (SD = 29.51 minutes) with a range of decrease between 7.00 and 110.00 minutes.

Table 7.9 The results of paired-sample *t* test of the changes in the total time of waking after sleep onset after bright light exposure with respect to the sleep satisfaction level

	Paired Mean Differences (min)	*t*	*p*
Increase group on Day 5 (n = 13)	-18.92	-2.17	0.050
Increase group on Day 6 (n = 11)	-6.45	-0.73	0.481
Decrease group on Day 5 (n = 10)	-27.90	-3.37	0.008
Decrease group on Day 6 (n = 5)	-34.20	-1.25	0.280

The increase group on Day 6 There were 11 subjects with SSL increased on Day 6. Their related WASOts changed insignificantly (Table 7.9). Among them, there were 63.6% (n = 7) of the subjects with their WASOts increased but 36.4% (n = 4) decreased. The *mean increase of WASOt* was 25.43 minutes (SD = 14.54 minutes) with a range of increase between 6.00 and 42.00 minutes. The *mean decrease of WASOt* was 26.75 minutes (SD = 10.63 minutes) with a range of decrease between 14.00 and 36.00 minutes.

The decrease group on Day 5 Ten subjects reported their SSLs decreased on Day 5 and their related WASOts changed significantly (Table 7.9). There were 90.0% (n = 9) of the subjects with WASOt increased while the remaining 10.0% (n = 1) showed a decrease. The *mean increase of WASOt* was 32.33 minutes (SD = 23.48 minutes) with a range of increase between 1.00 and 71.00 minutes. In the case of the subject with a WASOt decrease, the decrease in duration was 12.00 minutes.

The decrease group on Day 6 There were 5 subjects reporting their SSLs decreased on Day 6. Their related WASOts changed insignificantly (Table 7.9). Among them, 80.0% (n = 4) of the subjects had WASOts increased but 20.0% (n = 1) decreased. The *mean increase of WASOt* was 56.75 minutes (SD = 40.16 minutes) with a range of increase between 6.00 and 95.00 minutes. For the subjects with a WASOt decrease, the decrease in the duration was 56.00 minutes.

The change in the 6-sulphatoxymelatonin (aMT6s) level

The related aMT6s level change was not significantly correlated with the changes in the SSL (r = -0.03, p = 0.867 on Day 5; r = -0.14, p = 0.406 on Day 6) after bright light exposure.

The increase group on Day 5 Subjects with SSL increased on Day 5 (n = 13) showed no significance in their aMT6s levels (Table 7.10). 61.5% (n = 8) of the subjects had aMT6s levels increased and 38.5% (n = 5) decreased. The *mean increase in aMT6s level* was 4.28 pmol/ml (SEM = 1.14 pmol/ml) with a range of increase between 0.58 and 9.26 pmol/ml. The *mean decrease in aMT6s level* was 4.94 pmol/ml (SEM = 3.08 pmol/ml) with a range of decrease between 0.31 and 16.45 pmol/ml.

Table 7.10 The results of paired-sample *t* test of the changes in 6-sulphatoxymelatonin after bright light exposure with respect to the sleep satisfaction level

	Paired Mean Differences (pmol/ml)	*t*	*p*
Increase group on Day 5 (n = 13)	-0.74	-0.40	0.695
Increase group on Day 6 (n = 11)	-2.66	-1.01	0.338
Decrease group on Day 5 (n = 10)	-1.52	-0.83	0.426
Decrease group on Day 6 (n = 5)	-1.34	-1.98	0.119

The increase group on Day 6 There were 11 subjects with SSL increased on Day 6. Their aMT6s levels changed insignificantly after bright light exposure (Table 7.10). Among them, 45.5% (n = 5) had aMT6s levels increased while 54.5% (n =

6) had decreased. The *mean increase in aMT6s level* was 4.65 pmol/ml (SEM = 2.08 pmol/ml) with a range of increase between 0.14 and 12.19 pmol/ml. The *mean decrease in aMT6s level* was 8.76 pmol/ml (SEM = 2.55 pmol/ml) with a range of decrease between 3.05 and 19.15 pmol/ml.

The decrease group on Day 5 For those with their SSLs decreased (n = 10) on Day 5, their related aMT6s levels changed insignificantly (Table 7.10). There were 70.0% (n = 7) of the subjects with their aMT6s levels increased but 30.0% (n = 3) had theirs decreased. The *mean increase in aMT6s level* was 3.82 pmol/ml (SEM = 1.83 pmol/ml) with a range of increase between 0.20 and 13.65 pmol/ml. The *mean decrease in aMT6s level* was 3.83 pmol/ml (SEM = 2.51 pmol/ml) with a range of decrease between 1.06 and 8.83 pmol/ml.

The decrease group on Day 6 There were 5 subjects reporting to have SSL decreased on Day 6. The related aMT6s levels changed insignificantly (Table 7.10). Among them, 80.0% (n = 4) had aMT6s levels increased but 20.0% (n = 1) decreased. The *mean increase in aMT6s level* was 1.92 pmol/ml (SEM = 0.47 pmol/ml) with a range of increase between 0.52 and 2.40 pmol/ml. For the subject with aMT6s level decreased, the amount of decrease was 0.96 pmol/ml.

Summary

Sleep quality of the subjects showed improvement after bright light exposure. Nevertheless, the improvement was not significant. The alternative hypothesis 1 was rejected. Most of the subjects mainly had their SSLs unchanged. For those with their SSLs changed, there were more subjects having their SSLs increased than decreased. The change in SSL was not significantly correlated with the alterations in the corresponding aMT6s levels. It was, however, significantly correlated with the related SE, SWR, TST, SOT and WASOt on Day 5. Thus, alternative hypothesis 3 was supported while hypothesis 4 was rejected. Except for those reporting poor or very poor sleep, more than half of the subjects had their sleep efficiencies increased. Poor sleepers mainly reported decrease in SE after bright light exposure. When subjects had their SSLs increased on Day 5, there were more than 70% of the subjects having their SEs, SWRs and TSTs increased but WASOts decreased. Their SOTs mainly shifted forwards. Reverse phenomenon, however, was found in the decrease group on Day 5. In terms of those with their SSLs increased on Day 6, diverse alterations were observed. But for those with their SSLs decreased on Day 6, 80% of them had their SEs, SWRs and TSTs decreased but WASOts increased and their SOTs shifted forwards. This chapter has illustrated the light-induced effects on SSL but not the changes in the sleep-wake parameters and aMT6s levels. Further analyses on these two items are outlined in Chapters 8 and 9.

Chapter 8

Results (III) - The Effects of Bright Light Exposure on the Subjects: The Changes in Actigraphic Sleep-Wake Parameters

Introduction

This chapter contains results mainly addressing the research question 7. It also provides results for the fifth and eighth research questions. To show the effects of bright light on the subjects, this chapter will concentrate on the changes in the actigraphic data and the corresponding changes in the 6-sulphatoxymelatonin (aMT6s) level and sleep satisfaction level (SSL). The actigraphic sleep-wake parameters included in the analysis were sleep efficiency (SE), sleep-wake ratio (SWR), total sleep time (TST), total bed time (TBT), sleep onset latency (SOL), sleep onset time (SOT), wake after sleep onset (WASO) and sleep offset time (SoffT). WASO was assessed by the number of waking after sleep onset (WASOf), the duration of each waking after sleep onset (WASOd) and the total time of waking after sleep onset (WASOt). All the actigraphic sleep-wake parameters were measured at night. The post-bright light exposure effects on these parameters were examined separately on Days 5 and 6 (Post-Bright Light Exposure Stage) by comparing the findings with those on Day 2 (Pre-Bright Light

Exposure Stage). When the subjects had their parameters increased after bright light exposure, they were classified as the increase group. The decrease group was for those with their parameters decreased. In terms of SOT and SoffT, subjects with advancement of SOT or SoffT were classified as forward group while the delay as delay group.

Actigraphic sleep-wake parameters

Actigraphic sleep-wake parameters were measured from bedtime to rising time. During this period, the subjects were sleeping in a relatively dark environment (mean intensity = 8.61 lux). Thirty-eight subjects had completed the 6-day study procedure including actigraphic data recording, urine collection and sleep log. The first alternative hypothesis in the Chapter 1 was supported when the sleep-wake parameters were considered individually. The significance of the changes in their sleep-wake parameters is presented in Table 8.1.

Table 8.1 The significance of the changes in sleep-wake parameters (N = 38)

Sleep-Wake Parameters	Day 5	Day 6
SE	-	-
SWR	-	-
TST	-	-
TBT	-	-
SOL	-	-
SOT	-	-
WASOf	-	-
WASOd	-	-
WASOt	-	-
SoffT	-	-

Note: "-" = $p < 0.05$
"-" = $p > 0.05$

Sleep Efficiency (SE) and Sleep-Wake Ratio (SWR)

As shown by the paired-sample *t* test, there was no significant changes in SE and SWR after bright light exposure (Table 8.2). On Day 5, actigraphic data showed that 60.5% (n = 23) of the subjects had both of their SEs and SWRs increased but 39.5% (n = 15) had these two parameters decreased. On Day 6, while SE was increased in 55.3% (n = 21) of the subjects and SWR was increased in 52.6% (n = 20) of them, 2.6% of the subjects (n = 1) had her SWR unchanged and 44.7% (n = 17) had these two parameters decreased.

Table 8.2 The results of paired-sample *t* test of the changes in sleep efficiency, SE, and sleep-wake ratio, SWR, after bright light exposure (N = 38)

	Paired Mean Differences	Confidence Interval	*t*	df	*p*
Day 2 - Day 5: SE	-1.99	-4.92 to 0.95	-1.37	37	0.178
Day 2 - Day 5: SWR	-3.10	-9.21 to 3.02	-1.03	37	0.312
Day 2 - Day 6: SE	-0.56	-3.03 to 4.14	-0.32	37	0.754
Day 2 - Day 6: SWR	-0.69	-1.56 to 2.94	-0.63	37	0.536

Note: Paired mean differences and confidence interval of SE was measured in percentage. Paired mean differences and confidence interval of SWR was a ratio.

The increase group on Day 5 The *mean increase of SE* in this group of subjects (n = 23) was 7.35% (SD = 6.18%) with a range of increase between 0.03% and 21.12%. The *mean increase of SWR* was 7.48 (SD = 22.89) with a range of increase between 0.01 and 112.07. As shown by the paired-sample *t* test, their aMT6s levels changed insignificantly (Table 8.3). There were 43.5% (n = 10) of the subjects whose aMT6s levels were increased while the remaining 56.5% (n = 13) had theirs decreased. The related *mean increase in aMT6s level* was 4.20 pmol/ml (SEM = 1.37 pmol/ml) with a range of increase between 0.20 and 13.24 pmol/ml. The *mean decrease in aMT6s level* was 4.92 pmol/ml (SEM = 1.39 pmol/ml) with a range of decrease between 0.31 and 16.68 pmol/ml. For the sleep satisfaction level (SSL) of this increase group, the findings of Wilcoxon test showed that the mean of the sleep quality on Day 2 was higher than that on Day 5 (mean of sleep quality = 2.78 on Day 2; 2.26 on Day 5). Therefore, these subjects found better sleep quality on Day 5 ($p = 0.017$). There were 43.5% (n = 10) subjects having their SSLs increased while 8.7% (n = 2) had theirs decreased and 47.8% (n = 11) unchanged.

Table 8.3 The results of paired-sample *t* test of the 6-sulphatoxymelatonin, aMT6s, level of different groups of subjects after bright light exposure with respect to the sleep efficiency, SE, and sleep-wake ratio, SWR

	Paired Mean Differences (pmol/ml)	*t*	*p*
Increase group on Day 5 (n = 23)	-0.95	-0.70	0.492
SE Increase group on Day 6 (n = 21)	-1.56	-0.57	0.577
SWR Increase group on Day 6 (n = 20)	-1.49	-0.51	0.614
Decrease group on Day 5 (n = 15)	-0.62	-0.24	0.817
Decrease group on Day 6 (n = 17)	-0.02	-0.01	0.989

The increase group on Day 6 For the subjects (n = 21) with their SEs increased on Day 6, the *mean increase of SE* was 7.64% (SD = 5.61%) with a range of increase between 0.01% and 20.49%. When the related aMT6s levels were examined, the changes were not significant (Table 8.3). There were 38.1% (n = 8) of them with their levels increased while 61.9% of them (n = 13) decreased. The *mean increase in aMT6s level* was 8.17 pmol/ml (SEM = 3.71 pmol/ml) with a range of increase between 0.14 and 32.19 pmol/ml. For the *mean decrease in aMT6s level*, it was 7.55 pmol/ml (SEM = 2.78 pmol/ml) with a range of decrease between 0.66 and 37.59 pmol/ml. For the sleep satisfaction level (SSL) of this increase group, the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.57 on Day 2; 2.29 on Day 6). These subjects found better sleep quality on Day 6 ($p = 0.084$). There were 23.8% (n = 5) subjects having their SSLs increased while 4.8% (n = 1) had theirs decreased and 71.4% (n = 15) unchanged.

Concerning the 20 subjects having their SWRs increased on Day 6, the *mean increase of SWR* was 3.99 (SD = 2.79) with a range of increase between 0.02 and 9.52. Similar to SE, the change in the aMT6s levels of SWR was insignificant after bright light exposure (Table 8.3). 40.0% (n = 8) of the subjects had levels increased while 60.0% of them (n = 12) decreased. The related *mean increase in aMT6s level* was 8.17 pmol/ml (SEM = 3.71 pmol/ml) with a range of increase between 0.14 and 32.19 pmol/ml. For the *mean decrease in aMT6s level*, it was 7.92 pmol/ml (SEM = 2.99 pmol/ml) with a range of decrease between 0.66 and 37.59 pmol/ml. When their SSLs were studied, the findings showed that the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.45 on Day 2; 2.15 on Day 6). Therefore, these subjects found better sleep quality on Day 6 (p = 0.084). There were 25.0% (n = 5) subjects having their SSLs increased while 5.0% (n = 1) had theirs decreased and 70.0% (n = 14) unchanged.

The decrease group on Day 5 This group of subjects (n = 15) had a *mean decrease of sleep efficiency* as 6.24% (SD = 5.53%) with a range of decrease between 0.04% and 18.67%. For their SWRs, the *mean decrease of SWR* was 3.63 (SD = 3.37) with a range of decrease between 0.09 and 10.23. Concerning the change in their aMT6s levels, it was not significant (Table 8.3). There were 66.7% (n = 10) of the subjects with their aMT6s levels increased while 33.3% of them (n = 5) decreased. The *mean increase in*

aMT6s level was 4.05 pmol/ml (SEM = 1.29 pmol/ml) with a range of increase between 0.57 and 13.65 pmol/ml. For the *mean decrease in aMT6s level*, it was 9.95 pmol/ml (SEM = 5.73 pmol/ml) with a range of decrease between 1.06 and 29.61 pmol/ml. According to Wilcoxon test, this group of subjects reported that the mean of the sleep quality on Day 2 was lower than that on Day 5 (mean of sleep quality = 2.33 on Day 2; 2.87 on Day 5). Thus, these subjects found poorer sleep quality on Day 5 ($p = 0.070$). There were 20.0% (n = 3) subjects having their SSLs increased while 53.3% (n = 8) had theirs decreased and 26.7% (n = 4) unchanged.

The decrease group on Day 6 These 17 subjects had their *mean decrease of SE* as 10.69% (SD = 6.19%) with a range of decrease between 0.84% and 23.91%. For their SWRs, the *mean decrease of SWR* was 6.24 (SD = 6.24) with a range of decrease between 0.40 and 24.57. Exploring the change in the related aMT6s levels after bright light exposure, the change was insignificant (Table 8.3). 58.8% (n = 10) of the subjects with their aMT6s levels increased while 41.2% (n = 7) showed a decrease. The *mean increase in aMT6s level* was 4.59 pmol/ml (SEM = 1.12 pmol/ml) with a range of increase between 0.42 and 12.16 pmol/ml. For the *mean decrease in aMT6s level*, it was 6.50 pmol/ml (SEM = 2.52 pmol/ml) with a range of decrease between 0.96 and 19.15 pmol/ml. For the sleep satisfaction level (SSL), the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.65 on Day 2; 2.41 on Day 6). These subjects found better

sleep quality on Day 6 (p = 0.405). There were 35.3% (n = 6) subjects having their SSLs increased while 23.5% (n = 4) had theirs decreased and 41.2% (n = 7) unchanged.

Except those in the groups on Day 5, all the subjects showed similar duration in the occurrence of sleep disturbance. Nearly half of the subjects considered their sleep acceptable, good or very good while the other half considered theirs as bad or very bad before bright light exposure. The details of the characteristics of the different groups of subjects are described in Table 8.4.

Table 8.4 The characteristics of the different groups of subjects before bright light exposure

	Duration of sleep complaint (years)	Number of cases reported bad or very bad sleep
The increase group on Day 5 (n =23)	6.66	13 (56.5%)
The increase group on Day 6 (SE, n = 21)*	8.83	11 (52.4%)
The increase group on Day 6 (SWR, n = 20)*	8.28	10 (50.0%)
The decrease group on Day 5 (n = 15)	11.83	10 (66.7%)
The decrease group on Day 6 (n = 17)	8.54	12 (70.6%)

* SE represents sleep efficiency
SWR represents sleep-wake ratio

Total Sleep Time (TST)

No significant change in TST was observed after bright light exposure (Table 8.5). According to the Day 5 actigraphic data, 60.5% of the subjects (n = 23) showed a TST increase while 39.5% (n = 15) decreased. For Day

6. the situation was diverse as 50.0% (n = 19) showed a TST increase and the remaining a decrease.

Table 8.5 The results of paired-sample *t* test of the changes in the total sleep time after bright light exposure (N = 38)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-10.09	-26.84 to 6.66	1.22	37	0.230
Day 2 - Day 6	-5.67	-16.01 to 27.35	0.53	37	0.599

The increase group on Day 5 For this group of subjects (n = 23), the *mean increase of TST* was 41.05 minutes (SD = 28.01 minutes) with a range of increase between 6.00 and 110.00 minutes. When the corresponding aMT6s levels were investigated, no significant change was found (Table 8.6). 56.6% (n = 13) of the subjects had aMT6s levels increased and 43.5% (n = 10) decreased. The *mean increase in aMT6s level* was 4.17 pmol/ml (SEM = 1.09 pmol/ml) with a range of increase between 0.20 and 13.24 pmol/ml. The *mean decrease in aMT6s level* was 6.10 pmol/ml (SEM = 1.95 pmol/ml) with a range of decrease between 0.69 and 16.68 pmol/ml. When the related SSLs were studied, the mean of the sleep quality on Day 2 was higher than that on Day 5 (mean of sleep quality = 2.78 on Day 2; 2.13 on Day 5). These subjects found better sleep quality on Day 5 (p = 0.003). There were 52.2% (n = 12) subjects having their SSLs increased while 4.3% (n = 1) had theirs decreased and 43.5% (n = 10) unchanged.

Table 8.6 The results of paired-sample *t* test of the 6-sulphatoxymelatonin, aMT6s, level of different groups of subjects after bright light exposure with respect to the total sleep time

	Paired Mean Differences (pmol/ml)	*t*	*p*
Increase group on Day 5 (n = 23)	-0.29	-0.20	0.845
Increase group on Day 6 (n = 19)	-0.08	-0.03	0.974
Decrease group on Day 5 (n = 15)	-1.63	-0.67	0.517
Decrease group on Day 6 (n = 19)	-1.63	-0.67	0.511

The increase group on Day 6 This group of subjects (n = 19) had their *mean increase of TST* at 47.82 minutes (SD = 25.31 minutes) with a range of increase between 10.00 and 99.33 minutes. The related aMT6s levels changed insignificantly (Table 8.6). There were 36.8% (n = 7) of them with their aMT6s levels increased while 63.2% (n = 12) had theirs decreased. Their *mean increase in aMT6s level* was 9.58 pmol/ml (SEM = 3.99 pmol/ml) with a range of increase between 2.19 and 32.19 pmol/ml. The *mean decrease in aMT6s level* was 5.71 pmol/ml (SEM = 1.68 pmol/ml) with a range of decrease between 0.66 and 19.15 pmol/ml. When the related SSLs were examined, the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.58 on Day 2; 2.11 on Day 6). These subjects found better sleep quality on Day 6 (p = 0.047). There were 31.6% (n = 6) subjects having their SSLs increased while 5.3% (n = 1) had theirs decreased and 63.2% (n = 12) unchanged.

The decrease group on Day 5 These 15 subjects showed a *mean decrease of TST* as 37.38 minutes (SD = 40.50 minutes) with a range of decrease

between 3.00 and 132.00 minutes. When the related aMT6s levels were explored, no significant change was identified (Table 8.6). There were 46.7% (n = 7) of the subjects with their aMT6s levels increased while the remaining 53.3% (n = 8) had theirs decreased. The *mean increase in aMT6s level* was 4.05 pmol/ml (SEM = 1.77 pmol/ml) with a range of increase between 0.57 and 13.65 pmol/ml. For the *mean decrease in aMT6s level*, it was 6.59 pmol/ml (SEM = 3.55 pmol/ml) with a range of decrease between 0.31 and 29.61 pmol/ml. For the sleep satisfaction level (SSL), the mean of the sleep quality on Day 2 was lower than that on Day 5 (mean of sleep quality = 2.33 on Day 2; 3.07 on Day 5). These subjects found poorer sleep quality on Day 5 ($p = 0.013$). There were 6.7% (n = 1) subjects having their SSLs increased while 60.0% (n = 9) had theirs decreased and 33.3% (n = 5) unchanged.

The decrease group on Day 6 For this group of subjects (n = 19), their *mean decrease of TST* was 59.16 minutes (SD = 47.59 minutes) with a range of decrease between 2.00 and 130.00 minutes. The related aMT6s levels also changed insignificantly (Table 8.6). There were 57.9% (n = 11) of the subjects with their aMT6s levels increased while 42.1% (n = 8) had theirs decreased. The related *mean increase in aMT6s level* was 4.02 pmol/ml (SEM = 1.13 pmol/ml) with a range of the increase between 0.14 and 12.16 pmol/ml. The *mean decrease in aMT6s level* was 9.39 pmol/ml (SEM =

4.31 pmol/ml) with a range of decrease between 0.96 and 37.59 pmol/ml. For the sleep satisfaction level (SSL), the mean of the sleep quality on Day 2 was slightly higher than that on Day 6 (mean of sleep quality = 2.63 on Day 2; 2.58 on Day 6). These subjects found better sleep quality on Day 6 (p = 0.739). There were 26.3% (n = 5) subjects having their SSLs increased while 21.1% (n = 4) had theirs decreased and 52.6% (n = 10) unchanged.

Examining the characteristics of these four groups of subjects, the decrease groups tended to have a longer history of sleep disturbance than the increase groups. In addition, there were more subjects reporting their sleep as bad or very bad in the decrease groups than those in the increase groups (Table 8.7). There were 78.9% of the subjects (n = 30) with their desirable duration for sleeping fulfilled.

Table 8.7 The characteristics of the different groups of subjects before bright light exposure

	Duration of sleep complaint (years)	Number of cases reported bad or very bad sleep
The increase group on Day 5 (n =23)	7.15	12 (52.2%)
The increase group on Day 6 (n = 19)	7.80	9 (47.4%)
The decrease group on Day 5 (n = 15)	11.09	11 (73.3%)
The decrease group on Day 6 (n = 19)	9.61	14 (73.7%)

Total Bed Time (TBT)

After bright light exposure, no significant change in TBT was observed (Table 8.8). On Day 5, there were 44.7% (n = 17) of the subjects with their

TBTs increased while 55.3% (n = 21) had theirs decreased. On Day 6, a similar situation was present. There were 50.0% (n = 19) with their TBTs increased while the remaining had theirs decreased.

Table 8.8 The results of paired-sample *t* test of the changes in the total bed time after bright light exposure (N = 38)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-1.77	-13.65 to 17.19	-0.23	37	0.817
Day 2 - Day 6	-4.26	-9.75 to 18.28	-0.62	37	0.542

The increase group on Day 5 This group of subjects (n = 17) had their *mean increase of TBT* as 37.72 minutes (SD = 34.03 minutes) with a range of increase between 0.16 and 129.67 minutes. When the related aMT6s levels were considered, no significant change was observed after bright light exposure (Table 8.9). There were 64.7% (n = 11) of the subjects with their aMT6s levels increased while 35.3% (n = 6) had theirs decreased. The corresponding *mean increase in aMT6s level* was 2.52 pmol/ml (SEM = 0.68 pmol/ml) with a range of increase between 0.20 and 6.42 pmol/ml. The *mean decrease in aMT6s level* was 7.08 pmol/ml (SEM = 3.11 pmol/ml) with a range of decrease between 0.90 and 16.68 pmol/ml. When their SSLs were analysed, the mean of the sleep quality on Day 2 was higher than that on Day 5 (mean of sleep quality = 2.71 on Day 2; 2.53 on Day 5). These subjects found better sleep quality on Day 5 ($p = 0.499$). There were 47.1% (n = 8) subjects having their SSLs increased while 29.4% (n = 5) had theirs decreased and 23.5% (n = 4) unchanged.

Table 8.9 The results of paired-samples *t* test of the 6-sulphatoxymelatonin, aMT6s, level of different groups of subjects after bright light exposure with respect to the total bed time

	Paired Mean Differences (pmol/ml)	*t*	*p*
Increase group on Day 5 (n = 17)	+0.87	+0.54	0.594
Increase group on Day 6 (n = 19)	-0.21	-0.11	0.911
Decrease group on Day 5 (n = 21)	-0.78	-0.39	0.702
Decrease group on Day 6 (n = 19)	-1.50	-0.51	0.615

The increase group on Day 6 These 19 subjects had their *mean increase of TBT* as 30.77 minutes (SD = 19.87 minutes) with a range of increase between 5.00 and 78.84 minutes. For the corresponding aMT6s levels, no significant change was detected (Table 8.9). There were 42.1% (n = 8) of the subjects with their TBTs increased while 57.9% (n = 11) had theirs decreased. The *mean increase in aMT6s level* was 7.00 pmol/ml (SEM = 1.35 pmol/ml) with a range of increase between 2.19 and 12.19 pmol/ml. The *mean decrease in aMT6s level* was 5.45 pmol/ml (SEM = 1.76 pmol/ml) with a range of decrease between 0.66 and 19.15 pmol/ml. For the sleep satisfaction level (SSL), the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.63 on Day 2; 2.11 on Day 6). These subjects found better sleep quality on Day 6 ($p = 0.039$). There were 42.1% (n = 8) subjects having their SSLs increased while 10.5% (n = 2) had theirs decreased and 47.4% (n = 9) unchanged.

The decrease group on Day 5 These 21 subjects had their *mean decrease of TBT* as 33.74 minutes (SD = 27.35 minutes) with a range of decrease

between 2.00 and 109.00 minutes. When their related aMT6s levels were investigated, no significant change was shown (Table 8.9). There were 42.9% (n = 9) of the subjects with their aMT6s levels increased while the remaining 57.1% (n = 12) had theirs decreased. The *mean increase in aMT6s level* was 6.09 pmol/ml (SEM = 1.68 pmol/ml) with a range of increase between 0.57 and 13.65 pmol/ml. For the *mean decrease in aMT6s level*, it was 5.94 pmol/ml (SEM = 2.39 pmol/ml) with a range of decrease between 0.31 and 29.61 pmol/ml. For the SSLs of these 21 subjects, the mean of the sleep quality on Day 2 was slightly higher than that on Day 5 (mean of sleep quality = 2.52 on Day 2; 2.48 on Day 5). These subjects found better sleep quality on Day 5 (p = 0.917). There were 23.8% (n = 5) subjects having their SSLs increased while 23.8% (n = 5) had theirs decreased and 52.4% (n = 11) unchanged.

The decrease group on Day 6 These 19 subjects had their *mean decrease of TBT* as 39.30 minutes (SD = 27.43 minutes) with a range of decrease between 1.83 and 98.00 minutes. When their aMT6s levels were studied, the change in the levels was insignificant (Table 8.9). There were 52.6% (n = 10) of the subjects with their aMT6s levels increased while 47.4% (n = 9) had theirs decreased. The *mean increase in aMT6s level* was 5.53 pmol/ml (SEM = 3.04 pmol/ml) with a range of increase between 0.14 and 32.19 pmol/ml. For the *mean decrease in aMT6s level*, it was 9.31 pmol/ml (SEM

= 3.84 pmol/ml) with a range of decrease between 1.12 and 37.59 pmol/ml. For their SSLs, the mean of the sleep quality on Day 2 was the same as that on Day 6 (mean of sleep quality = 2.58 on Day 2; 2.58 on Day 6). There was no change in their sleep quality after bright light exposure (p = 1.000). There were 15.8% (n = 3) subjects having their SSLs increased while 15.8% (n = 3) had theirs decreased and 68.4% (n = 13) unchanged.

Since changes in TBT do not give an overall picture of sleep quality, TST should be taken into consideration together with TBT at the same time. For the increase groups, about 70% of the subjects had their TSTs increased while it was about 50% for the increase in SE. Detailed description of the changes in TST and SE of the four groups of subjects is provided in Table 8.10. Apart from the effects of bright light, one's expectation on the duration of sleep would affect the change in TBT. The desirable duration for sleeping was very similar among these four groups. The mean duration was 5.70 hours for the increase group on Day 5, 5.08 hours for the decrease group on Day 5, 6.07 hours for the increase group on Day 6 and 4.66 hours for the decrease group on Day 6.

Table 8.10 The changes in total sleep time, TST, and sleep efficiency, SE, of the four groups of subjects after bright light exposure with respect to total bed time

	TST		SE	
	Increase	Decrease	Increase	Decrease
The increase group on Day 5 (n =17)	12 (70.6%)	5 (29.4%)	8 (47.1%)	9 (52.9%)
The increase group on Day 6 (n = 19)	13 (68.4%)	6 (31.6%)	9 (47.4%)	10 (52.6%)
The decrease group on Day 5 (n = 21)	11 (52.4%)	10 (47.6%)	15 (71.4%)	6 (28.6%)
The decrease group on Day 6 (n = 19)	6 (31.6%)	13 (68.4%)	12 (63.2%)	7 (36.8%)

Sleep Onset Latency (SOL)

There was no significant change in SOL after bright light exposure (Table 8.11). The effects of bright light on the SOL seemed to be diverse. On Day 5, there were 47.4% (n = 18) of subjects with their SOLs increased while 44.7 % (n = 17) had theirs decreased and 7.9% (n = 3) had theirs unchanged. Similar to Day 5, there were 44.7% (n = 17) of the subjects with their SOLs increased but 42.1% (n = 16) had theirs decreased and 13.2% (n = 5) had theirs unchanged on Day 6.

Table 8.11 The results of paired-sample *t* test of the changes in sleep onset latency after bright light exposure (N = 38)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-0.27	-6.70 to 6.16	-0.09	37	0.932
Day 2 - Day 6	-1.38	-7.93 to 5.17	-0.43	37	0.671

The increase group on Day 5 These 18 subjects had their *mean increase of SOL* as 13.18 minutes (SD = 15.40 minutes) with a range of increase between 0.17 and 65.00 minutes. When the corresponding aMT6s levels were studied, no significant change in the level was observed after bright light exposure (Table 8.12). There were 44.4% (n = 8) of the subjects with their aMT6s levels increased while 55.6% (n = 10) had theirs decreased. The *mean increase in aMT6s level* was 2.28 pmol/ml (SEM = 0.71 pmol/ml) with a range of increase between 0.20 and 5.62 pmol/ml. For the SSLs of these 18 subjects, the mean of the sleep quality on Day 2 was lower than

that on Day 5 (mean of sleep quality = 2.61 on Day 2: 2.83 on Day 5). These subjects found poorer sleep quality on Day 5 (p = 0.314). There were 16.7% (n = 3) subjects having their SSLs increased while 38.9% (n = 7) had theirs decreased and 44.4% (n = 8) unchanged.

Table 8.12 The results of paired-sample *t* test of the 6-sulphatoxymelatonin, aMT6s, level of different groups of subjects after bright light exposure with respect to the sleep onset latency

	Paired Mean Differences (pmol/ml)	*t*	*p*
Increase group on Day 5 (n = 18)	-1.47	-1.13	0.272
Increase group on Day 6 (n = 17)	-0.35	-0.13	0.896
Decrease group on Day 5 (n = 17)	-0.01	-0.00	0.998
Decrease group on Day 6 (n = 16)	-1.75	-0.66	0.519

The increase group on Day 6 Subjects in this group (n = 17) had their *mean increase of SOL* as 15.61 minutes (SD = 16.24 minutes) with a range of increase between 2.33 and 74.34 minutes. When the related aMT6s levels were examined, no significant change was identified (Table 8.12). There were 41.2% (n = 7) of the subjects with their aMT6s levels increased while 58.8% (n = 10) had theirs decreased. The *mean increase in aMT6s level* was 8.43 pmol/ml (SEM = 4.22 pmol/ml) with a range of increase between 0.52 and 32.19 pmol/ml. The *mean decrease in aMT6s level* was 6.49 pmol/ml (SEM = 1.55 pmol/ml) with a range of decrease between 1.57 and 15.12 pmol/ml. When their SSLs were considered, the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.76 on Day 2: 2.29 on Day 6). These subjects found better sleep quality on

Day 6 (p = 0.084). There were 35.3% (n = 6) subjects having their SSLs increased while 11.8% (n = 2) had theirs decreased and 52.9% (n = 9) unchanged.

The decrease group on Day 5 These 17 subjects had their *mean decrease of SOL* as 13.34 minutes (SD = 15.76 minutes) with a range of decrease between 0.16 and 66.16 minutes. For the related aMT6s levels, the change in the level was insignificant (Table 8.12). There were 58.8% (n = 10) of the subjects with their aMT6s levels increased while 41.2% (n = 7) had theirs decreased. The *mean increase in aMT6s level* was 5.28 pmol/ml (SEM = 1.64 pmol/ml) with a range of increase between 0.57 and 13.65 pmol/ml. For the *mean decrease in aMT6s level*, it was 7.52 pmol/ml (SEM = 3.84 pmol/ml) with a range of decrease between 0.31 and 29.61 pmol/ml. When their related SSLs were investigated, the mean of the sleep quality on Day 2 was higher than that on Day 5 (mean of sleep quality = 2.53 on Day 2; 2.24 on Day 5). These subjects found better sleep quality on Day 5 (p = 0.265). There were 41.2% (n = 7) subjects having their SSLs increased while 17.6% (n = 3) had theirs decreased and 41.2% (n = 7) unchanged.

The decrease group on Day 6 These group of subjects (n = 16) had their *mean decrease of SOL* as 13.30 minutes (SD = 15.44 minutes) with a range of decrease between 0.16 and 66.16 minutes. When the corresponding aMT6s levels were examined, no significant change was detected (Table

8.12). There were 43.8% (n = 7) of the subjects with their aMT6s levels increased while the remaining 56.3% (n = 9) had theirs decreased. The *mean increase in aMT6s level* was 4.51 pmol/ml (SEM = 1.51 pmol/ml) with a range of increase between 0.42 and 12.19 pmol/ml. The *mean decrease in aMT6s level* was 6.62 pmol/ml (SEM = 3.92 pmol/ml) with a range of decrease between 0.66 and 37.59 pmol/ml. When their SSLs were explored, the mean of the sleep quality on Day 2 was lower than that on Day 6 (mean of sleep quality = 2.38 on Day 2; 2.44 on Day 6). These subjects found poor sleep after bright light exposure ($p = 0.655$). There were 12.5% (n = 2) subjects having their SSLs increased while 18.8% (n = 3) had theirs decreased and 68.8% (n = 11) unchanged.

The subjects in the increase groups not only had a longer SOL but also experienced a longer period of sleep disturbance when compared with those in the decrease groups and those with their SOLs unchanged. Moreover, more subjects in the increase groups complained of difficulty in initiating sleep (DIS) than the others did (Table 8.13).

Table 8.13 The characteristics of the different groups of subjects before bright light exposure

	Duration of sleep complaint (years)	Number of cases reported difficulty in initiating sleep
The increase group on Day 5 (n = 18)	9.44	12 (66.7%)
The increase group on Day 6 (n = 17)	9.53	11 (64.7%)
The unchanged group on Day 5 (n = 3)	6.33	0
The unchanged group on Day 6 (n = 5)	6.43	1 (20.0%)
The decrease group on Day 5 (n = 17)	8.15	7 (41.2%)
The decrease group on Day 6 (n = 16)	8.53	7 (43.8%)

Sleep Onset Time (SOT)

The change in SOT after bright light exposure was not significant (Table 8.14). On Day 5, there were 44.7% (n = 17) of subjects with their SOTs shifted backwards while 55.3% (n = 21) had theirs shifted forwards. On Day 6, a similar phenomenon was presented. There were 47.4% (n = 18) of the subjects with their SOTs shifted backwards but 52.6% (n = 20) had theirs shifted forwards.

Table 8.14 The results of paired-sample *t* test of the changes in the sleep onset time after bright light exposure (N = 38)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-0.62	-8.60 to 7.35	-0.16	37	0.873
Day 2 - Day 6	-0.35	-7.30 to 8.00	-0.09	37	0.925

The backward group on Day 5 There were 17 subjects with their SOTs shifted backwards on Day 5. The *mean duration for SOT of backward shift* was 21.05 minutes (SD = 20.28 minutes) with a range of shift between 2.43 and 73.67 minutes. For the related aMT6s levels, no significant change in the level was found (Table 8.15). There were 41.2% (n = 7) of the subjects with their aMT6s levels increased while 58.8% (n = 10) had theirs decreased. The *mean increase in aMT6s level* was 4.78 pmol/ml (SEM = 1.73 pmol/ml) with a range of increase between 0.58 and 13.65 pmol/ml. The *mean decrease in aMT6s level* was 7.33 pmol/ml (SEM = 3.00 pmol/ml) with a range of decrease between 0.68 and 29.61 pmol/ml. When

the subjective reports of the subjects were considered. the mean of the sleep quality on Day 2 was lower than that on Day 5 (mean of sleep quality = 2.41 on Day 2; 2.76 on Day 5). These subjects found poorer sleep quality on Day 5 (p = 0.107). There were 11.8% (n = 2) subjects having their SSLs increased while 35.3% (n = 6) had theirs decreased and 52.9% (n = 9) unchanged.

Table 8.15 The results of paired-sample *t* test of the 6-sulphatoxymelatonin, aMT6s, level of different groups of subjects after bright light exposure with respect to the sleep onset time

	Paired Mean Differences (pmol/ml)	*t*	*p*
Backward group on Day 5 (n = 17)	-2.34	-0.99	0.339
Backward group on Day 6 (n = 18)	-1.27	-0.40	0.697
Forward group on Day 5 (n = 21)	-0.41	-0.30	0.768
Forward group on Day 6 (n = 20)	-0.48	-0.30	0.765

The backward group on Day 6 This group of subjects (n = 18) had their *mean duration for SOT of backward shift* at 18.93 minutes (SD = 16.10 minutes) with a range of shift between 2.43 and 61.67 minutes. When the related aMT6s levels were considered. the change was not significant (Table 8.15). There were 50% (n = 9) of the subjects with their aMT6s levels increased and 50% (n = 9) had theirs decreased. The *mean increase in aMT6s level* was 7.25 pmol/ml (SEM = 3.35 pmol/ml) with a range of increase between 0.14 and 32.19 pmol/ml. The *mean decrease in aMT6s level* was 9.79 pmol/ml (SEM = 3.79 pmol/ml) with a range of decrease between 1.57 and 37.59 pmol/ml. For the related SSLs. the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality

= 2.72 on Day 2: 2.44 on Day 6). These subjects found better sleep quality on Day 6 (p = 0.096). There were 27.8% (n = 5) subjects having their SSLs increased while 5.6% (n = 1) had theirs decreased and 66.7% (n = 12) unchanged.

The forward group on Day 5 There were 21 subjects with their SOTs shifted forwards on Day 5 after bright light exposure. The *mean duration for SOT of forward shift* was 15.90 minutes (SD = 10.97 minutes) with a range of shift between 2.00 and 45.22 minutes. When the related aMT6s levels were investigated, no significant change was observed (Table 8.15). There were 61.9% (n = 13) of the subjects with their aMT6s levels increased while the remaining 38.1% (n = 8) had theirs decreased. The *mean increase in aMT6s level* was 3.77 pmol/ml (SEM = 1.10 pmol/ml) with a range of increase between 0.20 and 13.24 pmol/ml. The *mean decrease in aMT6s level* was 5.05 pmol/ml (SEM = 1.97 pmol/ml) with a range of decrease between 0.31 and 16.45 pmol/ml. When the related SSLs were studied, the mean of the sleep quality on Day 2 was higher than that on Day 5 (mean of sleep quality = 2.76 on Day 2: 2.29 on Day 5). These subjects found better sleep quality on Day 5 (p = 0.084). There were 52.4% (n = 11) subjects having their SSLs increased while 19.0% (n = 4) had theirs decreased and 28.6 % (n = 6) unchanged.

The forward group on Day 6 20 subjects had their *mean duration for SOT of forward shift* at 17.72 minutes (SD = 12.45 minutes) with a range of shift between 2.78 and 57.22 minutes. When the related aMT6s levels were examined, no significant change was found (Table 8.15). There were 45.0% (n = 9) of the subjects with their aMT6s levels increased and 55.0% (n = 11) had theirs decreased. The *mean increase in aMT6s level* was 5.11 pmol/ml (SEM = 1.25 pmol/ml) with a range of increase between 0.52 and 12.19 pmol/ml. The *mean decrease in aMT6s level* was 5.05 pmol/ml (SEM = 1.73 pmol/ml) with a range of decrease between 0.66 and 19.15 pmol/ml. When the related SSLs were considered, the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.50 on Day 2; 2.25 on Day 6). These subjects found better sleep quality on Day 6 (p = 0.305). There were 30.0% (n = 6) subjects having their SSLs increased while 20.0% (n = 4) had theirs decreased and 50.0% (n = 10) unchanged.

Neither the duration of the occurrence of the sleep disturbance nor the number of subjects complaining of difficulty in initiating sleep revealed a dominant difference among the four groups of subjects. The related information is described in Table 8.16. Reviewing the corresponding sleep offset time (SoffT) of the subjects, the shift in SOT did not well correlate with the shift in SoffT (Day 5: r = 0.016, p = 0.922; Day 6: r = -0.027, p = 0.873). Table 8.17 illustrates the associated information.

Table 8.16 The characteristics of the different groups of subjects before bright light exposure

	Duration of sleep complaint (years)	Number of cases reported difficulty in initiating sleep
The backward group on Day 5 (n = 17)	10.05	9 (52.9%)
The backward group on Day 6 (n = 18)	8.35	9 (50.0%)
The forward group on Day 5 (n = 21)	7.61	10 (47.6%)
The forward group on Day 6 (n = 20)	9.02	10 (50.0%)

Table 8.17 The change of the corresponding sleep offset time, SoffT, of the subjects after bright light exposure with respect to the sleep onset time

	SoffT	
	Backward	Forward
The backward group on Day 5 (n = 17)	10 (58.8%)	7 (41.2%)
The backward group on Day 6 (n = 18)	9 (50.0%)	9 (50.0%)
The forward group on Day 5 (n = 21)	12 (57.1%)	9 (42.9%)
The forward group on Day 6 (n = 20)	10 (50.0%)	10 (50.0%)

Wake After Sleep Onset (WASO)

The WASO was investigated in two dimensions. Firstly, it was studied according to the frequency of occurrence. Then, the duration was examined. The frequency of occurrence referred to the number of waking after sleep onset (WASOf). The duration of WASO was divided into two aspects: the duration of each waking after sleep onset (WASOd) and the total time of waking after sleep onset (WASOt).

For ***WASOf***, despite no significant change in it on Day 5, it changed significantly on Day 6 (Table 8.18). On Day 5, there were 44.7% (n = 17) of the subjects with their WASOfs increased while 13.2% (n = 5) and 42.1% (n = 16) had theirs unchanged and decreased respectively. For Day 6, the

increased portion (60.5%, n = 23) become larger when the other two portions decreased. There were 5.3% (n = 2) of the subjects with their WASOfs unchanged and 34.2% (n = 13) decreased.

Table 8.18 The results of paired-sample *t* test of the changes in number of waking after sleep onset after bright light exposure (N = 38)

	Paired Mean Differences (Times)	Confidence Interval (Times)	*t*	df	*p*
Day 2 - Day 5	-0.32	-1.77 to 1.14	-0.44	37	0.662
Day 2 - Day 6	-2.34	-4.39 to -0.30	-2.32	37	0.026

The increase group on Day 5 When the 17 subjects with their WASOfs increased on Day 5 were grouped together, the *mean increase of WASOf* was times 4.00 (SD = 2.98 times) with a range of increase between 1.00 and 13.00 times. Towards the related aMT6s levels, no significant change was detected (Table 8.19). There were 52.9% (n = 9) of the subjects with their aMT6s levels increased while the remaining 47.1% (n = 8) had theirs decreased. The *mean increase in aMT6s level* was 4.42 pmol/ml (SEM = 1.76 pmol/ml) with a range of the increase between 0.57 and 13.65 pmol/ml. The *mean decrease in aMT6s level* was 2.56 pmol/ml (SEM = 1.05 pmol/ml) with a range of decrease between 0.31 and 9.62 pmol/ml. For the sleep satisfaction level (SSL), the mean of the sleep quality on Day 2 was lower than that on Day 5 (mean of sleep quality = 2.47 on Day 2; 2.76 on Day 5). These subjects found poorer sleep quality on Day 5 (p = 0.285). There were 11.8% (n = 2) subjects having their SSLs increased while 35.3% (n = 6) had theirs decreased and 52.9% (n = 9) unchanged.

Table 8.19 The results of paired-sample *t* test of the 6-sulphatoxymelatonin, aMT6s, level of different groups of subjects after bright light exposure with respect to the number of waking after sleep onset

	Paired Mean Differences (pmol/ml)	*t*	*p*
Increase group on Day 5 (n = 17)	-1.13	-0.84	0.412
Increase group on Day 6 (n = 23)	-0.75	-0.29	0.771
Decrease group on Day 5 (n = 16)	-2.17	-0.88	0.394
Decrease group on Day 6 (n = 13)	-1.98	-0.92	0.374

The increase group on Day 6 These 23 subjects had their *mean increase of WASOf* as 6.30 times (SD = 4.25 times) with a range of increase in the frequency from 1.00 to 20.00 times. When the related aMT6s levels were examined, no significant change in the level was shown (Table 8.19). There were 47.8% (n = 11) of the subjects with their aMT6s levels increased while 52.2% (n = 12) had theirs decreased. The *mean increase in aMT6s level* was 6.74 pmol/ml (SEM = 2.76 pmol/ml) with a range of increase between 0.14 and 32.19 pmol/ml. The *mean decrease in aMT6s level* was 7.61 pmol/ml (SEM = 3.09 pmol/ml) with a range of decrease between 0.66 and 37.59 pmol/ml. For the sleep satisfaction level (SSL), the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.74 on Day 2; 2.43 on Day 6). These subjects found better sleep quality on Day 6 (p = 0.088). There were 34.8% (n = 8) subjects having their SSLs increased while 13.0% (n = 3) had theirs decreased and 52.2% (n = 12) unchanged.

The decrease group on Day 5 16 subjects had a *mean decrease of WASOf* as 3.50 times (SD = 2.78 times) with a range of decrease between 1.00 and

10.00 times. When the related aMT6s levels were evaluated, the change in the levels was not significant (Table 8.19). There were 56.3% (n = 9) of the subjects with their aMT6s levels increased while 43.8% (n = 7) had theirs decreased. The *mean increase in aMT6s level* was 3.85 pmol/ml (SEM = 0.97 pmol/ml) with a range of increase between 0.20 and 9.26 pmol/ml. The *mean decrease in aMT6s level* was 9.91 pmol/ml (SEM = 3.94 pmol/ml) with a range of decrease between 0.68 and 29.61 pmol/ml. With respect to their SSLs, the mean of the sleep quality on Day 2 was higher than that on Day 5 (mean of sleep quality = 2.69 on Day 2; 2.44 on Day 5). These subjects found better sleep quality on Day 5 (p = 0.206). There were 43.8% (n = 7) subjects having their SSLs increased while 18.8% (n = 3) had theirs decreased and 37.5% (n = 6) unchanged.

The decrease group on Day 6 For these 13 subjects, the *mean decrease of WASOf* was 4.31 times (SD = 2.69 times) with a range of decrease between 1.00 and 10.00 times. When their aMT6s levels were considered, no significant change in the levels was observed (Table 8.19). There were 38.5% (n = 5) of the subjects with their aMT6s levels increased while 61.5% (n = 8) had theirs decreased. The *mean increase in aMT6s level* was 5.32 pmol/ml (SEM = 1.98 pmol/ml) with a range of increase between 0.52 and 12.19 pmol/ml. The *mean decrease in aMT6s level* was 6.54 pmol/ml (SEM = 1.92 pmol/ml) with a range of decrease between 1.12 to 15.12 pmol/ml. For the SSLs of these 13 subjects, the mean of the sleep quality

on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.38 on Day 2; 2.08 on Day 6). These subjects found better sleep quality on Day 6 (p = 0.257). There were 23.1% (n = 3) subjects having their SSLs increased while 7.7% (n = 1) had theirs decreased and 69.2% (n = 9) unchanged.

For ***WASOd***, it changed insignificantly after bright light exposure (Table 8.20). On Day 5, there were 47.4% (n = 18) of the subjects with their WASOds increased while 52.6% (n = 20) had theirs decreased. On Day 6, 50% (n = 19) had their WASOds increased and the remaining had theirs decreased.

Table 8.20 The results of paired-sample *t* test of the changes in the duration of each waking after sleep onset after bright light exposure (N = 38)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-1.78	-0.24 to 3.80	-1.78	37	0.083
Day 2 - Day 6	-1.83	-0.34 to 4.00	-1.71	37	0.095

The increase group on Day 5 These 18 subjects had their *mean increase of WASOd* as 1.97 minutes (SD = 1.25 minutes) with a range of increase between 0.17 and 4.01 minutes. When the related aMT6s levels were evaluated, the change was diverse and insignificant (Table 8.21). Half (n = 9) of the subjects had their aMT6s levels increased and half of them had theirs decreased. The *mean increase in aMT6s level* was 4.77 pmol/ml (SEM = 1.47 pmol/ml) with a range of increase between 0.20 and 13.65 pmol/ml. The *mean decrease in aMT6s level* was 7.78 pmol/ml (SEM =

3.30 pmol/ml) with a range of decrease between 0.68 and 29.61 pmol/ml. With respect to their SSLs. the mean of the sleep quality on Day 2 was lower than that on Day 5 (mean of sleep quality = 2.50 on Day 2: 2.72 on Day 5). These subjects found poorer sleep quality on Day 5 (p = 0.334). There were 27.8% (n = 5) subjects having their SSLs increased while 38.9% (n = 7) had theirs decreased and 33.3% (n = 6) unchanged.

Table 8.21 The results of paired-sample *t* test of the 6-sulphatoxymelatonin. aMT6s. level of different groups of subjects after bright light exposure with respect to the duration of each waking after sleep onset

	Paired Mean Differences (pmol/ml)	*t*	*p*
Increase group on Day 5 (n = 18)	-1.50	-0.65	0.526
Increase group on Day 6 (n = 19)	-2.56	-1.03	0.315
Decrease group on Day 5 (n = 20)	-0.21	-0.15	0.883
Decrease group on Day 6 (n = 19)	-0.85	-0.36	0.723

The increase group on Day 6 The *mean increase of WASOd* of this group of subjects (n = 19) was 2.21 minutes (SD = 2.66 minutes) with a range of increase between 0.02 and 8.84 minutes. The change in the related aMT6s levels was insignificant (Table 8.21). There were 42.1% (n = 8) of the subjects with their aMT6s levels increased while 57.9% (n = 11) had theirs decreased. The *mean increase in aMT6s level* was 5.09 pmol/ml (SEM = 1.24 pmol/ml) with a range of increase between 2.35 and 12.19 pmol/ml. The *mean decrease in aMT6s level* was 8.12 pmol/ml (SEM = 3.30 pmol/ml) with a range of decrease between 0.66 and 37.59 pmol/ml. When their SSLs were evaluated. the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.74 on Day 2: 2.42 on

Day 6). These subjects found better sleep quality on Day 6 (p = 0.190). There were 31.6% (n = 6) subjects having their SSLs increased while 15.8% (n = 3) had theirs decreased and 52.6% (n = 10) unchanged.

The decrease group on Day 5 These 20 subjects had their *mean decrease of WASOd* as 5.15 minutes (SD = 6.85 minutes) with a range of decrease between 0.14 and 30.66 minutes. When the related aMT6s levels were examined, no significant change was identified (Table 8.21). 55.0% (n = 11) of the subjects had their aMT6s levels increased but 45.0% (n = 9) had theirs decreased. The *mean increase in aMT6s level* was 3.59 pmol/ml (SEM = 1.19 pmol/ml) with a range of increase between 0.57 and 13.24 pmol/ml. The *mean decrease in aMT6s level* was 4.85 pmol/ml (SEM = 1.76 pmol/ml) with a range of decrease between 0.31 and 16.45 pmol/ml. When their related SSLs were considered, the mean of the sleep quality on Day 2 was higher than that on Day 5 (mean of sleep quality = 2.70 on Day 2; 2.30 on Day 5). These subjects found better sleep quality on Day 5 (p = 0.142). There were 40.0% (n = 8) subjects having their SSLs increased while 15.0% (n = 3) had theirs decreased and 45.0% (n = 9) unchanged.

The decrease group on Day 6 The subjects with their WASOd decreased on Day 6 (n = 19) had their *mean decrease of WASOd* as 5.87 minutes (SD = 6.93 minutes) with a range of decrease between 0.50 and 32.19 minutes. For the related aMT6s levels, no significant change was shown (Table 8.21).

There were 52.6% (n = 10) of the subjects with their aMT6s levels increased but 47.4% (n = 9) of them had theirs decreased. The *mean increase in aMT6s level* was 7.05 pmol/ml (SEM = 3.05 pmol/ml) with a range of increase between 0.14 and 32.19 pmol/ml. The *mean decrease in aMT6s level* was 6.04 pmol/ml (SEM = 1.88 pmol/ml) with a range of decrease between 1.57 and 19.15 pmol/ml. For the sleep satisfaction level (SSL), the mean of the sleep quality on Day 2 was slightly higher than that on Day 6 (mean of sleep quality = 2.47 on Day 2; 2.26 on Day 6). These subjects found better sleep quality on Day 6 ($p = 0.206$). There were 26.3% (n = 5) subjects having their SSLs increased while 10.5% (n = 2) had theirs decreased and 63.2% (n = 12) unchanged.

WASOt also changed insignificantly after bright light exposure (Table 8.22). On Day 5, there were 44.7% (n = 17) of the subjects with their WASOts increased, 2.6% (n = 1) unchanged and 52.6% (n = 20) decreased. On Day 6, there were 52.6% (n = 20) of the subjects with their WASOts increased while the remaining 47.4% (n = 18) had theirs decreased.

Table 8.22 The results of paired-sample *t* test of the changes in the total time of waking after sleep onset after bright light exposure (N = 38)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	+5.16	-6.67 to 16.99	+0.88	37	0.383
Day 2 - Day 6	-4.13	-18.48 to 10.22	-0.58	37	0.563

The increase group on Day 5 For the WASOt in this group of subjects (n = 17), the *mean increase of WASOt* was 23.76 minutes (SD = 20.97 minutes) with a range of increase between 1.00 and 71.00 minutes. When the correlated aMT6s levels were reviewed, the change in the level was not significant (Table 8.23). There were 64.7% (n = 11) of the subjects with their aMT6s levels increased while 35.3% (n = 6) had theirs decreased. The *mean increase in aMT6s level* was 3.40 pmol/ml (SEM = 1.22 pmol/ml) with a range of increase between 0.20 and 13.65 pmol/ml. The *mean decrease in aMT6s level* was 7.65 pmol/ml (SEM = 4.59 pmol/ml) with a range of decrease between 1.06 and 29.61 pmol/ml. When the correlated SSLs were considered, the mean of the sleep quality on Day 2 was lower than that on Day 5 (mean of sleep quality = 2.29 on Day 2; 2.88 on Day 5). These subjects found poorer sleep quality on Day 5 ($p = 0.026$). There were 11.8% (n = 2) subjects having their SSLs increased while 52.9% (n = 9) had theirs decreased and 35.3% (n = 6) unchanged.

Table 8.23 The results of paired-sample *t* test of the 6-sulphatoxymelatonin, aMT6s, level of different groups of subjects after bright light exposure with respect to the total time of waking after sleep onset

	Paired Mean Differences (pmol/ml)	*t*	*p*
Increase group on Day 5 (n = 17)	+0.50	-0.23	0.820
Increase group on Day 6 (n = 20)	-1.92	-0.77	0.451
Decrease group on Day 5 (n = 20)	-1.27	-0.74	0.468
Decrease group on Day 6 (n = 18)	-0.34	-0.14	0.888

The increase group on Day 6 For the *mean increase of WASOt* in this group of subjects (n = 20), it was 36.00 minutes (SD = 31.00 minutes) with a range

of increase between 2.00 and 107.00 minutes. For the corresponding aMT6s levels, no significant change was detected (Table 8.23). There were 55.0% (n = 11) of the subjects with their aMT6s levels increased but 45.0% (n = 9) had theirs decreased. The *mean increase in aMT6s level* was 4.84 pmol/ml (SEM = 1.04 pmol/ml) with a range of increase between 0.42 and 12.16 pmol/ml. The *mean decrease in aMT6s level* was 10.19 pmol/ml (SEM = 3.97 pmol/ml) with a range of decrease between 0.66 and 37.59 pmol/ml. For the sleep satisfaction level (SSL), the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.70 on Day 2; 2.40 on Day 6). These subjects found better sleep quality on Day 6 (p = 0.218). There were 35.0% (n = 7) subjects having their SSLs increased while 20.0% (n = 4) had theirs decreased and 45.0% (n = 9) unchanged.

The decrease group on Day 5 For this group of subjects (n = 20), the *mean decrease of WASOt* was 30.00 minutes (SD = 27.44 minutes) with a range of decrease between 7.00 and 110.00 minutes. When the aMT6s levels were examined, the related levels changed insignificantly (Table 8.23). There were 40.0% (n = 8) of the subjects with their aMT6s levels increased but 60.0% (n = 12) had theirs decreased. The *mean increase in aMT6s level* was 5.31 pmol/ml (SEM = 1.55 pmol/ml) with a range of increase between 0.58 and 13.24 pmol/ml. The *mean decrease in aMT6s level* was 5.65 pmol/ml (SEM = 1.74 pmol/ml) with a range of decrease between 0.31 and

16.68 pmol/ml. When their related SSLs were studied, the mean of the sleep quality on Day 2 was higher than that on Day 5 (mean of sleep quality = 2.90 on Day 2; 2.20 on Day 5). These subjects found better sleep quality on Day 5 (p = 0.005). There were 55.0% (n = 11) subjects having their SSLs increased while 5.0% (n = 1) had theirs decreased and 40.0% (n = 8) unchanged.

The decrease group on Day 6 These 18 subjects had their *mean decrease of WASOt* as 31.28 minutes (SD = 23.49 minutes) with a range of decrease between 2.00 and 91.00 minutes. For their corresponding aMT6s levels, no significant change was found (Table 8.23). There were 38.9% (n = 7) of the subjects with their aMT6s levels increased while 61.1% (n = 11) had theirs decreased. The *mean increase in aMT6s level* was 8.29 pmol/ml (SEM = 4.28 pmol/ml) with a range of increase between 0.14 and 32.19 pmol/ml. The *mean decrease in aMT6s level* was 4.73 pmol/ml (SEM = 1.32 pmol/ml) with a range of decrease between 1.12 and 15.12 pmol/ml. When the related SSLs were considered, the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.50 on Day 2; 2.28 on Day 6). These subjects found better sleep quality on Day 6 (p = 0.157). There were 22.2% (n = 4) subjects having their SSLs increased while 5.6% (n = 1) had theirs decreased and 72.2% (n = 13) unchanged.

As fragmentation of sleep was one of the major sleep complaints among the subjects, the changes in WASOf played an important role in determining sleep quality. According to the WASOf groups, the duration of the subjects experiencing disturbance did not seem to be an influencing factor on the effects of bright light exposure. In addition, the proportion of subjects complaining of difficulty in maintaining sleep was similar among the four groups (Table 8.24).

Table 8.24 The characteristics of the different groups of subjects before bright light exposure

	Duration of sleep complaint (years)	Number of cases reported difficulty in maintaining sleep
The increase group on Day 5 (n = 17)	10.93	11 (64.7%)
The increase group on Day 6 (n = 23)	8.07	12 (52.2%)
The unchanged group on Day 5 (n = 5)	9.63	2 (40.0%)
The unchanged group on Day 6 (n = 2)	11.25	2 (100.0%)
The decrease group on Day 5 (n = 16)	6.04	9 (56.3%)
The decrease group on Day 6 (n = 13)	9.42	8 (61.5%)

When WASOf was analysed from the sleep log, the subjects tended to report their WASOfs as unchanged or decreased after bright light exposure. This was inconsistent with the actigraphic recordings. According to the sleep log, there were 18.4% of the subjects (n = 7) with their WASOfs increased, 42.1% (n = 16) decreased and 39.5% (n = 15) unchanged on Day 5 (paired difference mean = 0.32 times; confidence interval 0.03 to 0.60 times; t = 2.23, df = 37, p = 0.032). For Day 6, there were 23.7% of the subjects (n = 9) with their WASOfs increased, 31.6% (n = 12) decreased and 44.7% (n = 17) unchanged (paired difference mean = 0.11 times; confidence interval -0.19 to 0.40 times; t = 0.73, df = 37, p = 0.473). Even the

actigraphic recording illustrated an increase in the WASOf, but most of the subjects did not report an increase in their WASOfs. The details of the inconsistency are displayed in Table 8.25.

Table 8.25 The comparison between the actigraphic recording and the sleep log with respect to the number of waking after sleep onset

Actigraphic Recording	Sleep log reporting		
	Increase	Unchanged	Decrease
Increase group on Day 5 (n = 17)	2 (11.8%)	5 (29.4%)	10 (58.8%)
Increase group on Day 6 (n = 23)	6 (26.1%)	11 (47.8%)	6 (26.1%)
Decrease group on Day 5 (n = 16)	3 (18.8%)	9 (56.3%)	4 (25.0%)
Decrease group on Day 6 (n = 13)	3 (23.1%)	6 (46.2%)	4 (30.8%)

Apart from the inconsistency, the investigator also observed that WASOf was negatively correlated with WASOd ($r = -0.42$, $p = 0.008$ on Day 5: $r = -0.23$, $p = 0.175$ on Day 6) but positively correlated with WASOt ($r = 0.29$, $p = 0.079$ on Day 5: $r = 0.49$, $p = 0.002$ on Day 6) (Table 8.26).

Table 8.26 The changes in the duration of each waking after sleep onset, WASOd, and the total time of waking after sleep onset, WASOt, of the four groups of subjects after bright light exposure with respect to the number of waking after sleep onset, WASOf

	WASOd		WASOt	
	Increase	Decrease	Increase	Decrease
The increase group on Day 5 (n = 17)	5 (29.4%)	12 (70.59%)	11 (64.7%)	6 (35.3%)
The increase group on Day 6 (n = 23)	9 (39.1%)	14 (60.9%)	16 (69.6%)	7 (30.4%)
The unchanged group on Day 5 (n = 5)	1 (20.0%)	4 (80.0%)	1 (20.0%)	4 (80.0%)
The unchanged group on Day 6 (n = 2)	2 (100.0%)	0	2 (100.0%)	0
The decrease group on Day 5 (n = 16)	12 (75.0%)	4 (25.0%)	5 (31.3%)	10 (62.5%)
The decrease group on Day 6 (n = 13)	8 (61.5%)	5 (38.5%)	2 (15.4%)	11 (84.6%)

Sleep Offset Time (SoffT)

The change in SoffT was not significant after bright light exposure (Table 8.27). On Day 5, 57.9% (n = 22) of the subjects showed a SoffTs backward shift and 42.1% (n = 16) a forward shift. On Day 6, the situation was different. Half of subjects (n = 19) showed a backward SoffTs while the remaining a forward shift.

Table 8.27 The results of paired-sample *t* test of the changes in the sleep offset time after bright light exposure (N = 38)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-5.55	-18.17 to 7.03	-0.90	37	0.377
Day 2 - Day 6	-1.88	-12.65 to 16.45	-0.26	37	0.793

The backward group on Day 5 These 22 subjects had their *mean duration for SoffT of backward shift* as 29.80 minutes (SD = 27.93 minutes) with a range of shift between 1.68 and 111.5 minutes. When the related aMT6s levels were reviewed, the change in the levels was not significant (Table 8.28). There were 59.1% (n = 13) of the subjects with their aMT6s levels increased while 40.9% (n = 9) had theirs decreased. The *mean increase in aMT6s level* was 2.72 pmol/ml (SEM = 0.65 pmol/ml) with a range of increase between 0.20 and 7.47 pmol/ml. The *mean decrease in aMT6s level* was 6.32 pmol/ml (SEM = 2.16 pmol/ml) with a range of decrease between 0.90 and 16.68 pmol/ml. For the sleep satisfaction level (SSL) of this backward group, the mean of the sleep quality on Day 2 was higher than

that on Day 5 (mean of sleep quality = 2.64 on Day 2; 2.45 on Day 5). Therefore, these subjects found better sleep quality on Day 5 (p = 0.396). There were 36.4% (n = 8) subjects having their SSLs increased while 22.7% (n = 5) had theirs decreased and 40.9% (n = 9) unchanged.

Table 8.28 The results of paired-sample *t* test of the 6-sulphatoxymelatonin, aMT6s, level of different groups of subjects after bright light exposure with respect to the sleep offset time

	Paired Mean Differences (pmol/ml)	*t*	*p*
Backward group on Day 5 (n = 22)	-0.98	-0.73	0.476
Backward group on Day 6 (n = 19)	-0.87	-0.27	0.788
Forward group on Day 5 (n = 16)	-0.61	-0.24	0.815
Forward group on Day 6 (n = 19)	-0.83	-0.63	0.539

The backward group on Day 6 This group of subjects (n = 19) showed a *mean duration for SoffT of backward shift* as 31.23 minutes (SD = 26.20 minutes) with a range of shift between 0.28 and 101.57 minutes. When their related aMT6s levels were investigated, no significant change was found (Table 8.28). There were 42.1% (n = 8) of the subjects with their aMT6s levels increased while 57.9% (n = 11) had theirs decreased. The *mean increase in aMT6s level* was 9.73 pmol/ml (SEM = 3.52 pmol/ml) with a range of increase between 2.19 and 32.19 pmol/ml. The *mean decrease in aMT6s level* was 8.58 pmol/ml (SEM = 3.38 pmol/ml) with a range of decrease between 0.66 and 37.59 pmol/ml. For the sleep satisfaction level (SSL) of this backward group, the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.58 on Day 2; 2.16 on Day 6). Therefore, these subjects found better sleep

quality on Day 6 (p = 0.084). There were 31.6% (n = 6) subjects having their SSLs increased while 10.5% (n = 2) had theirs decreased and 57.9% (n = 11) unchanged.

The forward group on Day 5 These 16 subjects had their *mean duration for SoffT of forward shift* as 27.75 minutes (SD = 22.07 minutes) with the range of shift between 0.93 and 80.92 minutes. When their related aMT6s levels were examined, no significant change was illustrated (Table 8.28). There were 43.8% (n = 7) of the subjects with their aMT6s levels increased but 56.3% (n = 9) had theirs decreased. The *mean increase in aMT6s level* was 6.73 pmol/ml (SEM = 2.07 pmol/ml) with a range of increase between 0.57 and 13.65 pmol/ml. The *mean decrease in aMT6s level* was 6.31 pmol/ml (SEM = 3.14 pmol/ml) with a range of decrease between 0.31 and 29.61 pmol/ml. For the sleep satisfaction level (SSL) of this forward group, the mean of the sleep quality on Day 2 was the same as that on Day 5 (mean of sleep quality = 2.56 on Day 2; 2.56 on Day 5). Therefore, these subjects had no change in their quality of sleep on Day 5 (p = 0.874). There were 31.3% (n = 5) subjects having their SSLs increased while 31.3% (n = 5) had theirs decreased and 37.5% (n = 6) unchanged.

The forward group on Day 6 These 19 subjects had their *mean duration for SoffT of forward shift* as 35.02 minutes (SD = 32.07 minutes) with a range of shift between 0.93 and 108.35 minutes. In terms of their related aMT6s

levels, no significant change was detected (Table 8.28). There were 52.6% (n = 10) of the subjects with their aMT6s levels increased while 47.4% (n = 9) had theirs decreased. The *mean increase in aMT6s level* was 3.35 pmol/ml (SEM = 0.87 pmol/ml) with a range of increase between 0.14 and 8.21 pmol/ml. The *mean decrease in aMT6s level* was 5.48 pmol/ml (SEM = 1.53 pmol/ml) with a range of decrease between 1.12 and 15.12 pmol/ml. When their SSLs were examined, the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.63 on Day 2; 2.53 on Day 6). Therefore, these subjects found better sleep quality on Day 6 (p = 0.480). There were 26.3% (n = 5) subjects having their SSLs increased while 15.8% (n = 3) had theirs decreased and 57.9% (n = 11) unchanged.

With the exception of the *backward group on Day 5*, all the other groups experienced similar duration of sleep disturbance. The cases of early morning awakening were evenly distributed among the four groups. Detailed description is provided in Table 8.29. All the four groups of subjects reported their refreshment levels as largely unchanged after bright light exposure. The change in SoffT in all the 38 subjects was not significantly correlated with the change in SOT (r = 0.02, p = 0.920 in Day 5; r = 0.00, p = 1.000 in Day 6). The corresponding changes in SOT are presented in Table 8.30.

Table 8.29 The characteristics of the different groups of subjects before bright light exposure

	Duration of sleep complaint (years)	Number of cases reported early morning awakening
The backward group on Day 5 (n = 22)	10.33	10 (45.5%)
The backward group on Day 6 (n = 19)	7.64	7 (36.8%)
The forward group on Day 5 (n = 16)	6.46	6 (37.5%)
The forward group on Day 6 (n = 19)	9.76	7 (36.8%)

Table 8.30 The change of the corresponding sleep onset time, SOT, of the subjects after bright light exposure with respect to the sleep offset time

SoffT	SOT	
	Backward	Forward
The backward group on Day 5 (n = 22)	10 (45.5%)	12 (54.5%)
The backward group on Day 6 (n = 19)	9 (47.4%)	10 (52.6%)
The forward group on Day 5 (n = 16)	7 (43.8%)	9 (56.3%)
The forward group on Day 6 (n = 19)	9 (47.4%)	10 (52.6%)

Summary

The first and third alternative hypotheses were supported when the sleep-wake parameters were considered individually. The second one was rejected. The effects of bright light on most of the actigraphic sleep-wake parameters were not marked but the changes of each parameter did show a pattern. The pattern of changes in the parameter are described below:-

Sleep Efficiency (SE) and Sleep-Wake Ratio (SWR)

The changes in SE and SWR after bright light exposure were not statistically significant, nor were the changes in their related aMTos levels.

However, for the subjects with their SEs and SWRs increased on Day 5, they found better sleep quality as compared with that on Day 2 (p = 0.017). There were about 43.5% of them having their sleep quality improved. After bright light exposure, subjects mainly had their SEs and SWRs increased.

Total Sleep Time (TST)

Similar to SE and SWR, there was no statistical significant change in TST after bright light exposure. The related aMT6s levels also did not demonstrate a significant alteration. When the subjects had their TSTs increased in the post-bright light exposure stage, they reported a better sleep as compared with the pre-bright light exposure stage (p = 0.003 on Day 5; p = 0.047 on Day 6). More than 30% of these subjects had their sleep quality improved after bright light exposure. However, 60% of the subjects in the decrease group on Day 5 reported a decrease in sleep satisfaction (p = 0.013) after bright light exposure. The change in the TST in the post-bright light exposure stage was mainly the increase on Day 5 while it was unpredictable on Day 6. Those with their TSTs decreased after bright light exposure tended to have a longer history of sleep disturbance and over 60% of them claimed their sleep quality as bad or very bad sleep before the light exposure.

Total Bed Time (TBT)

No significant change in TBT, after bright light exposure, was observed. The same situations were also observed in the related aMT6s levels and SSLs. The trend of change in TBT could not be determined after bright light exposure. However, there was a significant improvement in the quality of sleep in the increase group on Day 6 (p = 0.039). About 40% of these subjects had their quality of sleep improved after bright light exposure. When the correlated TSTs were investigated, the increase groups tended to have their TSTs increased though the associated SEs could not display a clear trend of alteration.

Sleep Onset Latency (SOL)

Statistically, there was no significant change in SOL after bright light exposure. No prominent changes in the related aMT6s levels and SSLs were found. Half of the subjects had their SOL decreased after exposure to bright light. The subjects with their SOLs increased were characterized with longer period of sleep disturbance as compared with the decrease groups. In addition, more than 60% of them complained of difficulty in initiating sleep.

Sleep Onset Time (SOT)

SOT changed insignificantly after bright light exposure. Similar to other parameters, no prominent alterations in the related aMT6s levels and SSLs were observed. About 60% of the subjects had their SOTs shifted forwards. The phase shifting of SOT was not well correlated with the shift of the related sleep offset time (SoffT).

Wake After Sleep Onset (WASO)

With the exception of the change in WASOf on Day 6, all the changes of WASO parameters were insignificant after bright light exposure. WASOfs and WASOts were found to decrease in more than 39% of the subjects while it was more than 50% for WASOds in the post-bright light exposure stage. There were no significant changes in the related aMT6s levels. Nonetheless, significant changes in quality of sleep were identified on Day 5. For those with their WASOts increased on Day 5, they found poorer sleep quality as compared with that on Day 2 ($p = 0.026$). Over 40% of them had their SSLs decreased after exposure to bright light. For those with their WASOts decreased on Day 5, they found better sleep quality after bright light exposure. More than 40% of them had their quality of sleep improved. Actigraphic WASOfs were inconsistent with WASOfs from the sleep log in which the subjects tended to report their WASOfs as unchanged

or decreased in the post-bright light stage. According to the sleep log, the changes in WASOf were prominent ($p = 0.032$). There were 41.7% having their WASOfs unchanged and 37.5% decreased after bright light exposure. WASOf was positively correlated with WASOt on Day 6 but negatively correlated with WASOd on Day 5.

Sleep Offset Time (SoffT)

There was no significant change observed in SoffT after bright light exposure. In addition, the changes of their related aMT6s levels were not significant. After bright light exposure, the SoffTs of the subjects shifted diversely.

The light-induced changes in the sleep-wake parameters are described in this chapter. The findings of the alterations in 6-sulphatoxymelatonin level after bright light exposure will be presented in the coming chapter.

Chapter 9

Results (IV) - The Effects of Bright Light Exposure on the Subjects: The Changes in 6-sulphatoxymelatonin (aMT6s) Level

Introduction

This chapter focuses mainly on the ninth research question and partly research questions six and eight. The 6-suphatoxymelatonin (aMT6s) levels were measured in pmol/ml. The collection of urine specimens was started at 1800 hours up to the first morning urine of the next day. The collection was divided into two time periods: Light On Period (from 1800 hours to bedtime) and Light Off Period (from bedtime to rising time). In this way, the nocturnal change in aMT6s level was studied. For the Light On Period, the direct effect of bright light on aMT6s level was analysed by comparing the findings on Day 2 with Day 3 and Day 3 with Day 4. However, for the Light Off Period, the change in the level was determined by comparing the levels in the pre-bright light exposure stage (Day 2) with the levels in the post bright light exposure stage (Days 5 and 6). Those with their aMT6s levels increased were classified as the increase group, decreased as the decrease group and unchanged as the unchanged group. Apart from aMT6s level, the related changes in the actigraphic sleep-wake parameters and sleep

satisfaction level (SSL) were explored. In terms of SOT and SoffT, the advancement of SOT or SoffT was described as a forward shift while the delay was stated as a backward shift.

Light On Period

Urine specimens were collected from 1800 hours to bedtime. During this time period, the subjects were exposed to either red dim light (<450 lux) or white bright light (2460 – 3990 lux) under room light condition for three hours (1800 hours – 2100 hours). With reference to the Light On Period, 30 subjects had completed the 6-day study procedure including urine collection, actigraphic data recording and sleep log. As revealed by the paired-sample *t* test, the changes in the aMT6s level were not statistically significant in the bright light exposure stage, Days 3 and 4 (Table 9.1) so the first alternative hypothesis in the Chapter 1 was rejected. The related changes are described in Figure 9.1.

Table 9.1 The results of paired-sample *t* test of the changes in the 6-sulphatoxymelatonin level with respect to the Light On Period (N = 30)

	Paired Mean Differences (pmol/ml)	Confidence Interval (pmol/ml)	*t*	df	*p*
Day 2 - Day 3	-0.09	-0.94 to 1.13	-0.18	29	0.858
Day 3 - Day 4	-0.46	-1.16 to 2.08	-0.58	29	0.567

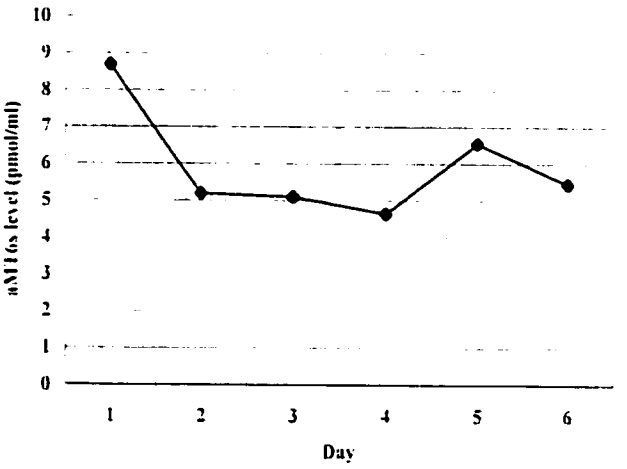


Figure 9.1 The changes in the 6-sulphatoxymelatonin, aMT6s, level with respect to the Light On Period (N = 30)

When the findings on Day 3 were compared with those of Day 2, 40.0% (n = 12) of the subjects had their aMT6s levels increased while 60.0% (n = 18) had theirs decreased. The *mean increase in aMT6s level* was 2.53 pmol/ml (SEM = 0.56 pmol/ml) with a range of increase between 0.11 and 7.02 pmol/ml. The *mean decrease in aMT6s level* was 1.84 pmol/ml (SEM = 0.38 pmol/ml) with a range of decrease between 0.16 and 5.97 pmol/ml. Similarly, when the findings on Day 4 were compared with those of Day 3, 40.0% (n = 12) of the subjects had their aMT6s levels increased and 60.0% (n = 18) decreased. The *mean increase in aMT6s level* was 2.98 pmol/ml (SEM = 0.83 pmol/ml) with a range of increase between 0.12 and 10.62 pmol/ml. The *mean decrease in aMT6s level* was 2.75 pmol/ml (SEM = 0.84 pmol/ml) with a range of decrease between 0.21 and 14.93 pmol/ml. The aMT6s levels tended to decrease during bright light exposure.

Light Off Period

Urine specimens were collected from bedtime to rising time including the first morning urine. During this time period, the subjects were sleeping in a comparatively dark environment (mean intensity = 8.61 lux). With respect to this Light Off Period, 38 subjects had completed the 6-day study procedure including urine collection, actigraphic data recording and sleep log. After bright light exposure, there was no statistically significant change in the aMT6s level in the post bright light exposure stage, Days 5 and 6 (Table 9.2). The first alternative hypothesis in the Chapter 1 was rejected. The related changes in the aMT6s level throughout the experiment are described in Figure 9.2.

Table 9.2 The results of paired-sample *t* test of the changes in 6-sulphatoxymelatonin level with respect to the Light Off Period (N = 38)

	Paired Mean Differences (pmol/ml)	Confidence Interval (pmol/ml)	*t*	df	*p*
Day 2 - Day 5	-0.82	-1.83 to 3.47	-0.63	37	0.533
Day 2 - Day 6	-0.85	-2.61 to 4.32	-0.50	37	0.621

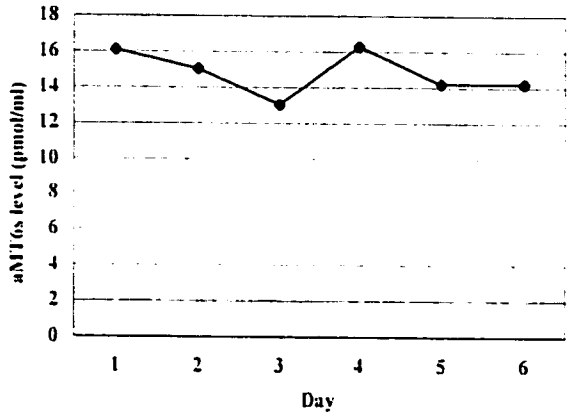


Figure 9.2 The changes in the 6-sulphatoxymelatonin, aMT6s, level throughout the experiment with respect to the Light Off Period (N = 38)

On Day 5, there were 52.6% (n = 20) of the subjects with aMT6s levels increased while 47.4% (n = 18) showed a decrease. The *mean increase in aMT6s level* was 4.13 pmol/ml (SEM = 0.91 pmol/ml) with a range of increase between 0.20 and 13.65 pmol/ml. The *mean decrease in aMT6s level* was 6.32 pmol/ml (SEM = 1.85 pmol/ml) with a range of decrease between 0.31 and 29.61 pmol/ml. A different situation was presented on Day 6 in which 47.4% (n = 18) of the subjects showed aMT6s levels increased but 52.6% (n = 20) showed a decrease. The *mean increase in aMT6s level* was 6.18 pmol/ml (SEM = 1.75 pmol/ml) with a range of increase between 0.14 and 32.19 pmol/ml. The *mean decrease in aMT6s level* was 7.18 pmol/ml (SEM = 1.97 pmol/ml) with a range of decrease between 0.66 and 37.59 pmol/ml. With respect to the corresponding sleep satisfaction level and sleep-wake parameters, the results are displayed as follow:-

The change in the related sleep satisfaction level (SSL)

The increase group on Day 5 When subjects had their aMT6s levels increased (n = 20), the mean of the sleep quality on Day 2 was the same as that on Day 5 (mean of sleep quality = 2.55 on Day 2; 2.55 on Day 5). Therefore, there was no change in their sleep quality on Day 5 (p = 0.976). There were 40.0% (n = 8) subjects having their SSLs increased while 35.0% (n = 7) had theirs decreased and 25.0% (n = 5) unchanged.

The increase group on Day 6 When subjects had their aMT6s levels increased (n = 18), the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.33 on Day 2; 2.22 on Day 6). Therefore, these subjects found better sleep quality on Day 6 (p = 0.564). There were 27.8% (n = 5) subjects having their SSLs increased while 22.2% (n = 4) had theirs decreased and 50.0% (n = 9) unchanged.

The decrease group on Day 5 For the subjects whose aMT6s levels decreased (n = 18), the mean of the sleep quality on Day 2 was higher than that on Day 5 (mean of sleep quality = 2.67 on Day 2; 2.44 on Day 5). Therefore, these subjects found better sleep quality on Day 5 (p = 0.429). There were 27.8% (n = 5) subjects having their SSLs increased while 16.7% (n = 3) had theirs decreased and 55.6% (n = 10) unchanged.

The decrease group on Day 6 For the subjects whose aMT6s levels decreased (n = 20), the mean of the sleep quality on Day 2 was higher than that on Day 6 (mean of sleep quality = 2.85 on Day 2; 2.45 on Day 6). Therefore, these subjects found better sleep quality on Day 6 (p = 0.054). There were 30.0% (n = 6) subjects having their SSLs increased while 5.0% (n = 1) had theirs decreased and 65.0% (n = 13) unchanged.

As a conclusion, the fourth alternative hypothesis in the Chapter 1 was rejected.

The change in the corresponding sleep-wake parameters

Sleep Efficiency (SE) and Sleep-Wake Ratio (SWR)

The increase group on Day 5 A paired-sample t test demonstrated that the changes in SE and SWR of these 20 subjects were insignificant after bright light exposure (Table 9.3). 50.0% (n = 10) of subjects showed an increase in these two parameters while the remaining 50.0% (n = 10) had theirs decreased. The *mean increase of SE* was 7.82% (SD = 6.38%) with a range of increase between 0.03% and 20.92%. The *mean decrease of SE* was 5.79% (SD = 4.57%) with a range of decrease between 0.47% and 12.25%. For the SWR, the *mean increase of SWR* was 3.79 (SD = 2.41) with a range

of increase between 0.01 and 8.39. The *mean decrease of SWR* was 4.70 (SD = 3.57) with the range of decrease between 0.31 to 10.23.

Table 9.3 The results of paired-sample *t* test of the changes in sleep efficiency, SE, and sleep-wake ratio, SWR, after bright light exposure with respect to the increase groups of the 6-sulphatoxymelatonin level

	Paired Mean Differences	*t*	*p*
Day 2 - Day 5: SE (n = 20)	-1.01	-0.51	0.613
Day 2 - Day 5: SWR (n = 20)	-0.45	-0.38	0.706
Day 2 - Day 6: SE (n = 18)	-2.75	-1.21	0.242
Day 2 - Day 6: SWR (n = 18)	-2.41	-1.16	0.262

Note: Paired mean differences of SE was measured in percentage.
Paired mean differences of SWR was a ratio.

The increase group on Day 6 The changes in the SE and SWR of this group of subjects (n = 18) after bright light exposure was not significant (Table 9.3). Both the SE and SWR were increased in 44.4% (n = 8) of the subjects and decreased in 55.6% (n = 10) of them. The *mean increase of SE* was 7.03% (SD = 2.90%) with a range of increase between 2.45% and 11.55%. The *mean decrease of SE* was 10.57% (SD = 3.91%) with a range of decrease between 3.82% and 17.54%. In terms of the SWR, the *mean increase of SWR* was 5.15 (SD = 1.94) with a range of increase between 0.98 and 7.44. The *mean decrease of SWR* was 8.46 (SD = 7.25) with a range of decrease between 1.36 and 24.57.

The decrease group on Day 5 The changes in the SE and SWR of these 18 subjects were not significant after bright light exposure (Table 9.4). These two parameters were increased in 72.2% (n = 13) of the subjects and

decreased in 27.8% (n = 5) of them. The *mean increase of SE* was 7.00% (SD = 6.26%) with a range of increase between 1.67% to 21.12%. The *mean decrease of SE* was 7.16% (SD = 7.63%) with a range of decrease between 0.04% and 18.67%. For SWR, the *mean increase of SWR* was 10.32 (SD = 30.59) with a range of increase between 0.30 and 112.07. The *mean decrease of SWR* was 1.50 (SD = 1.59) with a range of decrease between 0.09 and 4.14.

Table 9.4 The results of paired-sample *t* test of the changes in sleep efficiency, SE, and sleep-wake ratio, SWR, after bright light exposure with respect to the decrease groups of the 6-sulphatoxymelatonin level

	Paired Mean Differences	*t*	*p*
Day 2 - Day 5: SE (n = 18)	-3.07	-1.42	0.174
Day 2 - Day 5: SWR (n = 18)	-7.04	-1.14	0.272
Day 2 - Day 6: SE (n = 20)	-1.41	-0.53	0.600
Day 2 - Day 6: SWR (n = 20)	-0.85	-0.94	0.357

Note: Paired mean differences of SE was measured in percentage.
Paired mean differences of SWR was a ratio.

The decrease group on Day 6 The changes in the SE and SWR of these 20 subjects were insignificant (Table 9.4). For the SE, there were 65.0% (n = 13) of the subjects with their SEs increased while 35.0% (n = 7) had theirs decreased. The *mean increase of SE* was 8.02% (SD = 6.87%) with a range of increase between 0.01% and 20.49%. The *mean decrease of SE* was 10.86% (SD = 8.90%) with a range of decrease between 0.84% and 23.91%. In terms of the SWR, there were 60.0% of the subjects (n = 12) with their SWRs increased but 35.0% (n = 7) had theirs decreased and 5.0% (n = 1) had theirs unchanged. The *mean increase of SWR* was 3.22 (SD = 3.06)

with a range of increase between 0.02 and 9.52. The *mean decrease of SWR* was 3.08 (SD = 2.25) with a range of decrease between 0.40 and 7.28.

Total Sleep Time (TST)

The increase group on Day 5 In this group of subjects (n = 20), the related TSTs changed insignificantly (Table 9.5). There were 65.0% (n = 13) of the subjects with their TSTs increased while the remaining 35.0% (n = 7) had theirs decreased. The *mean increase of TST* was 44.32 minutes (SD = 31.34 minutes) with a range of increase between 7.00 and 110.00 minutes. The *mean decrease of TST* was 38.86 minutes (SD = 48.36 minutes) with a range of decrease between 3.00 and 132.00 minutes.

Table 9.5 The results of paired-sample *t* test of the changes in total sleep time after bright light exposure with respect to the 6-sulphatoxymelatonin level

	Paired Mean Differences (min)	*t*	*p*
Increase group on Day 5 (n = 20)	-15.21	-1.24	0.231
Increase group on Day 6 (n = 18)	-22.60	-1.41	0.177
Decrease group on Day 5 (n = 18)	-4.41	-0.40	0.696
Decrease group on Day 6 (n = 20)	-9.57	-0.69	0.497

The increase group on Day 6 This group of subjects (n = 18) had their related TSTs changed insignificantly (Table 9.5). There were 38.9% (n = 7) of the subjects with their TSTs increased while 61.1% (n = 11) had theirs decreased. The corresponding *mean increase of TST* was 45.74 minutes (SD = 25.00 minutes) with the range of increase between 10.00 and 84.00

minutes. For the *mean decrease of TST*, it was 66.09 minutes (SD = 46.27 minutes) with a range of decrease between 6.00 and 128.00 minutes.

The decrease group on Day 5 The TSTs of these 18 subjects changed insignificantly (Table 9.5). There were 55.6% (n = 10) of the subjects with their TSTs increased while the remaining 44.4% (n = 8) had theirs decreased. The *mean increase of TST* was 36.80 minutes (SD = 23.94 minutes) with a range of increase between 6.00 and 79.00 minutes. The *mean decrease of TST* was 36.08 minutes (SD = 35.66 minutes) with a range of decrease between 3.00 and 115.00 minutes.

The decrease group on Day 6 This group of subjects (n = 20) had their TSTs changed insignificantly (Table 9.5). There were 60.0% (n = 12) of the subjects with their TSTs increased while 40.0% (n = 8) had theirs decreased. The *mean increase of TST* was 49.03 minutes (SD = 26.51 minutes) with a range of increase between 11.00 and 99.33 minutes. For the *mean decrease of TST*, it was 49.63 minutes (SD = 50.85 minutes) with a range of decrease between 2.00 and 130.00 minutes.

Total Bed Time (TBT)

The increase group on Day 5 The change in the TBT of these 20 subjects was insignificant (Table 9.6). There were 55.0% (n = 11) of the subjects with their TBTs increased while the remaining 45.0% (n = 9) had theirs decreased. The *mean increase of TBT* was 44.35 minutes (SD = 35.41 minutes) with a range of increase between 11.66 and 129.67 minutes. For the *mean decrease of TBT*, it was 30.22 minutes (SD = 30.78 minutes) with a range of decrease between 2.34 and 109.00 minutes.

Table 9.6 The results of paired-sample *t* test of the changes in total bed time after bright light exposure with respect to the 6-sulphatoxymelatonin level

	Paired Mean Differences (min)	*t*	*p*
Increase group on Day 5 (n = 20)	-10.79	-0.96	0.347
Increase group on Day 6 (n = 18)	-10.33	-0.88	0.389
Decrease group on Day 5 (n = 18)	-15.73	-1.67	0.113
Decrease group on Day 6 (n = 20)	-1.20	-0.15	0.882

The increase group on Day 6 TBT of these 18 subjects changed insignificantly (Table 9.6). There were 44.4% (n = 8) of the subjects with their TBTs increased while the remaining 55.6% (n = 10) had theirs decreased. The *mean increase of TBT* was 35.75 minutes (SD = 16.17 minutes) with a range of increase between 14.66 and 63.67 minutes. For the *mean decrease of TBT*, it was 47.20 minutes (SD = 32.36 minutes) with a range of decrease between 1.83 and 98.00 minutes.

The decrease group on Day 5 These 18 subjects had their TBTs changed insignificantly (Table 9.6). There were 33.3% (n = 6) of the subjects with their TBTs increased while 66.7% (n = 12) had theirs decreased. The *mean increase of TBT* was 25.56 minutes (SD = 30.39 minutes) with a range of increase between 0.16 and 65.50 minutes. The *mean decrease of TBT* was 36.38 minutes (SD = 25.55 minutes) with a range of decrease between 2.00 and 75.50 minutes.

The decrease group on Day 6 Similar to the decreased group on Day 5, the TBTs of these 20 subjects changed insignificantly (Table 9.6). There were 55.0% (n = 11) of the subjects with their TBTs increased while the remaining 45.0% (n = 9) had theirs decreased. The *mean increase of TBT* was 27.15 minutes (SD = 22.21 minutes) with a range of increase between 5.00 and 78.84 minutes. For the *mean decrease of TBT*, it was 30.52 minutes (SD = 18.71 minutes) with a range of decrease between 10.34 and 65.00 minutes.

Sleep Onset Latency (SOL)

The increase group on Day 5 The changes in the SOLs of these 20 subjects were insignificant (Table 9.7). There were 40.0% (n = 8) of the subjects with their SOLs increased, 50.0% (n = 10) decreased and 10.0% (n = 2)

unchanged. The related *mean increase of SOL* was 8.60 minutes (SD = 6.31 minutes) with a range of increase between 0.17 and 17.50 minutes. For the *mean decrease of SOL*, it was 15.07 minutes (SD = 19.65 minutes) with a range of decrease between 0.33 and 66.16 minutes.

Table 9.7 The results of paired-sample *t* test of the changes in sleep onset latency after bright light exposure with respect to the 6-sulphatoxymelatonin level

	Paired Mean Differences (min)	*t*	*p*
Increase group on Day 5 (n = 20)	-4.09	-1.01	0.327
Increase group on Day 6 (n = 18)	-1.81	-0.72	0.480
Decrease group on Day 5 (n = 18)	-5.12	-1.07	0.302
Decrease group on Day 6 (n = 20)	-1.00	-0.17	0.865

The increase group on Day 6 The SOLs of these 18 subjects changed insignificantly (Table 9.7). There were 38.9% (n = 7) of the subjects with their SOLs increased, 38.9% (n = 7) decreased and 22.2% (n = 4) unchanged. The *mean increase of SOL* was 12.48 minutes (SD = 7.19 minutes) with a range of increase between 2.33 and 22.83 minutes. The *mean decrease of SOL* was 7.83 minutes (SD = 4.86 minutes) with a range of decrease between 0.33 and 13.84 minutes.

The decrease group on Day 5 Similar to the increase groups, the SOLs of this group of subjects (n = 18) changed insignificantly (Table 9.7). There were 55.6% (n = 10) of the subjects with their SOLs increased, 38.9% (n = 7) decreased and 5.6% (n = 1) unchanged. The *mean increase of SOL* was 16.83 minutes (SD = 19.59 minutes) with a range of increase between 2.16

and 65.00 minutes. The *mean decrease of SOL* was 10.88 minutes (SD = 8.45 minutes) with a range of decrease between 0.16 and 21.66 minutes.

The decrease group on Day 6 For this group of subjects (n = 20), no significant change in their SOLs was observed (Table 9.7). There were 50.0% (n = 10) of the subjects with their SOLs increased, 45.0% (n = 9) decreased and 5.0% (n = 1) unchanged. The *mean increase of SOL* was 17.80 minutes (SD = 20.53 minutes) with a range of increased between 3.50 and 74.34 minutes. The *mean decrease of SOL* was 17.55 minutes (SD = 19.56 minutes) with a range of decrease between 0.16 and 66.16 minutes.

Sleep Onset Time (SOT)

The increase group on Day 5 When this group of subjects (n = 20) were examined for their SOTs, insignificant change in their SOTs was observed (Table 9.8). There were 35.0% (n = 7) of the subjects with their SOTs shifted backwards while 65.0% (n = 13) had shifted forwards. The *mean duration for SOT of backward shift* was 19.18 minutes (SD = 24.50 minutes) with a range of shift between 2.62 and 73.67 minutes. The *mean duration for SOT of forward shift* was 17.57 minutes (SD = 12.67 minutes) with a range of shift between 2.0 and 45.22 minutes.

Table 9.8 The results of paired-sample *t* test of the changes in sleep onset time after bright light exposure with respect to the 6-sulphatoxymelatonin level

	Paired Mean Differences (min)	*t*	*p*
Backward group on Day 5 (n = 20)	-4.70	-0.85	0.406
Backward group on Day 6 (n = 18)	-4.20	-0.67	0.512
Forward group on Day 5 (n = 18)	-6.57	-1.22	0.241
Forward group on Day 6 (n = 20)	-4.45	-1.02	0.322

The increase group on Day 6 The 18 subjects with their aMT6s levels increased on Day 6 had their SOTs changed insignificantly (Table 9.8). There were 50.0% (n = 9) of them with their SOTs shifted backwards while the remaining 50.0% (n = 9) showed a forward shift. The *mean duration for SOT of backward shift* was 25.55 minutes (SD = 20.4 minutes) with a range of shift between 5.32 and 61.67 minutes. The *mean duration for SOT of forward shift* was 17.13 minutes (SD = 8.02 minutes) with a range of shift between 3.50 and 29.48 minutes.

The decrease group on Day 5 Those subjects (n = 18) with their aMT6s levels decreased on Day 5 did not show a significant shift in their SOTs (Table 9.8). There were 55.6% (n = 10) of the subjects with their SOTs shifted backwards while 44.4% (n = 8) showed a forward shift. The *mean duration for SOT of backward shift* was 22.37 minutes (SD = 18.07 minutes) with a range of shift between 2.43 and 64.93 minutes. The *mean duration for SOT of forward shift* was 13.18 minutes (SD = 7.42 minutes) with a range of shift between 3.98 and 25.72 minutes.

The decrease group on Day 6 This group of subjects (n = 20) had demonstrated an insignificant shift in their SOTs (Table 9.8). 45.0% (n = 9) of the subjects showed a SOT backward shift while 55.0% (n = 11) showed a forward shift. The *mean duration for SOT of backward shift* was 12.32 minutes (SD = 5.98 minutes) with a range of shift between 2.43 and 18.60 minutes. The *mean duration for SOT of forward shift* was 18.18 minutes (SD = 15.57 minutes) with a range of shift between 2.78 and 57.22 minutes.

Wake After Sleep Onset (WASO)

Investigating WASO, the investigator focused on its frequency and duration of occurrence. For frequency, the number of waking after sleep onset (WASOf) was calculated. A consideration of the duration of occurrence included the duration of each waking after sleep onset (WASOd) and the total time of waking after sleep onset (WASOt).

The increase groups on Day 5 This group of subjects (n = 20) had their ***WASOf***s changed insignificantly (Table 9.9). There were 45.0% (n = 9) of subjects with WASOf increased, 45.0% (n = 9) decreased and 10.0% (n = 2) unchanged. The *mean increase of WASOf* was 5.11 times (SD = 3.52 times) with a range of increase between 2.00 and 13.00 times. The *mean decrease of WASOf* was 2.78 times (SD = 2.54 times) with a range of decrease between 1.00 and 8.00 times.

Table 9.9 The results of paired-sample *t* test of the changes in wake after sleep onset parameters after bright light exposure with respect to the increase groups of the 6-sulphatoxymelatonin level

	Paired Mean Differences	*t*	*p*
Day 2 - Day 5: WASOf (n = 20)	-1.05	-0.98	0.338
Day 2 - Day 5: WASOd (n = 20)	-1.03	-1.24	0.232
Day 2 - Day 5: WASOt (n = 20)	-2.75	-0.48	0.636
Day 2 - Day 6: WASOf (n = 18)	-2.61	-1.93	0.070
Day 2 - Day 6: WASOd (n = 18)	-1.34	-1.26	0.224
Day 2 - Day 6: WASOt (n = 18)	-10.06	-1.14	0.270

Note: WASOf – the number of waking after sleep onset
WASOd – the duration of each waking after sleep onset
WASOt – the total time of waking after sleep onset
Paired mean differences of WASOf was measured in times.
Paired mean differences of WASOd and WASOt were measured in minute.

When ***WASOd*** and ***WASOt*** were measured, the changes were found to be insignificant (Table 9.9). When ***WASOd*** was examined, there were 45.0% (n = 9) of the subjects with WASOd increased but 55.0% (n = 11) showed a decrease. The *mean increase of WASOd* was 1.96 minutes (SD = 1.07 minutes) with a range of increase between 0.40 and 3.72 minutes. The *mean decrease of WASOd* was 3.47 minutes (SD = 3.28 minutes) with a range of decrease between 0.14 and 10.61 minutes. For ***WASOt***, there were 55.0% (n = 11) of the subjects with their WASOts increased but 40.0% (n = 8) had theirs decreased and 5.0% (n = 1) showed no change. The *mean increase of WASOt* was 20.18 minutes (SD = 18.66 minutes) with a range of increase between 1.00 and 53.00 minutes. The *mean decrease of WASOt* was 20.88 minutes (SD = 12.53 minutes) with a range of decrease between 7.00 and 34.00 minutes.

The increase groups on Day 6 This group of subjects (n = 18) had their ***WASOf***s changed insignificantly (Table 9.9). There were 61.1% (n = 11) of the subjects with their WASOfs increased, 27.8% (n = 5) decreased and 11.1% (n = 2) unchanged. The *mean increase of WASOf* was 6.09 times (SD = 3.78 times) with a range of increase between 2.00 and 12.00 times. For the *mean decrease of WASOf*, it was 4.00 times (SD = 3.54 times) with a range of decrease between 1.00 and 10.00 times.

When ***WASOd*** and ***WASOt*** were studied, the changes were insignificant after bright light exposure (Table 9.9). For ***WASOd***, there were 44.4% (n = 8) of the subjects with their WASOds increased but 55.6% (n = 10) had theirs decreased. The *mean increase of WASOd* was 2.42 minutes (SD = 2.95 minutes) with a range of increase between 0.03 and 8.84 minutes. The *mean decrease of WASOd* was 4.35 minutes (SD = 2.99 minutes) with a range of decrease between 1.43 and 12.03 minutes. For ***WASOt***, there were 61.1% (n = 11) of the subjects with their WASOts increased but 38.9% (n = 7) had theirs decreased. The *mean increase of WASOt* was 33.00 minutes (SD = 26.06 minutes) with a range of increase between 2.00 and 82.00 minutes. The *mean decrease of WASOt* was 26.00 minutes (SD = 18.59 minutes) with a range of decrease between 2.00 and 56.00 minutes.

The decrease groups on Day 5 Among these 18 subjects, ***WASOf*** changed insignificantly (Table 9.10). There were 44.4% (n = 8) of the subjects with

WASOf increased. 38.9% (n = 7) decreased and 16.7% (n = 3) unchanged. The *mean increase of WASOf* was 2.75 times (SD = 1.67 times) with a range of increase between 1.00 and 6.00 times. The *mean decrease of WASOf* was 4.43 times (SD = 2.99 times) with a range of decrease between 1.00 and 10.00 times.

Table 9.10 The results of paired-sample *t* test of the changes in wake after sleep onset parameters after bright light exposure with respect to the decrease groups of the 6-sulphatoxymelatonin level

	Paired Mean Differences	*t*	*p*
Day 2 - Day 5: WASOf (n = 18)	-0.50	-0.54	0.599
Day 2 - Day 5: WASOd (n = 18)	-2.61	-1.37	0.188
Day 2 - Day 5: WASOt (n = 18)	-13.94	-1.35	0.196
Day 2 - Day 6: WASOf (n = 20)	-2.10	-1.39	0.181
Day 2 - Day 6: WASOd (n = 20)	-2.28	-1.25	0.226
Day 2 - Day 6: WASOt (n = 20)	-1.20	-0.11	0.914

Note: WASOf – the number of waking after sleep onset
WASOd – the duration of each waking after sleep onset
WASOt – the total time of waking after sleep onset
Paired mean differences of WASOf was measured in times.
Paired mean differences of WASOd and WASOt were measured in minute.

When ***WASOd*** and ***WASOt*** were considered. the changes were insignificant after bright light exposure (Table 9.10). There were half (n = 9) of the subjects with ***WASOd*** increased while the remaining half had theirs decreased. The *mean increase of WASOd* was 1.97 minutes (SD = 1.48 minutes) with a range of increase between 0.17 and 4.01 minutes. The *mean decrease of WASOd* was 7.20 minutes (SD = 9.46 minutes) with a range of decrease between 0.44 and 30.66 minutes. For ***WASOt***. there were 33.3% (n = 6) of the subjects with the WASOt increased but 66.7% (n = 12) showed a decrease. The *mean increase of WASOt* was 30.33 minutes (SD =

25.12 minutes) with a range of increase between 2.00 and 71.00 minutes. The *mean decrease of WASOt* was 36.08 minutes (SD = 33.17 minutes) with a range of decrease between 12.00 and 110.00 minutes.

The decrease groups on Day 6 These 20 subjects had WASOf changed insignificantly (Table 9.10). There were 60.0% (n = 12) of the subjects with their WASOfs increased while 40.0% (n = 8) had theirs decreased. The *mean increase of WASOf* was 6.50 times (SD = 4.80 times) with a range of increase between 1.00 and 20.00 times. The *mean decrease of WASOf* was 4.50 times (SD = 2.27 times) with a range of decrease between 1.00 and 9.00 times.

As with WASOf, both ***WASOd*** and ***WASOt*** changed insignificantly (Table 9.10). In the case of the ***WASOd***, there were 55.0% (n = 11) of the subjects with WASOd increased but 45.0% (n = 9) decreased. The *mean increase of WASOd* was 2.05 minutes (SD = 2.56 minutes) with a range of increase between 0.02 and 7.89 minutes. The *mean decrease of WASOd* was 7.56 minutes (SD = 9.58 minutes) with a range of decrease between 0.50 and 32.19 minutes. For ***WASOt***, there were 45.0% (n = 9) of the subjects with WASOt increased but 55.0% (n = 11) decreased. The *mean increase of WASOt* was 39.67 minutes (SD = 37.49 minutes) with a range of increase between 4.00 and 107.00 minutes. The *mean decrease of WASOt* was 34.64

minutes (SD = 26.44 minutes) with a range of decrease between 8.00 and 91.00 minutes.

Sleep Offset Time (SoffT)

The increase group on Day 5 This group of subjects (n = 20) did not have a significant shift in their SoffTs (Table 9.11). There were 65.0% (n = 13) of the subjects with SoffT shifted backwards but 35.0% (n = 7) shifted forwards. The *mean duration for SoffT of backward shift* was 32.32 minutes (SD = 30.97 minutes) with a range of shift between 1.68 and 111.50 minutes. The *mean duration for SoffT of forward shift* was 22.17 minutes (SD = 12.25 minutes) with a range of shift between 0.93 and 38.18 minutes.

Table 9.11 The results of paired-sample *t* test of the changes in sleep offset time after bright light exposure with respect to the 6-sulphatoxymelatonin level

	Paired Mean Differences (min)	*t*	*p*
Increase group on Day 5 (n = 20)	-13.23	-1.60	0.125
Increase group on Day 6 (n = 18)	-8.33	-0.84	0.414
Decrease group on Day 5 (n = 18)	-2.97	-0.32	0.751
Decrease group on Day 6 (n = 20)	-3.90	-0.38	0.711

The increase group on Day 6 Similar to Day 5, there was no significant shift in SoffTs of these 18 subjects (Table 9.11). There were 44.4% (n = 8) of the subjects with SoffT shifted backwards and 55.6% (n = 10) shifted forwards. The *mean duration for SoffT of backward shift* was 26.43 minutes (SD = 16.32 minutes) with a range of shift between 4.67 and 43.50

minutes. The *mean duration for SoffT of forward shift* was 36.17 minutes (SD = 34.97 minutes) with a range of shift between 1.20 and 108.35 minutes.

The decrease group on Day 5 In this group of subjects (n = 18), their SoffTs showed no significant shift (Table 9.11). Half (n = 9) of the subjects with SoffT shifted backwards while the remaining half had forward shift. The *mean duration for SoffT of backward shift* was 26.15 minutes (SD = 24.17 minutes) with a range of shift between 4.30 and 73.27 minutes. The *mean duration for SoffT of forward shift* was 32.08 minutes (SD = 27.42 minutes) with a range of shift between 1.35 and 80.92 minutes.

The decrease group on Day 6 This group of subjects (n = 20) had their SoffTs shifted insignificantly (Table 9.11). There were 55.0% (n = 11) of the subjects with SoffT shifted backwards while 45.0% (n = 9) had forward shift. The *mean duration for SoffT of backward shift* was 34.72 minutes (SD = 31.92 minutes) with a range of shift between 0.28 and 101.57 minutes. The *mean duration for SoffT of forward shift* was 33.75 minutes (SD = 30.58 minutes) with a range of shift between 0.93 and 102.75 minutes.

As a conclusion, the second alternative hypothesis in the Chapter 1 was rejected.

Summary

In the Light On Period, the 6-sulphatoxymelatonin (aMT6s) levels changed insignificantly in the bright light exposure stage. The findings on Day 3 illustrated that there were more subjects with their aMT6s levels decreased than increased when the levels were compared with that on Day 2. The same phenomenon was applied to Days 3 and 4. There were more subjects with their aMT6s levels decreased than increased on Day 4 as compared with that on Day 3. As revealed by the mean aMT6s level, the mean aMT6s level on Day 3 was lower than that on Day 2 but was higher than that on Day 4.

In the Light Off Period, no significant change in the aMT6s level was detected in the post-bright light exposure stage (Days 5 and 6). The changes in the aMT6s levels were diverse in the post-bright light exposure stage. Regardless of the change in the aMT6s level, the subjects mainly had their sleep satisfaction levels (SSLs) increased after bright light exposure. When the corresponding actigraphic sleep-wake parameters were studied, their changes were also statistically insignificant. No clear trend of changes in these sleep-wake parameters could be determined. In brief, the first, second and fourth hypotheses were rejected.

Integrating the results from Chapters 6 to 9, the investigator will try to link the relevant information so that the relationships between bright light, sleep and

melatonin may be identified. The organized material will be discussed in the Chapter 10.

Chapter 10

Summary of the Findings and Discussion

In this chapter, the main results are summarized according to the research questions cited in Chapter 1. Concluding from the findings, the investigator has attempted to explain the changes and evaluate the relationships between bright light, sleep-wake parameters and mean 6-sulphatoxymelatonin (aMT6s) level.

Summary of the findings

The major focus of this research was to identify the relationships between sleep, bright light and melatonin. In the case of sleep, its quality was determined by actigraphic sleep-wake parameters and sleep satisfaction level while the monitoring of melatonin depended on the mean aMT6s level. Quasi-experimental design and intra-subject control methods were employed to examine the ways in which bright white light acted as the experimental variable. Apart from the investigation of relationships, the characteristics of the subjects were also the investigator's concern.

The main findings of the experiment were integrated in relation to the two main aspects of the research questions. The two aspects are first the characteristics of the subjects. Second, the effects of bright light exposure on the subjects which included the changes in sleep satisfaction level, actigraphic sleep-wake parameters and aMT6s level.

The characteristics of the subjects

Sleep complaints

1. Difficulty in initiating sleep (DIS) (50.0%, n = 19), difficulty in maintaining sleep (DMS) (57.9%, n = 22) and early morning awakening (EMA) (36.8%, n = 14) were the common sleep complaints among the subjects (N = 38).
2. According to the subjective reporting, the mean sleep onset latency (SOL) of the DIS sufferers (152.50 minutes with a standard deviation of ± 90.33 minutes) was much longer than the mean SOL of the non-sufferers (66.00 minutes with a standard deviation of ± 62.57 minutes) even though their mean bedtimes were about the same (08:30 PM for the sufferers; 08:38 PM for the non-sufferers).
3. DMS was the most common sleep complaint among the subjects. In terms of DMS sufferers (n = 22), nearly half of them (45.5%, n = 10) woke up for a long period of time at night. In addition, their sleep was

more fragmented than the sleep of the non-sufferers (3.14 times with a standard deviation of ± 1.21 times versus 1.81 times with a standard deviation of ± 1.11 times). Among the cited reasons for waking at night (n = 37), nocturia (64.9%, n = 24) was claimed to be a major reason for waking. Micturition was reported as the main activity (80.0%, n = 32) after waking at night. However, nocturia was not found to be an aggravating factor in their sleep disturbance. One third of the subjects (34.2%, n = 13) said that nothing had worsened their sleep disturbances.

4. 92.9% of the EMA sufferers (n = 13) reported their sleep qualities as bad or very bad. However, no prominent differences between EMA sufferers and the non-sufferers in both their mean sleep offset times (SoffTs) (05:28 AM with a standard deviation of ± 311 minutes for the sufferers: 05:17 AM with a standard deviation of ± 52 minutes for the non-sufferers) and their mean rising times (05:34 AM for the sufferers: 05:57 AM for the non-sufferers) were identified. A large range in the SoffT (from 11:00 PM to 06:35 AM in the sufferers: from 03:30 AM to 06:45 AM in the non-sufferers) existed regardless of the presence of EMA. All the EMA sufferers except one were satisfied with their refreshment levels when getting out of bed.

Sleep-wake pattern

1. Napping was divided into intentional and unintentional naps. Few subjects (23.7%, n = 9) had the habit of intentional napping. Most of them (77.8%, n = 7) claimed tiredness as the main reason for napping but only two could fall asleep during the attempted nap. Unlike intentional napping, there were 42.1% of the subjects (n = 16) not able to resist unintentional napping. For both intentional and unintentional naps, the afternoon was the most popular time for napping. Napping was not significantly correlated with self-rated sleep quality (Intentional napping: r = 0.15, p = 0.380; unintentional napping: r = -0.26, p = 0.111). However, napping might be a way to relieve sleep disturbance for those claiming their sleep as bad or very bad as indicated by the reported habit of intentional (21.7%, n = 5) and unintentional (52.2%, n = 12) naps.
2. As shown by the actigraphic data, sleep was fragmented and the total time of waking after sleep onset (WASOt) was long in the subjects. When the subjects were classified into good sleepers or poor sleepers, there was no great difference between these two groups. The magnitudes of their sleep-wake parameters were alike. However, the sleep in the poor sleepers was more fragmented than the sleep in the good ones.

3. About one third of the subjects consumed caffeine-containing products (31.6%, n = 12) or dairy products (34.2%, n = 13) habitually. Chinese tea was the main caffeine-containing product consumed by the subjects (64.3%, n = 9). 30.4% of the poor sleepers (n = 7) consuming caffeinated food habitually. When the usual consumption of dairy products was considered, 46.7% good sleepers (n = 7) and 26.1% poor sleepers (n = 6) had this habit. For exercise and sunlight exposure, more than 60% of the subjects did the former (78.9%, n = 30) or had the latter (60.5%, n = 23) habitually. Among those doing exercise habitually, there were 86.7% good sleepers (n = 13) and 73.9% poor sleepers (n = 17) while for those exposed to sunlight, 53.3% were good sleepers (n = 8) and 65.2% were poor sleepers (n = 15). Morning was the most common time and 30 minutes was the most common duration for the subjects involved in these activities. Sleep quality was not significantly correlated with caffeine-containing products, dairy products, doing exercise or sunlight exposure.

4. The correlations of total bed time (TBT), total time of waking after sleep onset (WASOt) and sleep offset time (SoffT) between the sleep log and the actigraphic recording were well correlated (details refer to Chapter 6). The discrepancies in sleep efficiency (SE), sleep onset time (SOT) and WASOt between these two sets of data were insignificant. Except sleep onset latency (SOL), the sleep log tended to be underestimated as compared with the actigraphic recording

Sleep satisfaction level, SSL

60.5% of subjects (n = 23) considered their sleep as bad or very bad (poor sleepers) while the remaining (39.5%, n = 15) rated their sleep satisfaction level as very good, good or acceptable (good sleepers). The desirable duration for sleeping were 5.15 hours (SD = 1.16 hours) for good sleepers and 5.12 hours (SD = 1.36 hours) for the poor ones. No association between self-rated health status and sleep satisfaction level was identified.

The mean 6-sulphatoxymelatonin, aMT6s, level

When the subjects were classified as good or poor sleepers, their mean aMT6s levels were 15.36 pmol/ml (SEM = 2.63 pmol/ml) for good sleepers and 14.80 pmol/ml (SEM = 3.03 pmol/ml) for poor sleepers. The correlation coefficient of mean aMT6s level between Day 1 and Day 2, it was 0.644 (p = 0.000). There was no significant change (p = 0.556) in the level within these two days.

<u>The effects of bright light exposure on the subjects: The changes in sleep satisfaction level (SSL)</u>

1. Improvement in sleep quality after bright light exposure was illustrated (mean of sleep quality = 2.61 on Day 2; 2.50 on Day 5; 2.34 on Day 6)

Subjects found better sleep quality after bright light exposure (p = 0.631 on Day 5: 0.069 on Day 6). Apart from the unchanged group, there were more subjects with SSL increased (34.2%, n = 13 on Day 5: 28.9%, n = 11 on Day 6) than decreased (26.3%, n = 10 on Day 5: 13.2%, n = 5 on Day 6). The first alternative hypothesis in the Chapter 1 was rejected.

2. The changes in SSL were not significantly correlated with the alternations in the corresponding mean aMT6s levels (r = -0.03, p = 0.867 on Day 5: r = -0.14, p = 0.406 on Day 6). No prominent changes in the mean levels were observed. The fourth alternative hypothesis was rejected.

3. SSL was significantly associated with some sleep-wake parameters on Day 5. The parameters, SE (r = 0.42, p = 0.008), SWR (r = 0.42, p = 0.008), and TST (r = 0.63, p = 0.000) were positively correlated with SSL while SOT (r = -0.37, p = 0.021) and WASOt (r = -0.58, p = 0.000) were negatively associated with SSL. The third alternative hypothesis was supported when the sleep-wake parameters were considered individually.

4. When subjects had their SSLs increased on Day 5, more than 70% of the subjects had their SEs, SWRs and TSTs increased but WASOts decreased. Their SOTs mainly shifted forwards. In terms of those with their SSLs increased on Day 6, diverse alterations were observed.

5. In the case of subjects with a SSL decrease, most of them presented a decrease in SE (80.0%, n = 8 on Day 5; 80.0%, n = 4 on Day 6), SWR (80.0%, n = 8 on Day 5; 80.0%, n = 4 on Day 6) and TST (90.0%, n = 9 on Day 5; 80.0%, n = 4 on Day 6) but an increase in WASOt (90.0%, n = 9 on Day 5; 80.0%, n = 4 on Day 6). Their SOTs mainly shifted backwards on Day 5 (60.0%, n = 6) but forwards on Day 6 (80.0%, n = 4).

The effects of bright light exposure on the subjects: The changes in actigraphic sleep-wake parameters

1. After bright light exposure, there were more subjects who had their sleep efficiencies (SEs) and sleep-wake ratios (SWRs) increased (60.5%, n = 23 on Day 5; 55.3%, n = 21 for SE and 52.6%, n = 20 for SWR on Day 6) than decreased (39.5%, n = 15 on Day 5; 44.7%, n = 17 on Day 6). The changes in the SE and the SWR were insignificant as were the changes in their related aMT6s levels. A detailed description can be found in Chapter 8. However, the subjects with their SEs and SWRs increased on Day 5, found better quality of sleep as compared with that on Day 2 (mean of sleep quality = 2.78 on Day 2; 2.26 on Day 5; $p = 0.017$). Ten (43.5%) of them had their quality of sleep improved.
2. The change in the total sleep time (TST) in the post-bright light exposure stage was mainly increase (60.5%, n = 23) on Day 5. There

was no significant change in the TST after bright light exposure. The related aMT6s levels also did not demonstrate a prominent alteration. A detailed description can be found in Chapter 8. When the subjects had their TSTs increased in the post-bright light exposure stage, they reported a better sleep as compared with the pre-bright light exposure stage (mean of sleep quality = 2.78 on Day 2; 2.13, $p = 0.003$ on Day 5; mean of sleep quality = 2.58 on Day 2; 2.11, $p = 0.047$ on Day 6). Over 30% of these subjects had their sleep quality improved after bright light exposure. On Day 5, poorer sleep was observed in those with their TSTs decreased (mean of sleep quality = 2.33 on Day 2; 3.07 on Day 5; $p = 0.013$). There were 60.0% (n = 9) having their SSLs decreased on Day 5. Those with their TSTs decreased after bright light exposure, tended to have a longer history of sleep disturbance (more than 9 years for decrease groups; less than 8 years for increase groups) and over 70% of them claimed their sleep quality as bad or very bad sleep before the light exposure.

3. There were more subjects with their total bed times (TBTs) decreased (55.3%, n = 21) than increased (44.7%, n = 17) on Day 5 while half of them (n = 19) reported a reduction and the other half claimed to have their TBTs increased on Day 6. No significant change in the TBT, after bright light exposure, was observed. The same situation was also observed in the related aMT6s levels. A detailed description can be found in Chapter 8. However, for the subjects with their TBTs

increased on Day 6, they found better quality of sleep as compared with that on Day 2 (mean of sleep quality = 2.63 on Day 2; 2.11 on Day 6; p = 0.039). Eight subjects (42.1%) subjects had their quality of sleep improved. When the correlated TSTs were investigated, the increase groups tended to have their TSTs increased (70.6%, n = 12 on Day 5; 68.4%, n = 13 on Day 6) though the associated SEs did not display a clear trend of alteration.

4. The number of subjects with their sleep onset latencies (SOLs) increased (47.4%, n = 18 on Day 5; 44.7%, n = 17 on Day 6) was relatively higher than those who showed a decrease (44.7%, n = 17 on Day 5; 42.1%, n = 16 on Day 6). There was no significant change in SOL after bright light exposure. No prominent changes in the related aMT6s levels and sleep satisfaction levels (SSLs) were found. A detailed description can be found in Chapter 8. The subjects with their SOLs increased was characterized with longer period of sleep disturbance (about 9.5 years) as compared with the decrease groups (6 to about 9 years). In addition, more than 60% of them complained of difficulty in initiating sleep.

5. Over 50% of the subjects tended to show sleep onset time (SOT) forward shift (55.3%, n = 21 on Day 5; 52.6%, n = 20 on Day 6). SOT changed insignificantly after bright light exposure. Similar to other parameters, no prominent alterations in the related aMT6s levels and SSLs were observed. A detailed description can be found in Chapter 8

The shift in SOT was not significantly correlated with the shift in sleep offset time (SoffT) (r = 0.02, p = 0.922 on Day 5; r = -0.03, p = 0.873 on Day 6).

6. There were more subjects showing a 'number of waking after sleep onset' (WASOf) increase (44.7%, n = 17 on Day 5; 60.5%, n = 23 on Day 6) than a decrease (42.1%, n = 16 on Day 5; 34.2%, n = 13 on Day 6) or no change (13.2%, n = 5 on Day 5; 5.3%, n = 2 on Day 6). More than half of the subjects on Day 5 had both the 'duration of each waking after sleep onset' (WASOd) (52.6%, n = 20) and the 'total time of waking after sleep onset' (WASOt) (52.6%, n = 20) shortened. The changes on Day 6, however, were undetermined for WASOd and tended to increase in WASOt (52.6%, n = 20). WASOf was negatively correlated with WASOd (r = -0.42, p = 0.008 on Day 5; r = -0.23, p = 0.175 on Day 6) but positively correlated with WASOt (r = 0.29, p = 0.079 on Day 5; r = 0.49, p = 0.002 on Day 6). Except for the change in the WASOf on Day 6, all the 'wake after sleep onset' (WASO) parameters changed insignificantly after bright light exposure. There were no significant changes in the related aMT6s levels. A detailed description can be found in Chapter 8. On Day 5, there was a significant change in their quality of sleep after bright light exposure. For those with a WASOt increase, 52.9% (n = 9) had their SSLs decreased (mean of sleep quality = 2.29 on Day 2; 2.88 on Day 5; p = 0.026). For those with a WASOt decrease, there were 55.0% (n = 11)

subjects having their SSLs increased (mean of sleep quality = 2.90 on Day 2: 2.20 on Day 5: p = 0.005). Actigraphic WASOfs were inconsistent with WASOfs from the sleep log in which the subjects tended to report their WASOfs as unchanged (39.5%, n = 15 on Day 5: 44.7%, n = 17 on Day 6) or decreased (42.1%, n = 16 on Day 5: 31.6%, n = 12 on Day 6) in the post-bright light stage. Although the actigraphic recording illustrated an increase in the WASOf, most of the subjects did not report an increase in their WASOfs.

7. The change in the sleep offset time (SoffT) was not significant. No dominant trend of changes could be observed. When the correlated changes in their mean aMT6s levels and SSLs in relation to the shift of SoffT were examined, there were no significant alterations detected. A detailed description can be found in Chapter 8. As mentioned in point 5, the shift in the SoffT was not significantly associated with the shift in the SOT.

8. As a conclusion, the first and third alternative hypotheses in the Chapter 1 were supported. The second hypothesis was rejected when sleep-wake parameters were considered individually.

The effects of bright light exposure on the subjects: The changes in the mean 6-sulphatoxymelatonin (aMT6s) level

1. In the Light On Period (from 1800 hours to bedtime), the aMT6s levels changed insignificantly. A detailed description can be found in Chapter 9. The first alternative hypothesis in the Chapter 1 was rejected. The findings illustrated that there were more subjects with their aMT6s levels decreased (60.0%, n = 18) than increased (40.0%, n = 12) when the levels on Day 3 were compared with that on Day 2. The same phenomenon applied to Days 3 and 4. There were more subjects with their aMT6s levels decreased (60.0%, n = 18) than increased (40.0%, n = 12) when the level on Day 4 was compared with that on Day 3. As revealed by the mean aMT6s level, the mean level on Day 3 was lower than that on Day 2 (paired difference mean [Day 2 – Day 3]: 0.09 pmol/ml) and the mean level on Day 4 was lower than that on Day 3 (paired difference mean [Day 3 – Day 4]: 0.46 pmol/ml).
2. For the Light Off Period (from bedtime to rising time), no significant change in the mean aMT6s level was detected in the post-bright light exposure stage. A detailed description can be found in Chapter 9. No clear trend of change was observed. The first alternative hypothesis was rejected. Regardless of the insignificant correlation with the change in the aMT6s level ($r = -0.03$, $p = 0.867$ on Day 5; $r = -0.14$, $p = 0.406$ on Day 6), the subjects tended to have their sleep satisfaction

levels (SSLs) either increased or unchanged though the trend was not significant. Thus, the fourth hypothesis was rejected.

3. When the corresponding actigraphic sleep-wake parameters were studied, their changes were also statistically insignificant. No clear trend of changes in these sleep-wake parameters could be determined. The second hypothesis was rejected.

Discussion

Subjects would react differently to the bright light because of their different physical and sleep conditions. It was essential to investigate their characteristics. An examination of their characteristics was based on their sleep complaints, sleep-wake patterns, sleep satisfaction levels (SSL) and mean 6-sulphatoxymelatonin (aMT6s) levels. In the case of the experimental results, the light-induced effects on the subjects were measured in accordance with the changes in their SSLs, sleep-wake parameters and mean aMT6s levels. Finally, the limitations of this study will be discussed.

The characteristics of the subjects

Concurrence was found with the findings of the previous studies (Nakra, Grossberg and Peck, 1991; Gislason, Reynisdóttir, Kristbjarnarson and Benediktsdóttir, 1993), difficulty in initiating sleep (DIS), difficulty in maintaining sleep (DMS) and early morning awakening (EMA) were the common **sleep complaints** among the subjects.

Difficulty in initiating sleep (DIS)

DIS sufferers were characterized by long sleep onset latency (SOL). Melatonin level and living routines are suggested to be related to the long SOL. As reported by the DIS sufferers, their mean SOL was an hour longer than that of the non-sufferers even though their mean bedtime was just a few minutes earlier. Nevertheless, the mean SOL of the non-sufferers was not of short duration (66 minutes with mode as 60 minutes). In brief, the SOL of the subjects was long and it was much longer in the DIS sufferers. It is proposed that the long duration of SOL in the subjects may be associated with their melatonin levels and their daily routines. Since the melatonin level is lower in elderly people (Iguchi, Kato and Ibayashi, 1982; L'Hermite-Baleriaux, et al., 1989) and the intake of exogenous melatonin decreases SOL in elderly people with insomnia (Wurtman and Zhdanova, 1995), the long duration of SOL may be related to the low level of

melatonin. Apart from the melatonin level, daily routine may also be a critical factor in determining the duration of SOL. Some subjects reported that they would like to have a later bedtime so that they could fall asleep within a short period of time. In many elderly care homes, lights and television are turned off at 2200 hours. Residents are asked to go to bed around this time. It is difficult for them to sleep at their favoured time when their bedtime is different. As a result, the subjects either go to bed earlier than their preferred bedtime or maintain their activities in the bedroom while others are sleeping. When the subjects are disrupted, they tend to complain of DIS. On the other hand, when residents continue their activities after 2200 hours, quarrels may occur. To manage a large group of people, who are living together, the formulation of routines can facilitate their management. When setting routines for their residents, elderly care staff should understand their residents' needs. A simple assessment of sleep conditions, such as their usual bedtime, is recommended before the residents move in the elderly care home because the elderly care staff can use this information when allocating rooms. Such arrangements can minimize arguments associated with sleep disturbance. Quarrels are cultivated by many factors. There is no perfect method to deal with all the factors but we can make every effort to prevent quarrels occurring.

Difficulty in maintaining sleep (DMS)

DMS was identified to be the most common sleep complaint among the subjects (Gislason, Reynisdóttir, Kristbjarnarson and Benediktsdóttir, 1993). The sufferers were characterized with fragmented sleep and long waking at night. Nearly 50% of the DMS sufferers showed that the duration of each waking after sleep onset (WASOd) lasting for a long time. About two thirds of the cited reasons for waking at night were nocturia. Among the 40 reports of activities after waking at night, 80.0% were related to micturition. Interestingly, nocturia was not considered as an aggravating factor in sleep disturbance. One third of the subjects claimed that nothing made their sleep disturbance worse. According to Kirkland, Lye, Levy and Banerjee (1983), the excreted urine volume in elderly people during sleep (869 ml) was more than the volume when awake (783 ml). For young adults, the excreted urine volume during sleep (402 ml) was one third of the volume when awake (1209 ml). Since elderly people had a larger volume of urine excretion during sleep, they woke up more frequently at night. However, the subjects did not identify nocturia as an aggravating factor in their sleep disturbance. This may be because the subjects have accepted frequent micturition at night or there are some factors more prominent than nocturia in affecting their sleep.

Early morning awakening (EMA)

Instead of falling asleep again after waking at night. EMA sufferers could not return to sleep. They remained alert even though both the environment and timing were favourable for continuing sleep (Zammit. 1997). In this study. more than 90% of the EMA sufferers were not satisfied with their quality of sleep. To further investigate the dissatisfaction. the sleep offset time (SoffT). the rising time and the refreshment level of the subjects were studied. Reviewing the mean SoffT and the mean rising time. the investigator found that there were no prominent differences between the sufferers and the non-sufferers. Their SoffTs were in a great range (from 11:00 PM to 06:35 AM in the sufferers; from 03:30 AM to 06:45 AM in the non-sufferers). In terms of the refreshment level when getting out of bed. all the EMA sufferers except one content with their refreshment levels. Concluding the above observations. the investigator observed that there was no great difference between the EMA sufferers and the non-sufferers with reference to their SoffTs. rising times and refreshment levels. To clarify the dissatisfaction with the sleep quality. a more in-depth study is needed.

The **sleep-wake pattern** of the subjects was discussed in accordance with their napping. sleep-wake parameters and sleep-related factors. Before these three areas of the sleep-wake pattern are discussed. the characteristics of different kinds of sleepers should be described. Subjects who considered

their sleep as bad or very bad, were nominated as poor sleepers; whilst all others were classified as good sleepers. Since the description of the sleep-wake parameters was based on the actigraphic recording, the correlation between sleep log and actigraphic recording was evaluated. In addition, the first-night effect on aMT6s level will also be discussed.

Napping

Few subjects (23.7%, n = 9) had the habit of intentional napping but many (42.1%, n = 16) could not resist unintentional napping. Some subjects believed that intentional napping might worsen their sleep at night so that they were reluctant to go to bed other than at bedtime unless they felt tired. Tiredness was their main reason for intentional napping. To resist a nap, subjects kept themselves occupied with some activities, especially in the afternoon as this was the most common time for both intentional and unintentional naps. Another reason that the subjects did not welcome an intentional nap might be related to its limited effect on them. Since only two out of nine subjects with intentional napping habitually fell asleep, they might hesitate to spend time in bed. Intentional napping was not common in the subjects. Napping was insignificantly correlated with self-rated sleep quality. The importance of napping could not be denied as many subjects dozed habitually, particularly the poor sleepers. The findings showed that 52.2% of poor sleepers reported dozing regularly. As it was suggested that a

short nap might relieve the short-term effects of sleep deprivation and increase the refreshment effect (Ferrer, Bisson and French, 1995; Reiter and Robinson, 1995), a nap might play a role in sleep regulation. To gain the benefits of a nap, further understanding of the occurrence of both intentional and unintentional naps is needed.

Sleep-wake parameters

The actigraphic findings illustrated that sleep in the subjects was fragmented and the subjects awoke for a long time at night. This situation is frequently reported by elderly people (Orr, Altshuler and Stahl, 1982) and this may be related to a decrease in the arousal threshold (Swift and Shapiro, 1993). In addition, melatonin level may also be a contributing factor as the intake of exogenous melatonin has been found to decrease the number of waking at night in elderly people with insomnia (Wurtman and Zhdanova, 1995). When the subjects were grouped into good or poor sleepers, there was no great difference in the magnitude of their sleep-wake parameters except sleep in the poor sleepers was more fragmented at night than sleep in the good sleepers. Therefore, some subjects reported sleep quality of acceptable or above but they were still seeking improvement in sleep.

With respect to the similarity in the sleep-wake parameters and the more fragmented sleep in the poor sleepers, it is worth considering whether the

continuity of sleep is the determining factor for sleep satisfaction. Slow-wave sleep. SWS. (depth of sleep) and sleep efficiency. SE. (continuity of sleep) were suggested as ways of defining sleep quality (Keklund and Åkerstedt. 1997). The observation of SE includes all the sleep-wake parameters. The sleep onset latency (SOL) (Coates. et al.. 1982: Riedel and Lichstein. 1998) and the total time of waking after sleep onset (WASOt) (Coates. et al.. 1982) were suggested as major indices of sleep satisfaction. Examining the current actigraphic SOL of the subjects. the investigator found that there was no appreciable difference in the mean SOL of the good sleepers and the poor sleepers. These two groups of sleepers could fall asleep within 20 minutes. Therefore. the role of SOL in determining sleep satisfaction was not clearly shown in this study. In view of more fragmented sleep in the poor sleepers and WASOt is one of the indices of sleep satisfaction. the investigator found WASO parameters as the crucial index for sleep satisfaction.

Sleep-related factors

Because they were consumed regularly by about one third of the subjects. caffeine-containing products and dairy products were considered because of their sleep inhibiting or inducing properties. Since doing exercise and exposure to sunlight might also influence sleep. their effects on the subjects were also considered. Caffeine. being a central nervous system stimulant.

can disturb the sleep cycle (Ferrer, Bisson and French, 1995). It was understandable that the consumption rate of caffeine (31.6%, n = 12) was not high in the subjects. To alleviate sleep disturbance, some subjects purposefully replaced tea with boiled water. In the case of the poor sleepers (n = 23), only seven of them (30.4%) consumed caffeinated food regularly. Lugaresi and associates (1983) said that some poor sleepers hoped that the reduction in coffee consumption would prevent further sleep disruption. Chinese tea was the main caffeine-containing product consumed by the subjects. It is common for Chinese people, particularly elderly people, to consume Chinese tea. As tea is characterized by its diuretic and stimulant properties (Morgan, Healey and Healey, 1989) and caffeine clearance possibly falls with age (Curless, French, James and Wynne, 1993), it is easy to suggest that poor sleepers have the same problems.

As opposed to caffeine-containing products, dairy products, are rich in tryptophan (Reiter and Robinson, 1995), and are believed to be good sleep-inducing agents (Hauri and Linde, 1990). Nonetheless, the consumption rate of dairy products (34.2%, n = 13) was not high in the subjects. As claimed by the subjects, they believed that diarrhoea might occur after the intake of dairy products. Among the good sleepers (n = 15), 46.7% of them (n = 7) consumed dairy products regularly. In the case of the poor sleepers (n = 23), 26.1% of them (n = 6) had this habit. The consumption rate in the good sleepers was higher than that in the poor sleepers even though there

was no significant correlation between consumption of dairy products and sleep quality.

Unlike caffeine-containing products and dairy products, exercise (78.9%, n = 30) and sunlight exposure (60.5%, n = 23) were popular with the subjects. 86.7% (n = 13) good sleepers and 73.9% (n = 17) poor sleepers were doing exercise regularly. In the case of exposure to sunlight, 53.3% (n = 8) of good sleepers and 65.2% (n = 15) of poor sleepers reported this habit. Morning was the most favourable time and 30 minutes was the most common duration for subjects to do exercise and go outdoors. Both doing exercise and sunlight exposure were not well correlated with sleep quality, but it was proposed that regular exercise (Orr, Altshuler and Stahl, 1982) and light (Duffy, Kronauer and Czeisler, 1996) could facilitate sleep. A group of elderly people claimed that a one-hour walk could improve their perceived sleep quality (Bevier, Bliwise, Bliwise, Bunnell and Horvath, 1992). It has been reported that sleep quality can be improved after bright light exposure (Cooke, Kreydatus, Atherton and Thoman, 1998). Apart from regulating sleep, elderly people can gather together and establish a social network by doing exercise or going outdoors to have sunlight exposure. Since elderly people can gain such benefit, health workers may arrange more of these outdoor activities. Half an hour is suggested to be the optimum duration. Elderly people are recommended to do exercise and go

outside to enjoy sunlight regularly. The examination of the sleep-related factors in this study was so limited that further clarification was needed.

The correlation between the sleep log and the actigraphic recording

Both sleep log and wrist actigraph could record one's sleep quantity. However, only three sleep-wake parameters (TBT, WASOt and SoffT) between these two sets of data were well correlated. Different from polysomnography (PSG) and actigraphy, sleep log can detect any perceptual or cognitive distortions related to the disorders (Bootzin and Engle-Friedman, 1981). Such detection is crucial in the determining sleep quantity and has made sleep log superior to PSG and actigraphy. Wrist actigraph is used in sleep studies for motility measurement in which wrist movements are used as indicators of sleep (Closs, 1988). Thus, actigraphic data are just the estimations of sleep (Cohen-Mansfield, Waldhorn, Werner and Billig, 1990). The sleep quantity illustrated by the actigraphic recording is not identical to the measurements of other instruments. Measuring different dimensions of sleep, sleep log and wrist actigraph will not present the same magnitude and even the same trend of change of sleep-wake parameters. Therefore, not all the parameters between these two sets of data were well correlated.

In addition to measuring different dimensions of sleep, the characteristics of the sleep log and the actigraphic recording also contributed to the discrepancies between these two sets of data. As a self-reporting instrument, sleep log records information retrospectively. Although the subjects can fill out the sleep log as soon as possible after awakening, forgetfulness remains a problem (Bootzin and Engle-Friedman, 1981). Elderly people characterised with increase in daytime napping may further amplify the discrepancies (Webb, 1982; Rogers, Caruso and Aldrich, 1993). Unlike sleep log, wrist actigraph can detect any information, which may be missed by the subjects. In summarising the characteristics of the sleep log and the actigraphic recording, the investigator found that discrepancies between these two sets of data were unavoidable. However, the insignificant difference in terms of the sleep efficiency (SE), sleep onset time (SOT) and the total time of waking after sleep onset (WASOt) showed that the discrepancies between the sleep log and the actigraphic recording only caused a minimal effect on sleep quality. As mentioned in the previous section "Sleep-wake pattern – Sleep-wake parameters", SE (Keklund and Åkerstedt, 1997), SOL (Coates, et al., 1982; Riedel and Lichstein, 1998) and WASOt (Coates, et al., 1982) are one of the critical factors determining overall sleep quality in which SOL is related to SOT. The sleep quality presented by the sleep log or the actigraphic recording will not be significantly different from each other.

Apart from a minor effect on sleep quality, the trend of discrepancies between these two sets of data was predictable. When the sleep log was compared with the actigraphic recording, subjects consistently underestimated all of their sleep-wake parameters except the SOL. According to Tryon (1996), sleep onset was a gradual process. The process could be divided into five phases. The actigraph marked phase 1 of the process (Immobility) as sleep onset while the sleep log marked the fifth phase (Phase 5 – Perceived Sleep Onset). Because of this, the SOL from subject's reporting would be longer than that recorded by the actigraph. Subjects would, therefore, tend to overestimate their SOLs as compared with the actigraphic recording.

According to the nature and characteristics of the sleep log and actigraphic recording, it is acceptable to have unsatisfactory correlation and consistent discrepancies between them. These inadequacies have revealed the probability of combining the sleep log with actigraphic data especially in longitudinal or long-term basis study (Closs, 1988; Hauri and Wisbey, 1992; Chambers, 1994). Actigraphic recording is proposed to compensate the retrospective sleep log by forming the basic information of sleep-wake parameters while sleep log can be used to edit the recording from the perceptual or cognitive perspectives. This strategy is applied when accuracy is the critical factor of the study. With reference to the findings of this study, there was no need to edit actigraphic TBT, WASOt and SoffT as

good correlations were observed between these two sets of data. Similarly, no editing was needed in the sleep quality-related actigraphic SE and SOT because no significant difference was identified from these two sets of data on evaluating sleep quality. But for TST, SOL and WASOf, the interpretation of these actigraphic data should be carefully done because great discrepancies were found between the sleep log and the actigraphic data. The significant discrepancies could be due to the relative lack of motion even when the subjects awoke. Therefore, it was essential to review the sleep log in order to confirm the sleep status of the subject. After the combination of the information from the sleep log and the actigraphic recording, a clearer picture of an individual's sleep-wake pattern can be ascertained.

With respect to the **sleep satisfaction level** (SSLs), all subjects wanted to improve their sleep quality but not all of them considered their sleep as bad. 60.5% of the subjects (n = 23) considered their sleep as bad or very bad (poor sleepers) while the remaining (39.5%, n = 15) rated their sleep satisfaction level as very good, good or acceptable (good sleepers). Even good sleepers sought improvement. That may indicate that "good sleep" estimations need not to be equivalent to actual good sleep. This assumption is supported by two observations. First, the mean desirable duration for sleeping was found to be 5.15 hours (SD = 1.16 hours) for the good sleepers and 5.12 hours (SD = 1.36 hours) for the poor sleepers. The expectation in

the good sleepers was therefore similar to that of the poor sleepers. Second, similarities were found in their sleep-wake parameters and mean 6-sulphatoxymelatonin levels. Detailed description can be referred to the sections of sleep-wake parameters and mean 6-sulphatoxymelatonin level. Since the characteristics between good and poor sleepers were alike, the investigator suspected that there was no major difference in their sleep quality. To explain the reported "good sleep" in the good sleepers, it can be said that it may be common for those people to have a certain level of sleep disturbance. When the disturbance can be tolerated, sleep quality is rated as acceptable or above. Apart from the similarities between the good and poor sleepers, the investigator also postulated that there was no great difference in the sleep quality of comparatively healthy and ill subjects. According to the findings, there was no significant association between self-rated health status and sleep satisfaction level. Sleep disturbance was not confined to those who rated their health status as bad or very bad but also occurred in the healthy subjects.

Similar to the findings of the actigraphic sleep-wake parameters, there was no major difference between good and poor sleepers in their **mean 6-sulphatoxymelatonin (aMT6s) levels**. In addition, the mean aMT6s level also demonstrated an absence of first-night effect in this study. As mentioned earlier (the previous section on sleep satisfaction level), self-reported good sleepers may not achieve good sleep. This may be because

their mean aMT6s levels are similar to those of the poor ones. Another possible reason for the similarity in the mean aMT6s levels may be because the mean aMT6s levels may not be the main determining factor in their sleep quality, although melatonin was found effective in improving sleep quality (Arendt, Aldhous, English, Marks and Arendt, 1987). The investigator considered that this second cited reason was not convincing enough to explain the similarity. Claustrat, Brun, Garry, Roussel and Sassolas (1986) suggested including the first-night melatonin secretion in the data analysis. This idea was also supported in this study as no first-night effect in the mean aMT6s levels was found. The correlation coefficient of the mean aMT6s levels between Day 1 and Day 2 was high ($r = 0.644$, $p = 0.000$) and the mean aMT6s levels of these two days were alike. Hence, the investigator decides that there is no need to discard the first-day melatonin secretion data in future studies.

The effects of bright light exposure on the subjects: The changes in sleep satisfaction level (SSL)

This study could not confirm the effects of bright light exposure on SSL but the decrease in the mean sleep quality of the subjects indicated an improvement after bright light exposure. In the post-bright light exposure stage, SSL was mainly unchanged. In terms of the desirable duration of sleep, 78.9% of the subjects had their desirable duration fulfilled after bright

light exposure. In other words, their desires were satisfied. The fulfillment of sleep in a quantitative mode seemed to have negligible effects on the sleep quality of the subjects. It reveals that sleep quality is not only dependent on the amount of sleep. There should be some more elements contributing to the improvement such as the expectation of future sleep. According to Wehr, Skwerer, Jacobsen, Sack and Rosenthal (1987), one of their subjects with seasonal affective disorder (SAD) had quit the phototherapy because no noticeable therapeutic effect was found during the light treatment. The expectation of achieving prompt light-induced effects can cause the discontinuation of a treatment. Similarly, unrealistic or high expectations of the light-induced effects may influence an individual's judgement on SSL. Therefore, no change in SSL in the majority of the subjects may be presumed to be inefficient bright light effects on SSL.

Looking into the corresponding changes in the mean aMT6s level and sleep-wake parameters in relation to the alteration in SSL, the investigator observed that the mean aMT6s level changed insignificantly and no prominent change trend could be identified. Unlike the mean aMT6s level, some sleep-wake parameters altered significantly on Day 5. SE, SWR and TST were positively related to SSL while SOT and WASOt were negatively associated with SSL. In the case of subjects with their SSLs increased, the SE, SWR and TST increased but WASOt decreased. The SOT shifted forwards. For those with their SSLs decreased, SE, SWR and TST

decreased but WASOt increased. The change in SOT could not be determined. These changes were related to the amount of time one can sleep. Since elderly people are characterised with sleeping less (Orr, Altshuler and Stahl, 1982), increase in sleep duration can improve their sleep quality.

The effects of bright light exposure on the subjects: The changes in actigraphic sleep-wake parameters

After bright light exposure, the number of waking after sleep onset (WASOf) on Day 6 changed significantly. With regard to the other sleep-wake parameters and the related aMT6s levels, no significant alterations were observed. However, some trends of change were detected. In terms of sleep efficiency (**SE**) and sleep-wake ratio (**SWR**), the subjects mainly had these parameters increased. The increase trend was expected as parallel results reported before (Cooke, Kreydatus, Atherton and Thoman, 1998). Many subjects had a total sleep time (**TST**) increase after bright light exposure. For those with a total bed time (**TBT**) increase, the majority of them had their TSTs increased. Although no clear trend of alteration was shown in the related SEs, it could be assumed that there was some improvement in sleep quality, at least in a quantitative sense, after bright light exposure. Subjects did not need to lie in bed for a long time to achieve adequate sleep duration. The findings of the corresponding sleep

satisfaction levels (SSL) further substantiated the conclusion. On Day 6, the increase in TBT brought along with it a significant increase in SSL.

Regarding sleep onset latency (**SOL**) and sleep offset time (**SoffT**), they changed diversely after bright light exposure. In view of the diverse results, no conclusion can be drawn as both increase (Cajochen, Dijk and Borbély, 1992) and decrease (Tryon, 1996) in SOL are also discovered in some studies. Sleep onset time (**SOT**) mainly shifted forwards. The phase shifting in SOT was not significantly correlated with the shifting of SoffT. The trend of forward shift of SOT cannot be explained. There was no associated decrease in SOL and increase in SSL. It proved inconclusive to determine the reason for forward shift. Nevertheless, the insignificant correlation between SOT and SoffT has provided cues for the formulation of protocol for future light treatment. For instance, it is possible for the light-induced phase shifting on sleep-wake cycle to occur at only one end of the cycle. The forward shift of SOT may not be accompanied with a forward shift of SoffT. Thus, sleep researchers may not need to worry about the unnecessarily phase shifting at the other end of the cycle. Focused protocols for those complaining of difficulty in initiating sleep (DIS) and early morning awaking (EMA) can be designed. Since elderly people are characterised with an advance in sleep phase (Swift and Shapiro, 1993), their SoffTs will occur in a comparatively early period which is considered not to be the usual time for the person to awake (Espie, 1991). The

backward shift of their SoffTs can let them awake at a relatively late time so that they can get close to the "usual social schedule". The conflicts stemming from early waking hours may be, in turn, minimised. SSL is, therefore, increased with the improvement of quality of life by the associated adjustment in their social lives. The insignificant correlation between SOT and SoffT indicates the chance to tailor-made a protocol for them.

There was a significant change in the number of waking after sleep onset (**WASOf**) on Day 6. Generally, WASOf, the total time of waking after sleep onset (**WASOt**) and the duration of each waking after sleep onset (**WASOd**) were found to decrease in more than 30% of the subjects after bright light exposure. When WASOf was reviewed from the sleep log, most of the subjects either reported no change or a decrease in WASOf. The findings were in line with a previous study (Campbell, Dawson and Anderson, 1993). On Day 5, sleep satisfaction level (SSL) decreased when WASOt increased. SSL increased when WASOt decreased. Concerning the significant changes in the related SSL on Day 5, the investigator is convinced that WASOt is one of the determining factors of sleep quality (Coates, et al., 1982).

While WASOf was positively correlated with WASOt, it was negatively associated with WASOd. It is not difficult to understand the reasons for the

positive relationship but in the case of the negative relationship, the investigator suspects that bright light may regulate sleep by changing either WASOf or WASOd. According to the findings of this study, the sleep in the poor sleepers was more fragmented than that of good sleepers. It seemed that WASOf was an index of sleep quality. Therefore, the formulation of the protocol for those complaining of difficulty in maintaining sleep (DMS) may be dependent on the WASOf rather than WASOd. To achieve maximum and optimal light-induced effects, the interactions among the WASO parameters during sleep regulation should be further examined.

The effects of bright light exposure on the subjects: The changes in the mean 6-sulphatoxymelatonin (aMT6s) level

The change in the mean aMT6s level was not significant in both the Light On Period (from 1800 hours to bedtime) on Day 3 and Day 4 and the Light Off Period (from bedtime to rising time) on Day 5 and Day 6. However, trends of changes in the mean levels were detected. In the Light On Period, there were more subjects with their mean aMT6s levels decreased on Day 3 than Day 2 and Day 4 than Day 3. Their mean aMT6s level on Day 3 was lower than that on Day 2 and the level on Day 4 was lower than that on Day 3 (paired difference mean: 0.09 pmol/ml [Day 2 - Day 3]: 0.46 pmol/ml [Day 3 – Day 4]). The decrease in mean aMT6s level was most probably

due to the suppressive effect of bright light on the melatonin secretion. As the production of pineal melatonin depends on the neural activity within the suprachiasmatic nuclei (SCN) and the neural activity of the sympathetic fibers connecting SCN is suppressed by light (Reiter, 1988), the decrease in the aMT6s level in the Light On Period of the bright light exposure stage may be mostly caused by the bright light. The presence of this suppressive effect on melatonin secretion shows that light treatment is still feasible in elderly people.

With regard to the insignificant change of the mean aMT6s level in the Light Off Period, similar results were also demonstrated in another study (Shanahan and Czeisler, 1991). These insignificant findings may be associated with the limited suppression of the mean aMT6s level in the Light On Period. Demonstrated by the salivary melatonin level in twelve healthy adults, there was a positive correlation between the shifts of the melatonin offset and the amount of the melatonin suppression. The more the melatonin level was suppressed during light exposure, the larger was the degree of phase delay of melatonin offset on the following night (Laakso, Hätönen, Stenberg, Alila and Smith, 1993). Therefore, the insignificant suppression of the mean aMT6s level in the Light On Period may, in turn, lead to an insignificant change in the mean aMT6s level of the Light Off Period in the post-bright light exposure stage.

Although the change in the mean aMT6s level was insignificant in the Light Off Period, about 50% of the subjects had their levels increased after bright light exposure. The increase in the level can be due to the augmentation of melatonin secretion rhythm amplitude (Czeisler, Kronauer, Mooney, Anderson and Allan, 1987). Similar results were identified in previous studies (Hansen, Bratlid, Lingiärde and Brenn, 1987; McIntyre, Norman, Burrows and Armstrong, 1990). The method of collecting urine samples cannot support an accurate description of melatonin secretion rhythm, so the assumption of the augmentation cannot be confirmed. In the case of sleep satisfaction level (SSL), the change of SSL was not well correlated with the change of aMT6s level. The subjects tended to have their SSLs either increased or unchanged. With reference to the poor correlation, it can be supposed that the alterations of melatonin secretion rhythm can have little or even negligible effect on an individual's sleep quality. However, the insignificant changes in the mean aMT6s level may also be responsible for the poor correlation as exogenous melatonin has been found capable in improving sleep quality (Folkard, Arendt and Clark, 1993; Wurtman and Zhdanova, 1995). In terms of the corresponding sleep-wake parameters, no significant change was observed. The insignificant alterations in the mean aMT6s level may be a contributing factor.

Limitations of the study

The findings of this study cannot be generalized to all institutionalized elderly people. The generalization of the results was restricted by three factors. First, the method employed in this study was convenience sampling method, which might induce biases to the results because subjects were recruited on the basis of availability (Portney and Watkins, 1993). Nevertheless, the limitation indicated that there was an urge to seek improvement in the quality of sleep, as only those who were not satisfied with their quality of sleep would participate into this study. The convenience sampling technique was a preferred method to recruit subjects for the investigation of sleep management. Second, health problems such as hypertension and asthma are common in elderly people. Subjects with these illnesses were also eligible for the study unless the prescription for the related medications had any change in dosage or frequency during the experimental period. Therefore, the results of the study might not be true for those without these illnesses. Third, to avoid interrupting any routines or habits of the subjects, other sleep-related factors were not strictly controlled in this study. All these loosely controlled factors would interfere with the generalization of the results.

After bright light exposure, there was no significant change in the self-rated sleep satisfaction level, sleep-wake parameters and the mean aMT6s level.

There were several factors influencing the effectiveness of bright light exposure. The factors were related to the natural environment in which the investigator chose to launch the study. Both the setting of the experiment and the behavioural and physical monitoring of the subjects could affect the effectiveness of the bright light exposure.

The setting of the experiment

To minimize the first-night effect and avoid any interfering factors such as tiredness caused by travelling, this study was conducted in elderly care homes instead of in a sleep laboratory. Although sleep at home may facilitate the detection of sleep changes (Edinger, et al., 1997), the light-dark condition at home is difficult to control strictly. When there is a great contrast between light and dark, there will be a stronger coupling strength (a function of the range of its oscillation) of the time giver (Moore-Ede, Sulzman and Fuller, 1982). In this study, the investigator could not create an "absolutely dark" environment. The use of eye shields might help in achieving an "absolutely dark" condition but it was not popular with the subjects. Nevertheless, eye shields were used according to the habits of the subjects. The light intensity of the dark condition was maintained at about 8.61 lux. The effect of dim light on the coupling strength cannot be eliminated. Thus, attention should be paid to this while evaluating light-induced effects. Understanding the difficulties in attaining a rigorously

controlled situation in an elderly care home in which several residents share one bedroom, the investigator could not adjust the light intensity and temperature in the subjects' bedrooms. To ensure a stable experimental condition, the investigator, instead, recorded the light intensity and temperature of bedrooms on each experimental day. It was hoped that the interpretation of the findings might not be affected by any sudden or dramatic change in light intensity or temperature.

The behavioural and physical monitoring of the subjects

Apart from the light intensity of the dark condition, the investigator also found constant routine, free run, compliance and the physical condition of the pineal gland and eyes difficult to control. In view of these difficulties, the investigator will now address the related problems and management.

Constant routine Constant routine was not included in this study. The investigator found the comparatively flexible daily routines of the elderly care homes good enough to minimize the effects of other environmental time cues. The employment of a constant routine regimen is aimed at reducing the interference caused by all external rhythms so that the changes in the internal clock can be studied directly (Minors and Waterhouse, 1984). If more daily routines of the subjects are controlled, there will be less interference with the sleep-wake cycle. In this study, the investigator did

not impose any additional restrictions on the subjects' daily routines though the routines might not be as constant as one would wish. Living in elderly care homes, subjects had a fixed mealtime. They got up at similar time in the morning and went to bed at a fixed time. The routines in the elderly care homes were so stable that they could minimize the effects of environmental time cues. In order to identify the effects of bright light on the subjects in a real situation, however, the investigator was alert to the uncertainties brought about by the comparatively flexible routine in elderly care homes. For instance, the children of a subject would visit her once a week. After the visit, the subject claimed to have a poor sleep at night. It was difficult to determine whether the poor sleep was due to the visit or the bright light. Although the investigator could restrict such "masking" activities, she wondered if the absence of these activities would also affect sleep especially in an elderly care home. Balancing the advantages and disadvantages of restricting daily routines, the investigator allowed her subjects to keep their usual routines. The duration and nature of their activities and the kinds and amount of food consumed were recorded. In addition, emotional changes were documented. Any modifications in the routines were documented as a reference for the interpretation of the findings.

Free run To investigate the responses of a group of subjects towards a treatment, it is better to unify their circadian rhythms so as to avoid diverse results. Before their circadian rhythms are unified by constant routines,

their old rhythms will be wiped out first by a process called 'free run' (place subjects in a situation with no external time cues). Owing to the presence of a stable routine in the elderly care home, the investigator found it unnecessary to 'free run' the subjects because their rhythms might be unified after living in the elderly care home for more than a year. In addition, 'free run' may induce sleep loss by interrupting their habitual sleep patterns. Previous sleep loss may interfere with the evaluation of light treatment as sleep-wake parameters or subjective alertness can be affected by prior sleep loss and the duration of prior wakefulness (Dijk, et al., 1995). Since no 'free run' was launched before the experiment, the dispersal of the findings was, however, foreseeable.

Compliance Perceived illumination can be affected with the co-operation of the subjects. When subjects can maintain a long period of exposure, they will receive a higher percent of lux-hours (Dawson and Campbell, 1990) than those who cannot because of frequent blinking, closure of eyes for a long time or moving around. If the subjects close their eyes for a certain period of time, the influence will be prominent. In the light of these shortcomings, the investigator took action to minimize interference. The investigator kept the subjects' eyes opened during the light exposure period by watching television or chatting. Subjects were asked not to move around. This request was made not only to minimize any influence on the perceived illumination but was also tailor-made for the prevention of a fall

The experiment mostly took place in a room where the washroom was available, or nearby, so that the subjects did not have to walk for a long time or for a long way. Although the slow introduction of light could not solve the problem of intolerance to bright light in some subjects, the inclusion of adaptation time was expected to minimize the intolerance. All the subjects joining this study wanted to improve the quality of their sleep, and lucid explanation of the procedure was given to gain their co-operation. By carrying out the above measures, the investigator hoped that the perceived illumination might not be greatly affected.

Expectation As all the subjects in this study wanted to improve the quality of their sleep, they held a certain level of expectation. To diminish the effects of expectation, the investigator informed the subjects about the uncertainty of the effects of the bright light on their sleep before the study.

Age-related physical issues – Pineal gland In elderly people, pineal glands become calcified, so light-induced effects may be affected. As suggested by Pang, Huang, Ng and He (1985), the age-related decrease in melatonin level might be associated with a reduction in the functioning of the pineal gland in elderly people. Concurring with Pang and associates, Kunz, Bes, Schlattmann and Hermann (1998) also suggested that the increase in the degree of pineal calcification might lead to a decrease in melatonin production. They had illustrated a significant positive correlation between

the degree of pineal calcification and subjective chronic sleep impairment in their study. In view of the possible association between the degree of pineal calcification and melatonin production. the investigator included the aging pineal gland as one of the determining factors for evaluating light-induced effects.

Age-related physical issues – Eyes In elderly people. their eyes undergo certain changes which may give rise to cataract or presbyopia. Since these changes are common among them. subjects with either unilateral or bilateral cataract were recruited to this study. In addition. they were allowed to wear their glasses to correct the problem of presbyopia. The degree of calcification or changes is not easy to be determined. Different degrees of cataract will alter the penetrating power of the lens and the scattering of light from the lens increases gradually during the advance of age (De Natale. Flammer. Zulauf and Bebie. 1988). Because no well-defined cataract assessment is available in Hong Kong. the investigator can only pay heed to the effects of cataract on the light-induced changes. Apart from cataract. presbyopia is another matter to consider. Since subjects were expected to watch television during the light exposure period. they were allowed to wear glasses as usual because the investigator was not only concerned about light-induced effects but also their daily needs. Since different thicknesses of the lens will cause different penetrating power and scattering of light. the "dosage" of light received by those wearing glasses during bright light

exposure remains a concern. In addition to cataract and presbyopia, the control of pupil size in the subjects has aroused concern. Different pupil sizes cause different "doses" of light to be received by the subjects. Logically, when the pupil size is larger, a larger "dose" of light is received by the subjects and melatonin suppression may be more pronounced in them. Referring to the regulation of retinal stimulation, the pupil can also regulate the effect of light on the suprachiasmatic nucleus and thus the related circadian rhythm. In this way, the pupillary modulation of retinal stimulation also plays a role in the regulation of circadian rhythm (Gaddy, Rollag and Brainard, 1993). Since it is dangerous to control one's pupil size in a field setting especially in elderly people who may fall easily, the investigator concedes that incongruent and inconsistent "dosage" of light received by the subjects may result in inconclusive light-inducing effects on melatonin and sleep.

In addition to the mentioned factors, the data collection methods employed in this study did not allow a detailed examination of light-induced changes. The collection of urine samples and actigraphic data were unintrusive so that the sleep of the subjects was not disturbed. They were considered to be the best data collection methods for studying sleep in a field setting. In spite of their reported utility for field measurement, they were insufficient in providing certain kinds of information.

The **wrist actigraph** used in this study can only measure sleep-wake parameters but not electroencephalographic patterns. The measurement of sleep-wake parameters was actually the reflection of wrist movements (Closs, 1988). As suggested by Dijk and associates (1995), any treatment-induced changes might not be detected if electroencephalographic analysis was not sufficient. The understanding of the light-induced effects on the subjects was therefore limited in this study.

With respect to the **urine samples**, no detailed information but the mean aMT6s level could be calculated as the samples were collected whenever the subjects urinated. Any phase shifting of the melatonin rhythm could only be estimated by the changes in the mean aMT6s level. In order to detect light-induced phase shifting of melatonin rhythm in a more accurate way, some researchers had suggested measurement of multiple circadian endpoints. Some claimed however that the measurement of a single variable such as dim light melatonin onset (DLMO) was sufficient to identify the effect (Dijk, et al., 1995). The measurement of either multiple circadian endpoints or a single point of DLMO needed closed monitoring of the excreted aMT6s level. Urethral catheterization can achieve a detailed measurement but many related problems such as catheter-induced sleep loss will arise. As light-induced effects on sleep were examined in this study, the investigator found that urine samples were the most desirable way to monitor the alterations in melatonin without disturbing sleep. Nevertheless, owing to

the irregular times of sample collection. no other statistic other than the mean aMT6s levels could be calculated. No accurate measurement of the phase shifting in the melatonin rhythm was therefore possible.

Summary

Difficulty in initiating sleep (DIS). difficulty in maintaining sleep (DMS) and early morning awakening (EMA) were the common sleep complaints among the subjects. DIS sufferers were characterized by their long sleep onset latency (SOL). The SOL of non-sufferers was as much as one hour long. Long SOL seems to be associated with melatonin level and daily routines. DMS was the most common sleep complaint. DMS sufferers awoke frequently at night. Nearly half of the sufferers claimed that the duration of each waking after sleep onset (WASOd) lasted for a long time. Nocturia was the major reason for waking at night but it was not reported as an aggravating factor for their sleep disturbance. Acceptance may increase tolerance of frequent micturition at night. However. the investigator suspects that there are other factors that are more prominent than nocturia in affecting one's sleep. EMA sufferers were annoyed by being unable to return to sleep after waking at night. More than 90% of them were not satisfied with the quality of their sleep. Their mean sleep offset times (SoffTs) and rising times were much the same as that of the non-sufferers. In addition. all but one sufferer was content with their refreshment level

when getting out of bed. Therefore, a more detailed examination of their dissatisfaction is needed.

The investigation of sleep-wake patterns requires the assessments of napping, sleep-wake parameters and sleep-related factors. The evaluation of napping was divided into intentional and unintentional naps. Few subjects had habit of an intentional napping while many could not resist the unintentional napping. Some subjects said that intentional napping might impoverish their nocturnal sleep. In addition, most of them could not fall asleep during an attempted intentional napping. Hence, they did not welcome intentional napping. However, the significance of napping could not be denied as many subjects, especially the poor sleepers, dozed habitually. As shown by the actigraphic recording, the subjects participating in this study woke frequently at night and some of them were awake for a long time. These observations may be related to the decrease in the arousal threshold (Swift and Shapiro, 1993) and the alteration in melatonin level (Wurtman and Zhdanova, 1995). Since the poor sleepers woke more frequent than the good sufferers, the number of waking after sleep onset (WASOf) was recommended as the major index for sleep satisfaction. Chinese tea, being a major caffeine-containing product consumed by the subjects, was popular among the elderly Chinese people. Only one third of the subjects consumed caffeine-containing products regularly. The sleep inhibiting effects of caffeine may be responsible for the low consumption

rate. Although possessing sleep-inducing properties, the consumption rate of dairy products was not high. Diarrhoea was mentioned as the main reason for the low consumption rate. Unlike caffeine and dairy products, exercise and sunlight exposure were welcomed in more than 60% of the subjects. Through these activities, sleep may be improved. In addition, subjects may gain benefit by improving their social network.

To justify the findings, the correlation between the sleep log and the actigraphic recording was examined. Only three sleep-wake parameters (total bed time - TBT, the total time of waking after sleep onset - WASOt and SoffT) between these two sets of data were well correlated. Since sleep log and wrist actigraph measure different dimensions of sleep, unequal magnitude and even incongruous trend of change of the parameters are acceptable. The characteristics of these two instruments have further enhanced the discrepancies. The insignificant difference in terms of sleep efficiency (SE), sleep onset time (SOT) and WASOt showed that the discrepancies between these two sets of data only caused a minimal effect on sleep quality. Besides, the subjects consistently underestimated all the sleep-wake parameters except SOL. This had made the trend of discrepancies predictable. Summarising the nature and characteristics of the sleep log and actigraphic recording, the investigator found it possible to combine these two sets of data, particularly in longitudinal studies. When accuracy is the critical factor of a study, actigraphic recording is proposed to

compensate the retrospective sleep log by forming the basic information of sleep-wake parameters while sleep log can be used to edit the recording from the perceptual or cognitive perspectives.

In terms of the sleep satisfaction of the subjects, it was interesting that all the subjects joining this study wanted to improve their sleep quality but not all of them considered their sleep bad. Only 60.5% of the subjects rated their sleep as bad or very bad. These subjects were classified as poor sleepers. The remaining ones were classified as good sleepers. Since the good sleepers still sought improvement, it is supposed that the 'good sleep' rated by the good sleepers might not be actual 'good sleep'. Such ideas were supported by the sleep-wake parameters, the mean 6-sulphatoxymelatonin (aMT6s) levels, and the mean desirable duration for sleeping between the two groups of sleepers. In view of the similarities, it is assumed that there is no great difference in the sleep quality of good sleepers and poor sleepers.

The mean aMT6s level was studied according to the sleep satisfaction of the subjects. The first-night effect in the mean level was also determined. When subjects were grouped into good or poor sleepers, their mean aMT6s levels were similar. As mentioned before, this similarity may be related to the good sleepers not achieving an actual good sleep. However, it may also be because the mean aMT6s level is not a determining factor in the quality

of their sleep. For this latter assumption. further examination is needed as melatonin has been said to be effective in improving sleep quality (Arendt. Aldhous. English. Marks and Arendt. 1987). Apart from comparing the mean levels in good and poor sleepers. the first-night effect in the mean aMT6s level was also studied. The high correlation in the mean aMT6s levels between Day 1 and Day 2 demonstrated that no first-night effect was found in this study. This matched the finding of another study in which the researchers suggested using first-day melatonin secretion data in all future studies (Claustrat. Brun. Garry. Roussel and Sassolas. 1986).

The effects of bright light exposure on sleep satisfaction level (SSL) could not be determined in this study but the subjects had indicated improvement in their quality of sleep after bright light exposure. In view of the fulfillment of a desirable duration of sleep. the insignificant change in SSL may be in relation to the unrealistic or high expectation of light therapy on their sleep. With reference to the corresponding mean aMT6s level. no significant alteration was observed and no trend of change could be identified. Unlike the mean aMT6s level. some associated sleep-wake parameters changed significantly on Day 5. The parameters were SE. SWR. TST. SOT and WASOt.

After bright light exposure. all the sleep-wake parameters except the number of waking after sleep onset (WASOf) on Day 6 changed insignificantly.

The related mean aMT6s level had no significant change too. Regardless of the insignificant alterations, trends of changes in some sleep-wake parameters were observed. Many subjects had an increase in SE, SWR and total sleep time (TST). Together with the increase in TBT and the correlated SSLs, improvement in sleep quality after bright light exposure is assumed. Regarding the insignificant changes in SOL, SOT and SoffT, no conclusion can be drawn but the poor correlation between SOT and SoffT has suggested that light-induced phase shifting on sleep-wake cycle may have occurred at only one end of the cycle. Hence, sleep researchers can formulate focused protocols for different sleep disturbances. In line with the work conducted by Campbell, Dawson and Anderson (1993), the sleep log but not the actigraphic recording showed that there was a trend of decrease in WASOf after bright light exposure. The inconsistency may be in relation to the poor correlation in WASOf between the sleep log and the actigraphic recording. According to the changes in the WASOt on Day 5, the corresponding SSL altered significantly. This has substantiated that WASOt is one of the determining factors of sleep quality. WASOf was negatively correlated with WASOd in which WASOf is suggested to be more important in sleep regulation as the sleep in poor sleepers was more fragmented than that of good sleepers. The formulation of protocol for those complaining DMS should, therefore, focus on WASOf rather than WASOd.

As with the sleep-wake parameters, the change in the mean aMT6s level was not significant in both the Light On Period (from 1800 hours to bedtime) of Day 3 and Day 4 and the Light Off Period (from bedtime to rising time) of Day 5 and Day 6. In the Light On Period, there were more subjects with their mean aMT6s levels decreased on Day 3 than Day 2 and Day 4 than Day 3. The mean aMT6s level on Day 3 was lower than that on Day 2 and the mean level on Day 4 was lower than that on Day 3. The decrease in the mean aMT6s level during the bright light exposure may indicate the presence of suppressive effect of bright light on the melatonin secretion in the subjects. This indication provides an insight for light treatment in elderly people. In view of the insignificant suppression of the mean aMT6s level by the bright light in the Light On Period of Day 3 and Day 4, the changes in the mean aMT6s level in the Light Off Period of Day 5 and Day 6 were also insignificant. When the light-induced effects on the subjects were investigated according to the changes in the post-bright light exposure stage, it was observed that about 50% of the subjects with mean aMT6s levels increased. The light-induced augmentation of melatonin secretion rhythm may be responsible for the increase in the level. However, this idea is not confirmed because the method of collecting urine samples cannot support an accurate description of melatonin secretion rhythm. In the post-bright light exposure stage, the change of the corresponding SSL was mainly found increased or unchanged regardless of the alteration in the mean level. Since previous studies have suggested that melatonin can

improve sleep quality, the poor correlation between the change of SSL and that of aMT6s level may be in relation to the insignificant change in the aMT6s level.

The changes in the sleep-wake parameters, mean aMT6s level and SSL were mostly insignificant after bright light exposure. The investigator suspects that both the setting of the experiment and the behavioural and physical monitoring of the subjects may affect the light-induced effects. Even though the study was conducted in elderly care homes to facilitate the detection of sleep changes (Edinger, et al., 1997), it was difficult to create an "absolutely dark" environment. The absence of an "absolutely dark" environment will decrease the coupling strength of bright light and thus the light-induced effects are weakened. The relatively loose behavioural and physical monitoring of the subjects is also believed to interfere with the findings. Instead of adopting a strict routine, comparatively loose daily routines were employed in this study. It is known that when more daily routines are controlled, there is less interference on the sleep-wake cycle. Since the daily routines of the elderly care homes were considered to be good enough for minimizing the effects of environmental time cues, the investigator did not impose strict routines on the subjects. However, any modifications in the routines were recorded as a reference for interpretation of the findings. In view of the adoption of the usual daily routines, subjects living in elderly care homes for more than a year might have fixed rhythms

anyway. Hence, the experimental results might not be too diverse. A 'free run' (place subjects in a situation with no external time cues) was not employed before the commencement of the experiment. It is believed that this may add to sleep disruption in elderly people. Apart from constant routine and 'free run', the compliance of the subjects can also affect the light-induced effects as the actual illumination dose can be reduced by frequent blinking, closure of eyes for a long time or moving around. Moreover, the attainment of certain degree improvement in sleep quality may also interfere with the findings. Pineal gland and eye diseases in the subjects can also confound the light-induced effects. It has been proposed that a degree of pineal calcification is associated with the melatonin production (Pang, Huang, Ng and He, 1985; Kunz, Bes, Schlattmann and Herrmann, 1998). The unknown effects of pineal degeneration may also make the findings unclear. Similarly, the lack of information about the degree of cataract, the thickness of the subjects' glasses and the changes in the pupil size can also induce inaccuracy in the results as these three factors can affect the "dosage" of light received by the subjects. The investigator concedes that the ineffective light effects may have resulted from these uncontrollable factors.

Further field trial

This study illustrated that bright light could improve a person's self-rated quality of sleep. Sleep efficiency tended to increase after bright light exposure. Light suppressive effect on melatonin secretion was observed in the post-bright light exposure stage while the mean aMT6s level mainly increased after bright light exposure. These findings were not substantiated by statistically significant changes. At the same time, these findings were also under the influences of the limitations of the study. In view of the desire to develop alternative sleep management methods, the investigator found it worthwhile to conduct a further field trial to verify the light effects on sleep and melatonin. Chapter 11 presents the clarification of the findings.

Chapter 11

Further Field Trial

Introduction

In order to further verify the results obtained in the main study, a field trial was conducted. This chapter presents the results obtained in the main study and the field trial. By combining the findings from the main study and this field trial, it is hoped that the results will shed light on the light-induced effects on sleep and melatonin.

The findings of the further field trial

In this further field trial, 16 elderly women were recruited. Twelve of them were living in an elderly care home situated on Hong Kong Island while the remaining four at home. Two subjects quit the experiment because they could not endure the tiredness. One subject would rather join another activity. The drop-out rate was 18.8%. Two subjects were disqualified for taking medications which affected

their sleep. One subject could not complete the collection of urine samples. Finally, 10 subjects participated in the field trial. Eight subjects were living in the elderly care home and two at home. The characteristics of the two subjects living at home were similar to those living in the elderly care home. Levene's test showed that no remarkable differences in the findings were observed when their data were analysed together with that of the eight subjects (p = 0.793). Hence, these two subjects were considered to be no different from the residents of the elderly care home.

When the data of these 10 subjects were analysed together with the data of the 38 subjects in the main study, Levene's test demonstrated that no obvious differences in the findings were observed when compared with the results of the main study (p = 0.839). In addition, there were no great changes in the weather and socio-political environment in Hong Kong, so the subjects in the field trial were supposed to be under the same social and living conditions as that of the main study. It was, therefore, suggested that the external validity was maintained. The combination of the findings from the main study and the further field trial was thus accepted.

The combined findings of the main study and the further field trial

The data of the main study and the further field trial were pooled and analysed. The results were as follows:-

The characteristics of the subjects

Demographic information

After the combination, there were 48 subjects coming from 10 elderly care homes situated in Kowloon, the New Territories or on Hong Kong Island. Their mean age was 80.61 years old (SD = 6.20 years). Their mean body mass index (BMI) was 22.69 kg/m^2 (SD = 4.08 kg/m^2). 43 subjects (89.6%) had their BMIs less than 27 kg/m^2. 37 subjects (77.1%) accepted or were satisfied with their health status. 26 (54.2%) considered their sleep as bad or very bad and 7 (14.6%) found themselves still tired or sleepy just after a night of sleep. For those who slept bad or very bad, 26.9% (n = 7) of them were not satisfied with their health conditions. The association between self-rated health status and sleep quality could not be established in this study with the Spearman rho as 0.24 ($p = 0.115$).

Sleep history

Among these 48 subjects, 77.1% of them (n = 37) had experienced sleep disturbances for a year or more. The mean duration for the occurrence was 15.99 years (SD = 27.13 years). Twenty-six subjects (54.2%) claimed their sleep disturbances occurred every night. The mean occurrence rate was 5.68 times per week (SD = 2.05 times per week). Apart from the rate of occurrence, both the pattern and mode of the occurrence should also be considered in the assessment of sleep disturbance. There were 20.8% of the 48 subjects (n = 10) describing the disturbance as never stopping while 64.6% of them (n = 31) stated no fixed mode. All of the responses showed that the development of sleep disturbance was gradual. There were 60.4% of the subjects (n = 29) with sleep disturbance starting between the ages of 65 and 84. Their mean age of onset of the sleep disturbance was 74.49 years old (SD = 13.34 years). Facing such gradual but non-fixed changes, four subjects tried to relieve their disturbances by listening to radio (n = 1), taking sleeping pills regularly (n = 1) or irregularly (n = 1), or taking Piriton (n = 1) whenever necessary.

The most common sleep complaints among these 48 subjects were difficulty in initiating sleep, DIS (50.0%, n = 24), difficulty in maintaining sleep, DMS (58.3%, n = 28) and early morning awakening, EMA (39.6%, n = 19). Compared with the other two disturbances, the ones with EMA seemed to

have the worst sleep. In DIS cases (n = 24), there were 75.0% of the subjects (n = 18) reporting their sleep as bad or very bad. For DMS cases (n = 28), 60.7% of the subjects (n = 17) were dissatisified with their sleep. Among those complaining of EMA (n = 19), 84.2% of the subjects (n = 16) described their sleep as bad or very bad. The combined findings on sleep complaints were parallel to the results of main study.

Regardless of the similarities in the sleep complaints, different results were identified in napping. As shown in the main study, intentional napping (n = 9, 23.7%) was uncommon. Unintentional napping (n = 16, 42.1%) was habitual in more than 40.0% of the subjects. The combined findings, however, demonstrated that both kinds of napping were common among the subjects. Fourteen subjects (29.2%) declared the habit of intentional napping while eighteen (37.5%) reported unintentional napping.

The sleep-wake parameters and 6-sulphatoxymelatonin of the subjects

With reference to the main study, the magnitude of the parameters from the combined data (N = 48) was shown in Table 11.1.

Table 11.1 The sleep-wake parameters of the subjects (N = 48)

Sleep Parameters	mean	SD	maximum	minimum
SE	80.44	12.83	96.59	23.91
SWR	6.69	5.73	28.34	0.31
TST	403.51	71.42	529.00	122.00
TBT	502.71	50.57	615.33	390.17
SOL	15.53	19.88	66.33	0.00
SOT	09:57 PM	40.73	11:43 PM*	09:08 PM**
WASOf	8.67	4.52	19.00	2.00
WASOd	8.65	6.51	43.29	2.12
WASOt	69.42	50.81	278.17	10.17
SoffT	05:49 AM	49.17	07:19 AM*	03:57 AM**

Note: SE – Sleep Efficiency (%)
SWR – Sleep Wake Ratio
TST – Total Sleep Time (minute)
TBT – Total Bed Time (minute)
SOL – Sleep Onset Latency (minute)
SOT – Sleep Onset Time (time); SD is measured in minute
WASOf – Number of waking after sleep onset (times)
WASOd – Duration of each waking after sleep onset (minute)
WASOt – Total time of waking after sleep onset (minute)
SoffT – Sleep Offset Time (time); SD is measured in minute
* – the time for the last subject to fall asleep in SOT cases or the time for the last subject to wake up in SoffT cases
** – the time for the first subject to fall asleep in SOT cases or the time for the first subject to wake up in SoffT cases

Similar to the main study, the combined findings had demonstrated that the sleep of the poor sleepers (n = 26) might not be very poor when compared with the sleep of the good sleepers (n = 20) (Table 11.2). Sleep-wake parameters of the poor sleepers tended to show a better sleep than that of the good ones.

Table 11.2 The comparison of the mean actigraphic sleep-wake parameters between the good (n = 20) and poor sleepers (n = 26)

Sleep Parameters	Good sleepers (n = 20)	Poor sleepers (n = 26)
SE	79.27	81.05
SWR	5.20	7.86
TST	389.79	415.80
TBT	493.58	513.65
SOL	18.06	13.36
SOT	10:01 PM	09:45 PM
WASOf	7.55	9.27
WASOd	9.58	8.28
WASOt	66.47	73.02
SoffT	05:37 AM	05:54 AM

Note: SE – Sleep Efficiency (%)
SWR – Sleep Wake Ratio
TST – Total Sleep Time (minute)
TBT – Total Bed Time (minute)
SOL – Sleep Onset Latency (minute)
SOT – Sleep Onset Time (time)
WASOf – Number of waking after sleep onset (times)
WASOd – Duration of each waking after sleep onset (minute)
WASOt – Total time of waking after sleep onset (minute)
SoffT – Sleep Offset Time (time)

Forty-four subjects responded to the question of the desirable sleeping duration in accordance with the combined findings. Their mean desirable duration for sleeping was 5.36 hours (SD = 1.62 hours) with a range between 3.00 and 10.50 hours. When the subjects were grouped into either good or poor sleepers, the mean desirable duration for sleeping of the good sleepers was 5.53 hours (SD = 1.75 hours) with a range between 3.00 and 10.50 hours. For the poor sleepers, their mean desirable duration for sleeping was 5.10 hours (SD = 1.48 hours) with a range between 3.50 and 9.00 hours. For the aMT6s levels of the subjects, the mean was 15.80 pmol/ml (SEM = 1.74 pmol/ml) with a range between 1.90 and 58.28 pmol/ml. The aMT6s levels of these two groups of sleepers were almost the

same. For the good sleepers, their mean aMT6s level was 15.78 pmol/ml (SEM = 2.10 pmol/ml) with a range between 2.27 and 35.63 pmol/ml, while the poor sleepers, their mean aMT6s level was 14.92 pmol/ml (SEM = 2.69 pmol/ml) with a range between 1.90 and 58.28 pmol/ml. There were no changes in the range of the mean aMT6s levels in the combined data. The 10 subjects in the field trial had their mean levels within the range of the aMT6s levels in the main study.

Sleep-related factors

All the combined findings resembled those of the main study except the correlation between self-rated sleep quality and the dairy product consumption habit. The correlation between the self-rated sleep quality and the dairy product consumption habit became significant ($r = 0.31$, $p = 0.039$). Among the 26 poor sleepers, 30.8% of them (n = 8) consumed dairy products regularly and 69.2% (n = 18) did not have such a habit. For good sleepers (n = 20), 11 of them (55.0%) consumed dairy products habitually.

The effects of bright light exposure on the subjects: The changes in sleep satisfaction level (SSL)

Similar to the main study, the subjective reporting of the subjects (N = 48) indicated that their sleep qualities mainly improved after bright light

exposure but the first alternative hypothesis stated in the Chapter 1 was rejected. With the Wilcoxon test, the mean of the sleep quality of post-bright light exposure stage was lower than that of the pre-bright light exposure stage (mean of sleep quality = 2.63 on Day 2; 2.50 on Day 5; 2.42 on Day 6). Therefore, subjects found better sleep quality after bright light exposure (p = 0.455 on Day 5; 0.169 on Day 6). On Day 5, there were 31.3% (n = 15) of the subjects with their SSLs increased, 22.9% (n = 11) decreased and 45.8% (n = 22) unchanged. On Day 6, 31.3% (n = 15) of the subjects claimed to have their SSLs increased while 18.8% (n = 9) decreased and 50.0% (n = 24) were unchanged. The evaluation of their sleep qualities throughout the experiment is presented in Figure 11.1.

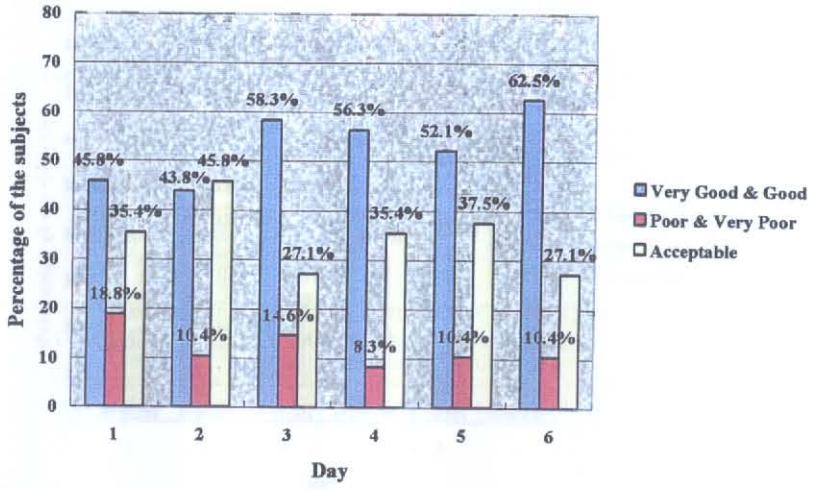


Figure 11.1 Sleep satisfaction level of the subjects throughout the experimental period (N = 48)

When the changes of the sleep efficiency (SE) and 6-sulphatoxymelatonin (aMT6s) level were examined with reference to the sleep satisfaction level

(Table 11.3 – Table 11.5), subjects had significant alterations in their SEs on Day 5. The third hypothesis was supported when the sleep-wake parameters were considered individually. For the increase group, the difference between the SE means on Day 2 and Day 5 was 6.15%, 95% confidence interval −10.41% to −1.88% (t = -3.09, df = 14, p = 0.008). It was 6.35%, 95% confidence interval 1.79% to 10.92% (t = 3.10, df = 10, p = 0.011) for the decrease group and 4.03%, 95% confidence interval −7.58% to −0.48% (t = -2.36, df = 21, p = 0.028) for the unchanged group. Except for those reporting poor or very poor sleep, more than half of the subjects had their sleep efficiencies increased. In terms of aMT6s level, no prominent trend of changes in the aMT6s levels was observed regarding the alterations of SSL. The fourth hypothesis was rejected.

Table 11.3 The change of the corresponding sleep efficiency and 6-sulphatoxymelatonin level on Day 5 with respect to the sleep satisfaction level

Sleep Satisfaction Level	Sleep Efficiency (SE)		6-sulphatoxymelatonin (aMT6s) Level	
	Increase	Decrease	Increase	Decrease
Very Good & Good (n = 25)	68.0%	32.0%	60.0%	40.0%
Poor & Very Poor (n = 5)	40.0%	60.0%	80.0%	20.0%
Acceptable (n = 18)	61.1%	38.9%	38.9%	61.1%

Table 11.4 The change of the corresponding sleep efficiency and 6-sulphatoxymelatonin level on Day 6 with respect to the sleep satisfaction level

Sleep Satisfaction Level	Sleep Efficiency (SE)		6-sulphatoxymelatonin (aMT6s) Level	
	Increase	Decrease	Increase	Decrease
Very Good & Good (n = 30)	53.3%	46.7%	60.0%	40.0%
Poor & Very Poor (n = 5)	20.0%	80.0%	40.0%	60.0%
Acceptable (n = 13)	53.8%	46.2%	38.5%	61.5%

Table 11.5 The change of the corresponding sleep efficiency and 6-sulphatoxymelatonin level after bright light exposure with respect to the sleep satisfaction level

Sleep Satisfaction Level	Sleep Efficiency (SE)		6-sulphatoxymelatonin (aMT6s) Level	
	Day 5	Day 6	Day 5	Day 6
Increase group	-	-	-	-
Decrease group	-	-	-	-
Unchanged group	-	-	-	-

Note: "-" = $p < 0.05$
"-" = $p > 0.05$

The changes in the corresponding sleep-wake parameters

In the main study, the Spearman test showed that significant correlations between the change in the SSL and the changes in the actigraphic sleep-wake parameters were only identified on Day 5. These significant correlations were found on both Day 5 and Day 6 in the combined findings. Among the parameters on Day 5, the changes in sleep efficiency (SE), sleep-wake ratio (SWR), total sleep time (TST), total time of waking after sleep onset (WASOt) and sleep offset time (SoffT) on Day 6 were significantly correlated with the changes in SSL (Table 11.6). The change in sleep onset time (SOT) was not significantly correlated with the alteration in SSL after the findings of the main study and the further field trial were analysed together. On the contrary, the correlation between the change in SoffT and the alteration of SSL became significant.

Table 11.6 The correlation coefficients and significant levels between sleep satisfaction level and sleep-wake parameters

Correlation Items	*Day 5*		*Day 6*	
	r	*p*	r	*p*
SSL - SE	0.48	0.001	0.09	0.559
SSL - SWR	0.46	0.001	0.10	0.517
SSL – TST	0.52	0.000	0.19	0.189
SSL – TBT	0.11	0.465	0.26	0.073
SSL - SOL	0.19	0.192	-0.04	0.806
SSL - SOT	-0.25	0.090	0.16	0.284
SSL - WASOf	0.27	0.066	-0.01	0.941
SSL - WASOd	0.25	0.083	-0.09	0.567
SSL – WASOt	0.42	0.003	-0.01	0.949
SSL – SoffT	-0.12	0.433	0.38	0.008

Note: SE – Sleep Efficiency
SWR – Sleep Wake Ratio
TST – Total Sleep Time
TBT – Total Bed Time
SOL – Sleep Onset Latency
SOT – Sleep Onset Time
WASOf – number of waking after sleep onset
WASOd – Duration of each waking after sleep onset
WASOt – Total time of waking after sleep onset
SoffT – Sleep Offset Time
SSL – Sleep Satisfaction Level

Similar to the main study, when subjects had their SSLs increased on Day 5, more than 70% of the subjects had their SEs, SWRs and TSTs increased but WASOts decreased. In terms of their SoffTs, the change was diverse. A reverse phenomenon, however, was found in the decrease group in the case of SE, SWR, TST and WASOt on Day 5. For those with their SSLs increased on Day 6, no prominent trend of change was identified. But for those with their SSLs decreased on Day 6, more than 65% of them had their SEs, SWRs and TSTs decreased but WASOts increased. 77.8% of them mainly had their SoffTs shifted forwards. The detailed description of the correlation between the change in SSL and the alteration in SoffT is presented in the following sections.

Sleep Offset Time (SoffT) On Day 6, the change in SSL was significantly correlated with the change in SoffT ($r = 0.38$, $p = 0.008$). However, no significant correlation was identified on Day 5 ($r = -0.12$, $p = 0.433$).

The increase group on Day 5

For those with a SSL increase on Day 5 (n = 15), the insignificant shift in SoffTs was shown (Table 11.7). There were 53.3% (n = 8) of the subjects with SoffT shifted backwards while 46.7% (n = 7) had shifted forwards. The *mean duration for SoffT of backward shift* was 41.02 minutes (SD = 33.13 minutes) with a range of duration of shift between 4.85 and 111.50 minutes. The *mean duration for SoffT of forward shift* was 15.18 minutes (SD = 9.82 minutes) with a range of duration of shift between 2.00 minutes and 26.50 minutes.

Table 11.7 The results of paired-sample *t* test of the changes in sleep offset time after bright light exposure with respect to the sleep satisfaction level

	Paired Mean Differences (min)	*t*	*p*
Increase group on Day 5 (n = 15)	-7.50	-0.61	0.553
Increase group on Day 6 (n = 15)	-5.52	-0.45	0.659
Decrease group on Day 5 (n = 11)	-4.83	-0.36	0.725
Decrease group on Day 6 (n = 9)	-32.90	-2.41	0.042

The increase group on Day 6

There were 15 subjects with SSL increased on Day 6. Similar to Day 5, their related SoffTs showed no significant shift after bright light exposure (Table 11.7). Among them, 60.0% (n = 9) of the subjects had SoffT shifted backwards but 33.3% (n = 5) shifted forwards and 6.7% (n = 1) were unchanged. The *mean duration for SoffT of backward shift* was 34.12 minutes (SD = 22.58 minutes) with a range of duration of shift between 0.28 and 78.20 minutes. The *mean duration for SoffT of forward shift* was 44.87 minutes (SD = 42.75 minutes) with a range of duration of shift between 0.93 and 102.75 minutes.

The decrease group on Day 5

These 11 subjects had their SoffTs shifted insignificantly after bright light exposure (Table 11.7). There were 45.5% (n = 5) of the subjects with SoffT shifted backwards and 54.5% (n = 6) shifted forwards. The *mean duration for SoffT of backward shift* was 35.78 minutes (SD = 30.32 minutes) with a range of duration of shift between 1.68 and 73.26 minutes. The *mean duration for SoffT of forward shift* was 38.70 minutes (SD = 13.15 minutes) with a range of duration of shift between 20.58 and 56.35 minutes.

The decrease group on Day 6

There were 9 subjects with their SSLs decreased on Day 6 and their related SoffTs shifted significantly after bright light exposure (Table 11.7). Among them, 22.2% (n = 2) of the subjects showed SoffT backward shift and 77.8% (n = 7) a forward shift. The *mean duration for SoffT of backward shift* was 13.77 minutes (SD = 0.12 minutes) with a range of duration of shift between 13.68 and 13.85 minutes. The *mean duration for SoffT of forward shift* was 46.25 minutes (SD = 36.08 minutes) with a range of duration of shift between 2.00 and 108.35 minutes.

The changes in the related 6-sulphatoxymelatonin (aMT6s) level

The change in SSL was not significantly correlated with the changes in the corresponding aMT6s levels. This finding was no different from the results of the main study.

The effects of bright light exposure on the subjects: The changes in actigraphic sleep-wake parameters

As with the main study, the first hypothesis stated in the Chapter 1 was supported when the sleep-wake parameters were considered individually.

Only the number of waking after sleep onset (WASOf) changed significantly after bright light exposure (p = 0.026). With reference to the confidence interval (CI) at the 95% degree of confidence, most of the CIs of the combined findings were narrower than those of the main study (Tables 11.8 – 11.16). This reflected that the findings of the further field trial were more precise than those of the main study.

Table 11.8 The results of paired-sample *t* test of the changes in sleep efficiency, SE, and sleep-wake ratio, SWR, after bright light exposure (N = 48)

	Paired Mean Differences	Confidence Interval	*t*	df	*p*
Day 2 - Day 5: SE	-2.31	-4.91 to 0.28	-1.79	47	0.079
Day 2 - Day 5: SWR	-2.61	-7.42 to 2.21	-1.09	47	0.281
Day 2 - Day 6: SE	-0.45	-2.51 to 3.41	-0.31	47	0.761
Day 2 - Day 6: SWR	-0.62	-1.16 to 2.39	-0.70	47	0.490

Note: Paired mean differences and confidence interval of SE was measured in percentage.
Paired mean differences and confidence interval of SWR was a ratio.

Table 11.9 The results of paired-sample *t* test of the changes in the total sleep time after bright light exposure (N = 48)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-10.30	-24.00 to 3.40	-1.51	47	0.137
Day 2 - Day 6	-3.86	-13.97 to 21.70	-0.44	47	0.665

Table 11.10 The results of paired-sample *t* test of the changes in the total bed time after bright light exposure (N = 48)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-3.85	-10.77 to 18.47	-0.53	47	0.599
Day 2 - Day 6	-3.30	-8.62 to 15.22	-0.56	47	0.580

Table 11.11 The results of paired-sample *t* test of the changes in sleep onset latency after bright light exposure (N = 48)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-2.87	-3.87 to 9.62	-0.86	47	0.396
Day 2 - Day 6	-1.19	-4.77 to 7.15	-0.40	47	0.689

Table 11.12 The results of paired-sample *t* test of the changes in the sleep onset time after bright light exposure (N = 48)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-1.98	-5.45 to 9.45	-0.54	47	0.592
Day 2 - Day 6	-3.48	-3.22 to 10.18	-1.05	47	0.301

Table 11.13 The results of paired-sample *t* test of the changes in number of waking after sleep onset after bright light exposure (N = 48)

	Paired Mean Differences (Times)	Confidence Interval (Times)	*t*	df	*p*
Day 2 - Day 5	-0.15	-1.12 to 1.42	-0.23	47	0.818
Day 2 - Day 6	-1.92	-3.66 to -0.18	-2.22	47	0.032

Table 11.14 The results of paired-sample *t* test of the changes in the duration of each waking after sleep onset after bright light exposure (N = 48)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-1.31	-0.37 to 2.99	-1.57	47	0.124
Day 2 - Day 6	-1.48	-0.30 to 3.26	-1.67	47	0.101

Table 11.15 The results of paired-sample *t* test of the changes in the total time of waking after sleep onset after bright light exposure (N = 48)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-6.21	-3.98 to 16.40	-1.23	47	0.226
Day 2 - Day 6	-5.27	-17.66 to 7.13	-0.86	47	0.397

Table 11.16 The results of paired-sample *t* test of the changes in the sleep offset time after bright light exposure (N = 48)

	Paired Mean Differences (min)	Confidence Interval (min)	*t*	df	*p*
Day 2 - Day 5	-2.08	-13.00 to 8.80	-0.39	47	0.701
Day 2 - Day 6	-2.08	-10.02 to 14.18	-0.35	47	0.731

As with the main study, no significant changes in the corresponding aMT6s levels were observed in the combined findings. The second hypothesis was rejected. However, significant alterations in the related SSLs were only found in the increase group of sleep efficiency (SE) and sleep-wake ratio (SWR) on Day 5 ($p = 0.022$), the increase groups of total sleep time (TST) ($p = 0.007$ on Day 5; $p = 0.032$ on Day 6) and the decrease group of the total time of waking after sleep onset (WASOt) on Day 5 ($p = 0.007$). The third hypothesis was supported when the sleep-wake parameters were considered individually.

The effects of bright light exposure on the subjects: The changes in 6-sulphatoxymelatonin (aMT6s) level

With reference to the Light On Period of the combined findings, 35 subjects had completed the 6-day study procedure including urine collection, actigraphic data recording and sleep log. As revealed by the paired-sample *t* test, the changes in the aMT6s level were not statistically significant in the bright light exposure stage, Days 3 and 4. The first hypothesis stated in Chapter 1 was rejected. With reference to the confidence interval (CI) at the 95% degree of confidence, the CI of the combined findings was wider than that of the main study (Tables 11.17). The combined findings of aMT6s levels seemed to be dispersed. The related changes are described in Figure 11.2.

Table 11.17 The results of paired-sample *t* test of the changes in the 6-sulphatoxymelatonin level with respect to the Light On Period (N = 35)

	Paired Mean Differences (pmol/ml)	Confidence Interval (pmol/ml)	*t*	df	*p*
Day 2 - Day 3	-0.72	-0.69 to 2.13	-1.03	34	0.310
Day 3 - Day 4	-0.51	-3.04 to 2.01	-0.42	34	0.681

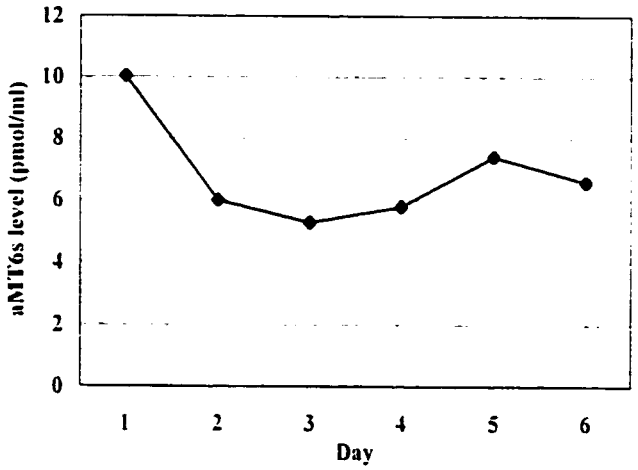


Figure 11.2 The changes in the 6-sulphatoxymelatonin, aMT6s, level with respect to the Light On Period (N = 35)

When the findings on Day 3 were compared with those of Day 2, 37.1% (n = 13) of the subjects had their aMT6s levels increased while 62.9% (n = 22) had theirs decreased. The *mean increase in aMT6s level* was 2.61 pmol/ml (SEM = 0.53 pmol/ml) with a range of increase between 0.11 and 7.02 pmol/ml. The *mean decrease in aMT6s level* was 2.68 pmol/ml (SEM = 0.81 pmol/ml) with a range of decrease between 0.16 and 18.20 pmol/ml. Similarly, when the findings on Day 4 were compared with those of Day 3, 42.9% (n = 15) of the subjects had their aMT6s levels increased and 57.1% (n = 20) decreased. The *mean increase in aMT6s level* was 5.02 pmol/ml (SEM = 2.26 pmol/ml) with a range of increase between 0.12 and 35.13

pmol/ml. The *mean decrease in aMT6s level* was 2.86 pmol/ml (SEM = 0.78 pmol/ml) with a range of decrease between 0.21 and 14.93 pmol/ml. The aMT6s levels in the Light On Period of the bright light exposure stage were lower than those before bright light exposure.

With respect to this Light Off Period, 48 subjects had completed the 6-day study procedure including urine collection, actigraphic data recording and sleep log. After bright light exposure, there was no statistically significant change in the aMT6s level in the post-bright light exposure stage, Days 5 and 6. The first hypothesis was rejected. With reference to the confidence interval (CI) at the 95% degree of confidence, the CI of the combined findings was slightly wider than that of the main study on Day 5 but narrower on Day 6 (Table 11.18). The related changes in the aMT6s level throughout the experiment are described in Figure 11.3.

Table 11.18 The results of paired-sample *t* test of the changes in 6-sulphatoxymelatonin level with respect to the Light Off Period (N = 48)

	Paired Mean Differences (pmol/ml)	Confidence Interval (pmol/ml)	*t*	df	*p*
Day 2 - Day 5	-0.27	-2.99 to 2.45	-0.20	47	0.844
Day 2 - Day 6	-0.68	-3.96 to 2.61	-0.41	47	0.681

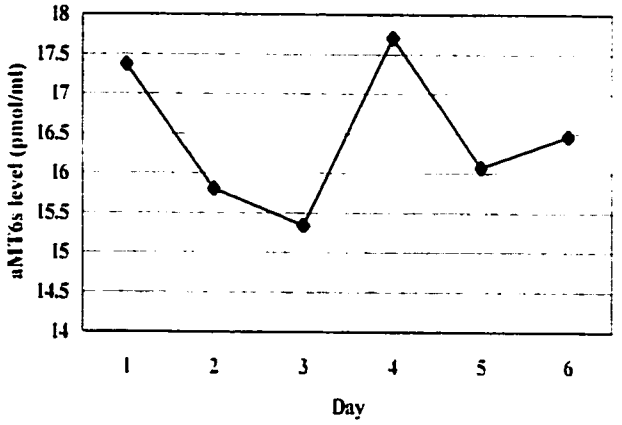


Figure 11.3 The changes in the 6-sulphatoxymelatonin, aMT6s, level throughout the experiment with respect to the Light Off Period (N = 48)

On Day 5, there were 54.2% (n = 26) of the subjects with aMT6s levels increased while 45.8% (n = 22) showed a decrease. The *mean increase in aMT6s level* was 6.13 pmol/ml (SEM = 1.29 pmol/ml) with a range of increase between 0.20 and 26.15 pmol/ml. The *mean decrease in aMT6s level* was 6.66 pmol/ml (SEM = 1.54 pmol/ml) with a range of decrease between 0.31 and 29.61 pmol/ml. A similar situation was presented on Day 6 in which 52.1% (n = 25) of the subjects showed aMT6s levels increased but 47.9% (n = 23) showed a decrease. The *mean increase in aMT6s level* was 7.99 pmol/ml (SEM = 1.66 pmol/ml) with a range of increase between 0.14 and 32.19 pmol/ml. The *mean decrease in aMT6s level* was 7.27 pmol/ml (SEM = 1.77 pmol/ml) with a range of decrease between 0.66 and 37.59 pmol/ml. After bright light exposure, the mean aMT6s level in the Light Off Period of the post-bright light exposure stage was higher than that on Day 2.

As with the main study, no significant changes were observed in the related SSLs. The fourth hypothesis was rejected. However, the corresponding sleep onset latency (SOL) altered significantly on Day 5 (p = 0.021) when the mean aMT6s level increased. About 60% of the increase group subjects on Day 5 had their corresponding SOLs increased. This alteration was not observed in the main study. The second hypothesis was supported in the combined findings when the sleep-wake parameters were considered individually.

Discussion

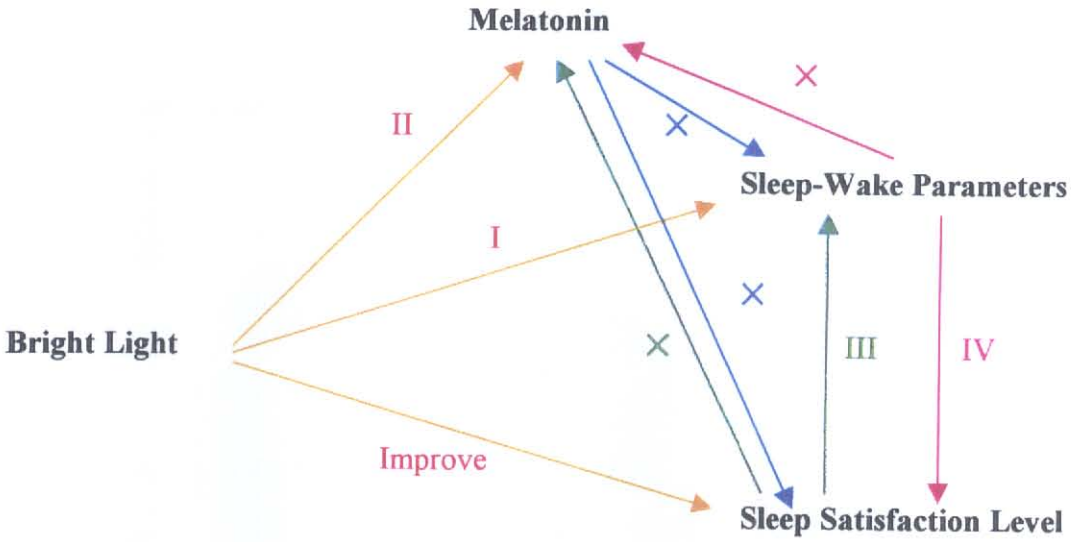
Different from the main study, there was a significant correlation between the consumption of dairy products and sleep quality as shown by the combined findings. Among the good sleepers (n = 20), 55.0% of them (n = 11) consumed dairy products regularly. In the case of the poor sleepers (n = 26), 30.8% of them (n = 8) had this habit. The consumption rate in the good sleepers was higher than that in the poor sleepers. Together with the significant correlation between the consumption of dairy products and sleep quality, this suggested that dairy products promote sleep.

Reviews of the corresponding changes in the mean aMT6s level and sleep-wake parameters in relation to the alteration in SSL after bright light exposure, the investigator observed that other than sleep efficiency (SE), sleep-wake ratio (SWR), total sleep time (TST) and the total time of waking after sleep onset (WASOt), sleep offset time (SoffT) was negatively associated with sleep satisfaction level (SSL) on Day 6. In the case of subjects with their SSLs increased, subjects mainly had their SoffTs shifted backwards. When the subjects had their SSLs decreased, they mainly had their SoffTs shifted forwards. These changes were related to the rising time. Since elderly people are characterised with advance in sleep phase (Swift and Shapiro, 1993), a comparatively late rising time can improve their sleep quality.

There were no great differences in the combined findings and the main study results in accordance with the sleep-wake parameters. As shown by the narrower confidence intervals (CIs) among the sleep-wake parameters, the combined findings were more precise than those of the main study results. This implies that the increase in the number of subjects may, most probably, result in the same insignificant findings as shown in the main study. When sample size may not be the key factors of the insignificant results, the confounding factors such as those stated in the limitations of the study in Chapter 10 are suspected to be the contributing factors.

In terms of aMT6s levels, no great differences were found between the main study results and the further field trial findings. The CIs in the Light On Period of the bright light exposure stage and in the Light Off Period on Day 5 were wider than those of the main study. The dispersal of the data may be due to the great variability of the light-induced effects on melatonin secretion. The variability is suggested to be related to the differences in the physical conditions of the subjects. The degrees of pineal calcification and cataract can influence the light-induced effects differently (Details refer to Chapter 10 – Limitations of the study). The significant alterations in the related sleep onset latency (SOL) in the increase group on Day 5 was consistent with the sleep-inducing effect of exogenous melatonin (Reiter and Robinson, 1995; Pierpaoli, Regelson and Colman, 1996) as this group of subjects mainly had their SOLs decreased. Sleep induction may be achieved by altering the endogenous melatonin secretion.

Summarising the combined findings, the investigator concluded that there were no statistically significant changes identified in the study. No cause-and-effect relationships were observed. However, trends of changes of the variables were found using the descriptive statistics. With reference to the descriptive results of the combined findings, the investigator revised the figure of the hypothesized relationships between bright light, melatonin and sleep (Figure 1.1). Figure 11.4 was the summary of the combined findings. From this summary, some research directions were brought to light.



Note:
- indicates bright light effects on sleep satisfaction level, sleep-wake parameters and melatonin
- indicates influences of sleep satisfaction level on sleep-wake parameters and melatonin
- indicates influences of sleep-wake parameters on sleep satisfaction level and melatonin
- indicates influences of melatonin on sleep satisfaction level and sleep-wake parameters
- × indicates no influences
- I states the light-induced increase trend in sleep efficiency and sleep-wake ratio
- II states the possible light-induced suppressive effect on melatonin secretion in the Light On Period
- III states the positive correlation between sleep satisfaction level and sleep efficiency, sleep-wake ratio, total sleep time, the total time of waking after sleep onset and sleep offset time
- IV states an improvement in sleep quality when there were increase in sleep efficiency, sleep-wake ratio and total sleep time, a decrease in the total time of waking after sleep onset and a backward shift of sleep offset time

Figure 11.4 Summary of the combined findings

Recommendations for future research directions

Since no statistically significant results were found in the study and the increase in the sample size may not help in obtaining significant findings, further studies on

bright light, sleep and melatonin should be planned with the consideration as stated in the limitations of the study in the Chapter 10. To examine a cause-and-effect relationship between the variables, case-control design is preferred. Apart from the above suggestions, this study has highlighted needs for several areas of development.

1. DIS, DMS and EMA were common among the subjects. Different sufferers possessed different characteristics of sleep disturbance. The investigator observed that such characteristics brought about a certain degree of conflict among the subjects in the elderly care homes. Studies on these conflicts may reveal urgent issues regarding sleep problems in elderly people especially those who are living in elderly care homes. Apart from this, studies on the effects of sunlight on elderly people should be conducted. Sunlight is essential for vitamin D production and maintaining one's well-being (Lillyquist, 1985). As light can regulate sleep (Duffy, Kronauer and Czeisler, 1996), a morning or evening walk may be beneficial to elderly people. Sunlight both in the morning and in the evening is mild. Elderly people exposed to sunlight may have their melatonin secretion rhythms and sleep-wake cycles altered. In addition, sunlight exposure also provides chances for elderly people to gather together and improve their social network.

2. Although subjects did not consider that nocturia was a serious cause of sleep disturbance, it still followed frequent waking at night. Even though such

waking does not seem to interrupt sleep, there is an increase in the chance of a fall. Therefore, nocturia in elderly people should not be ignored. Another study illustrated that nocturnal urine production was reduced after the administration of hypnotics in elderly patients (Asplund and Aberg, 1992). The relationship between nocturnal urine production and sleep should be further investigated. As frequent nocturia was believed to be the result of lower vasopressin levels, some researchers proposed that the cyclical vasopressin level might be related to the light-dark cycle or the melatonin cycle (Donahue and Lowenthal, 1997). Thus, further studies are needed to clarify the influence of nocturia on sleep and confirm the relationships between vasopressin level, melatonin level and the light-dark cycle.

3. As illustrated by the results, both intentional and unintentional naps were not significantly related to self-rated sleep quality. The reported characteristics of napping (tiredness as the main reason, afternoon as the most popular time and unintentional napping as an unavoidable episode) have encouraged the investigator to assume the presence of a pattern or rhythm of napping and its association with sleep or activity. It was interesting to observe that the subjects could not fall asleep in intentional napping but could not resist an unintentional nap. Further exploration of the nature of napping is necessary to understand this mechanism.

4. To assess one's sleep quality, it is important to define a good or poor sleep. According to the findings, SOL and WASOf seemed to be implicated in the determination of sleep satisfaction. The investigator wonders whether sleep quality can be identified in a quantitative way in the future by using SOL and WASOf only. Further exploration on sleep satisfaction and the SOL or the WASOf is needed to confirm the assumption.

5. Since measurement of the sleep-related factors was not thorough in this study, the findings concerning their associations between sleep satisfaction should be further studied. To study these associations, the investigator suggests conducting studies that include the detailed measurement of these factors on different dimensions. The dimensions include the amount consumed and the consumption time of the foodstuffs, the duration and energy expenditure during exercise, and the duration, intensity and exposure to sunlight.

6. Since WASOf has been identified to be negatively associated with WASOd, it is worth investigating the underlying mechanisms for monitoring the interaction between these two parameters during bright light exposure. If the continuity of sleep is a determining factor of a good sleep, WASOf can be decreased by increasing WASOd to a considerable degree. The investigator finds this information invaluable in formulating a protocol for sleep management.

7. By taking account of the results of this, the investigator has identified two trends of bright light exposure for future studies. In order to compensate for the unavailability of an "absolutely dark" environment, light intensity of more than 2500 lux should be employed to create a greater contrast between light and dark in future studies. As a result, a stronger coupling strength can be attained. Light intensity up to 10000 lux was suggested as a safe level (Blehar, Rosenthal, Terman and Wehr, 1990; Kogan and Guilford, 1998). By being aware of the occurrence of any ophthalmological abnormalities, light-induced effects on the subjects may be more easily observed. In addition, future studies should rely on extra-pineal means of bright light application. In view of the difficulties in monitoring the degree of pineal calcification and cataract, the thickness of glasses and the pupil size of elderly people, researchers (Campbell and Murphy, 1998; Lockley, et al., 1998) are encouraged to explore extra-pineal means of bright light application. In reality, intolerance to bright light and the occurrence of possible side effects can compromise the compliance of the subjects. Therefore, the development of extra-pineal means of bright light exposure is essential.

Conclusion

Ten subjects participated in this further field trial. As shown by the findings, there were no great differences between the data from this field trial and the main study. According to the combined findings, significant differences were not identified in all the variables. No cause-the-effect relationships were observed. Nonetheless, trends of changes of the variables were found using descriptive statistics. Based on the combined findings, large sample size and case-control design were recommended to be used in further studies. Future research directions were suggested in accordance with the insights from the results.

Chapter 12

Conclusion

This study was comprised of two parts: the main study and the further field trial. The main study was the core of the project while the further field trial provided information to verify the main study results.

Summary of the main study results

Sleep histories of the subjects were described in terms of their sleep complaints, sleep-wake pattern, sleep satisfaction level and mean 6-sulphatoxymelatonin (aMT6s) level. Difficulty in initiating sleep (DIS), difficulty in maintaining sleep (DMS) and early morning awakening (EMA) were the common sleep complaints among the subjects. For the DIS sufferers, their mean sleep onset latency (SOL) was an hour longer than that of the non-sufferers, whose SOL was already an hour long. DMS was the most common sleep complaint among the subjects. The sleep in the DMS sufferers was more fragmented than the sleep in the non-sufferers. Nearly half of DMS sufferers were awake for a long duration at night. Nocturia, was the major reason for waking at night. This was not

claimed to be an aggravating factor for their sleep disturbance though micturition was the main activities after waking at night. One third of the subjects found nothing aggravated their sleep disturbance. In terms of EMA sufferers, more than 90% of them reported their sleep quality as bad or very bad. There were no great differences between the sufferers and non-sufferers in their sleep offset times (SoffT) and rising times.

In the case of sleep-wake patterns, the conditions of napping, nocturnal sleep-wake parameters and sleep-related factors were examined. Finally, the correlation between sleep log, actigraphic recording and the first-night effect on aMT6s level was determined. Napping was divided into intentional and unintentional naps. Few subjects (n = 9) napped intentionally. Most of them claimed tiredness as the main reason for napping though only two could actually fall asleep during the attempted nap. Unlike intentional napping, subjects (n = 16) could not resist an unintentional nap. About half of those who considered their sleep as bad or very bad dozed habitually. Both intentional and unintentional naps occurred mostly in the afternoon and they were not significantly correlated with self-rated sleep quality. When the actigraphic sleep-wake parameters of the subjects were examined, it was found that sleep was fragmented in the subjects. In addition, the duration of waking at night was long. When the subjects were classified as good or poor sleepers, there was no great difference in the nocturnal sleep-wake parameters except poor sleepers awoke more at night. Regarding the sleep-related factors, caffeine-containing

products, dairy products, exercise and sunlight exposure were popular among the subjects with the last two activities more welcomed by the subjects. These sleep-related factors had no significant correlation with sleep satisfaction level. The correlations of total bed time (TBT), total time of waking after sleep onset (WASOt) and sleep offset time (SoffT) between the sleep log and the actigraphic recording were well correlated. The discrepancies in sleep efficiency (SE), sleep onset time (SOT) and WASOt between these two sets of data were insignificant. Generally, subjects tended to underestimate their sleep-wake parameters when compared with the actigraphic recording. In terms of the sleep satisfaction levels (SSLs) and the aMT6s levels, the desirable duration for sleeping and the mean aMT6s levels of the good and poor sleepers were similar. Self-rated health status was not significantly correlated with SSL. No first-night effect was demonstrated by their mean aMT6s levels.

All subjects wanted to improve their sleep quality. They had undergone a 6-day experiment in which they were exposed to bright light. To study the effects of bright light exposure on the subjects, the changes in the SSL, sleep-wake parameters and mean aMT6s level were assessed. Generally, there was an improvement in SSL despite subjects tending to show SSLs unchanged after bright light exposure. There were no significant changes in the corresponding aMT6s levels. The first and fourth hypotheses stated in the Chapter 1 were rejected. However, significant changes in some sleep-wake parameters were

found on Day 5. The parameters were SE. SWR. TST. SOT and WASOt. When subjects had their SSLs increased on Day 5. more than 70% of the subjects had their SEs. SWRs and TSTs increased but WASOts decreased. Their SOTs mainly shifted forwards. In the case of subjects with a SSL decrease. most of them indicated a decrease in SE. SWR and TST but an increase in WASOt. They mainly had their SOTs shifted backwards on Day 5. The third hypothesis was supported when the sleep-wake parameters were considered individually.

After bright light exposure. all sleep-wake parameters changed insignificantly except for the number of waking after sleep onset (WASOf) on Day 6. The first hypothesis was supported when the sleep-wake parameters were considered individually. Actigraphic WASOf showed a decrease in about 40% of the subjects in the post-bright light exposure stage while it was mostly reported as decreased or unchanged in the sleep log. WASOf was negatively correlated with the duration of each waking after sleep onset (WASOd) but was positively associated with WASOt. Although most of the changes were insignificant. some sleep-wake parameters demonstrated certain trends in their alterations. Subjects tended to show an increase in SE. SWR (sleep-wake ratio) and SOL. There were more subjects with their SOTs shifted forwards than backwards. The shift in SOT was not associated with that of SoffT. In the case of TBT (total bed time). the increase groups tended to show a TST (total sleep time) increase while the tendency was undetermined for those with TBT decreased. For the corresponding changes in the mean aMT6s levels and SSLs. no significant change

in the mean level was identified. Prominent alterations in the related SSL were reported in SE. SWR. TST. TBT and WASOt after bright light exposure. The second and third hypotheses were rejected.

When the changes in the mean aMT6s levels in both the Light On Period and the Light Off Period were studied. no significant changes were detected after bright light exposure. The first hypothesis was rejected. However. more subjects showed mean levels decreased rather than increased during the Light On Period when comparing with the day before (paired difference mean [Day 2 – Day 3]: 0.09 pmol/ml: [Day 3 – Day 4]: 0.46 pmol/ml). For the change in the mean aMT6s level during the Light Off Period. no dominant trend was observed. The related SSL tended to increase on Day 5 when the mean aMT6s level was increased. Apart from the increase in SSL. subjects mostly reported their SSLs as unchanged regardless of the changes in the mean aMT6s levels. When the corresponding actigraphic sleep-wake parameters were considered. the changes were insignificant but trends were observed. Subjects with mean aMT6s levels decreased tended to show an increase in SE. SWR. TST. SOL. WASOf and a decrease in WASOt after bright light exposure. The second and fourth hypotheses were rejected.

Summary of the combined findings

Ten subjects had joined the further field trial. Their characteristics and reactions towards the light-induced effects were similar to those in the main study. In view of the stability in the weather and socio-political environment in Hong Kong, subjects of the further field trial were assumed to be under similar social and living conditions to those in the main study. The main study results and the further field trial findings were analysed together.

In the combined findings, 48 subjects completed the study successfully. Their characteristics including demographic data, sleep histories, the sleep wake parameters, 6-sulphatoxymelatonin levels and sleep-related factors were similar to those in the main study. However, differences were found. In the combined findings, both intentional and unintentional nappings were common among the subjects (about 30%). The correlation between self-rated sleep quality and the dairy product consumption habit was significant ($r = 0.31$, $p = 0.039$).

As with the main study, improvement of sleep quality was observed after bright light exposure though the improvement was not prominent ($p = 0.455$ on Day 5; $p = 0.169$ on Day 6). No prominent trends of changes in the related aMT6s levels were observed regarding the alterations in SSL. Unlike the main study, significant correlations between the change in the SSL and the changes in the

corresponding actigraphic sleep-wake parameters were found on both Days 5 and 6. The change in the corresponding SOT was not significantly correlated with the alteration in SSL while the opposite was demonstrated by the change in the related SoffT. The first and fourth alternative hypotheses were rejected. The third was supported when the sleep-wake parameters were considered individually.

As with the main study, only the WASOf changed significantly after bright light exposure ($p = 0.026$). No prominent changes in the related aMT6s levels were observed. Significant alterations in the corresponding SSLs were only found in the increase group of SE and SWR on Day 5, the increase groups of TST and the decrease group of WASOt on Day 5. The first and third hypotheses were supported when the sleep-wake parameters were considered individually. The second hypothesis, however, was rejected.

No great variation between the main study results and the combined findings was observed in the changes of excreted melatonin levels. In the combined findings, the related SOL altered significantly on Day 5 when the mean aMT6s level increased. This significant alteration was not illustrated in the main study. In brief, the first and fourth hypotheses were rejected. The second hypothesis was supported in the combined findings when the sleep-wake parameters were considered individually.

In summary

This study has revealed the nature of sleep disturbances in institutionalized elderly women. By examining the characteristics of different sleep disturbances, the investigator discussed the possibility of including a simple sleep assessment in the management sleep in an elderly care home. In addition, the physical condition of the elderly people, the increase in nocturia and the chances of a fall should all be considered when assessing the implications of this study. When the subjects were classified into good or poor sleepers, the similarities in their actigraphic sleep-wake parameters and the mean aMT6s levels ascertained their need to improve their sleep. After bright light exposure, change trends in the sleep-wake parameters, sleep satisfaction level and aMT6s level were observed even though most of the alterations were not statistically significant and so most of the alternative hypotheses were not established. The change trends have provided valuable information for formulating a protocol for sleep management and defining sleep satisfaction. They have illustrated the feasibility of conducting sleep studies in a field setting, and this is considered to be important for the development of sleep studies. This study not only revealed the needs of the sufferers of sleep disturbance, it also demonstrated the way to regulate sleep outside the sleep laboratory.

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香港理工大學
護理及醫療科學系

編號:_____
日期:_____

老人之睡眠困擾（甄選部份）

第一部份　個人資料

請在適當的方格內加以「✓」號。

1. 年齡：_____

2. 性別：_____

3. 身高：_____（公分/呎）

4. 體重：_____（公斤/磅）

5. 你目前的健康狀況：

   ❑ 很好
   ❑ 好
   ❑ 普通
   ❑ 差
   ❑ 很差

6. 你的身體及精神上，有沒有什麼疾病？

   _____

7. 你有否長期服食藥物？*（請列明其名稱、劑量、每日的服食次數、該藥已服用的年期及被研究者對該藥的有關反應）*

   _____
   _____

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8. 通常你晚間睡得好嗎？

- ❑ 很好
- ❑ 好
- ❑ 普通
- ❑ 差
- ❑ 很差

9. 通常朝早起身時，你的精神好嗎？

- ❑ 精神奕奕
- ❑ 普通
- ❑ 精神不足
- ❑ 重係好想睡

10. 你是否獨睡一床？

- ❑ 是
- ❑ 否

11. 你有否要用其他東西協助入睡？請列明。

_____

第二部份　過去睡眠狀況

1. 你的睡眠困擾已持續了多久？ _____個月/年

2. 你的睡眠困擾狀況，通常一星期會有多少晚發生？

_____

3. 你的睡眠困擾之發生是：

- ❑ 漸發的
- ❑ 突發的

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4. 你的睡眠困擾之變化模式是：

- ❑ 週期性的(例如:每星期幾次、每個月幾次)
- ❑ 與季節有關的(例如:只發生在春天)
- ❑ 困擾未曾停過
- ❑ 沒有一定模式

5. 在什麼情況下，你在晚上的睡眠困擾情況會惡化？

- ❑ 經常要去廁所
- ❑ 太嘈
- ❑ 太凍或太熱
- ❑ 身體不適
- ❑ 不清楚
- ❑ 其他：_____

6. 你的睡眠困擾是否與往年所發生的事情有關？
(例如:親人逝世、退休、身體或精神疾病等)

_____

7. 你是否難於入睡？

- ❑ 經常是
- ❑ 間中是
- ❑ 不常是
- ❑ 不是

8. 你是否半夜常常醒來？

- ❑ 經常是
- ❑ 間中是
- ❑ 不常是
- ❑ 不是

9. 你是否很早便醒，但醒後又不可再入睡？

- ❑ 經常是
- ❑ 間中是
- ❑ 不常是
- ❑ 不是

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10. 你日間是否精神難以振奮？

- ❑ 經常是
- ❑ 間中是
- ❑ 不常是
- ❑ 不是

11. 你的睡眠困擾是否與某些徵狀有關(例如:呼吸困難、夢遊等)？
請列明該徵狀每週發生的次數。

_____

12. 在過去半年，你是否試過很憂慮或緊張？

- ❑ 是
- ❑ 否

13. 在過去半年，你是否常常處於很擔心的狀況(常常指已有數天)？

- ❑ 是
- ❑ 否

14. 你是否常常對於身邊的事物(不論喜好或不喜好)，提不起勁或不感興趣？(常常指差不多每天)

- ❑ 是
- ❑ 否

15. 在過去兩年，你有否情緒低落？

- ❑ 經常有
- ❑ 間中有
- ❑ 不常有
- ❑ 沒有

- 完 -

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Appendix 1

The Hong Kong Polytechnic University Date: _____
Department of Nursing and Health Sciences . Code: _____

Screening Assessment

Part I Demographic Information

Please put a ✓ in the appropriate box.

1. Age: _____

2. Sex: _____

3. Body Height: _____ (cm / ft & in)

4. Body Weight: _____ (kg / lbs)

5. How do you describe your present health status?

   ❑ Very good
   ❑ Good
   ❑ Acceptable
   ❑ Poor
   ❑ Very poor

6. Do you have any mental, medical or physical illness(es)?

   _____

7. Are you taking any medication(s)? Please specify the medication(s) with dosage, frequency, date of commencement & any reaction(s) related to the medication(s).

   _____
   _____

8. How do you describe your sleep status at night?

   ❑ Very good
   ❑ Good
   ❑ Acceptable
   ❑ Poor
   ❑ Very poor

9. How do you feel upon arising?

- ❑ Refreshed
- ❑ Acceptable
- ❑ Still tired
- ❑ Sleepy

10. Do you sleep alone?

- ❑ Yes
- ❑ No

11. Do you use any sleep aids? Please describe.

Part II Sleep History

1. How long have you been suffering from sleep disturbance?

____ month(s) / year(s)

2. How many night(s) a week do you have sleep disturbance?

____ nights per week

3. How do you describe the onset of your sleep disturbance?

- ❑ Gradual
- ❑ Sudden

4. How do you describe your course of sleep disturbance?

- ❑ Recur periodically (eg per week or per month)
- ❑ Recur in relation to season (eg especially in spring)
- ❑ Persistent without remission periods
- ❑ No fixed mode

5. What will exacerbate your sleep disturbance?

- ❑ Go to toilet frequently
- ❑ Too Noisy
- ❑ Temperature: too cold or too hot
- ❑ Physical discomfort
- ❑ I don't know
- ❑ Others: _____

6. Was/Were there any event(s) related to the onset of the sleep disturbance (eg death of loved one, retirement, physical or mental problems, etc)?

_____

7. Do you have any trouble in falling asleep at night?

- ❑ Frequently
- ❑ Sometimes
- ❑ Rarely
- ❑ Never

8. Do you have frequent awakenings during the night?

- ❑ Frequently
- ❑ Sometimes
- ❑ Rarely
- ❑ Never

9. Do you wake up too early in the morning?

- ❑ Frequently
- ❑ Sometimes
- ❑ Rarely
- ❑ Never

10. Do you have any difficulty in staying awake during the day?

- ❑ Frequently
- ❑ Sometimes
- ❑ Rarely
- ❑ Never

11. Do you have any symptoms (eg shortness of breath, nightmare, etc) related to your sleep disturbance? Please state the rate of occurrence per week.

_____

12. In the last six months, have you been particularly nervous or anxious?

- ❑ Yes
- ❑ No

13. In the last six months, had you say been worrying most of the time (more than a week)?

- ❑ Yes
- ❑ No

14. In the last six months, had you been less interested in most of the things (regardless of your preference) or unable to enjoy nearly every day?

- ❑ Yes
- ❑ No

15. For the past couple of years, have you been bothered by depressed mood?

- ❑ Frequently
- ❑ Sometimes
- ❑ Rarely
- ❑ Never

- The End -

香港理工大學　　編號:_____
護理及醫療科學系　　日期:_____

睡眠狀況問卷

第一部份　睡眠習慣

請在適當的方格內加以「✓」號。

1. 你通常幾點鐘上床瞓？_____

2. 通常需要多少時間才能入睡？_____分鐘

3. 入睡之後，你通常半夜會醒多少次？_____

3.1 半夜醒後，通常要多久才可以再入睡？

- ❑ 好快（醒一醒轉頭立刻可以再入睡）
- ❑ 一陣間（要一段短時間才可以再入睡）
- ❑ 都幾耐（要一段頗長的時間才可以再入睡）
- ❑ 好耐（要一段好長的時間才可以再入睡）
- ❑ 醒後就不可以再入睡
- ❑ 不知道／無一定

3.2 通常半夜醒的原因：

- ❑ 要去廁所
- ❑ 太嘈
- ❑ 太凍或太熱
- ❑ 身體不適
- ❑ 不清楚
- ❑ 無原因
- ❑ 其他：_____

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3.3 通常你半夜醒後會做些什麼？

- ❑ 仍在床上休息
- ❑ 起身做其他事（如去廁所等），等想睡才再上床
- ❑ 食安眠藥
- ❑ 其他：_____

4. 通常你幾點鐘瞓醒？_____

5. 通常你幾點鐘落床？_____

6. 你有否在日間上床瞓？

- ❑ 經常有 (請續答6.1 - 6.3)
- ❑ 間中有
- ❑ 不常有
- ❑ 沒有

6.1 通常你會在何時上床瞓？

- ❑ 早上（中午十二時前）
- ❑ 下午（下午六時前）
- ❑ 晚上（下午六時後）
- ❑ 無一定

6.2 每次大約瞓多少時間？ 躺了_____分鐘/小時
眞正瞓著了_____分鐘/小時

6.3 日間上床瞓的原因？

- ❑ 得閒無事做
- ❑ 疲倦
- ❑ 因爲夜晚睡得不好
- ❑ 無原因
- ❑ 不知道
- ❑ 其他：_____

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7. 你有否瞌睡(瞌眼瞓)？

- ❑ 經常有 (請續答7.1 - 7.2)
- ❑ 間中有
- ❑ 不常有
- ❑ 沒有

7.1 通常會在何時瞌睡？

- ❑ 早上（中午十二時前）
- ❑ 下午（下午六時前）
- ❑ 晚上（下午六時後）
- ❑ 無一定

7.2 每次大約瞌幾耐？

- ❑ 極短，轉頭就醒
- ❑ 瞌一陣
- ❑ 都幾耐
- ❑ 瞌好耐
- ❑ 不知道／無一定
- ❑ 其他：_____

第二部份　生活習慣

1. 你有沒有每天抽煙的習慣？

- ❑ 無。
- ❑ 有。通常你會在幾點抽最後一支煙？_____

2. 你有沒有每天進食含咖啡因的食品的習慣？

- ❑ 無。
- ❑ 有。 這些含咖啡因的食品是：中國茶、咖啡、奶茶、其他:_____
  每天會進食多少？_____
  通常你最後會在幾點進食這類食品？_____

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3. 你有沒有每天飲酒的習慣？

❑ 無。
❑ 有。 每天會飲多少杯/兩？_____杯/兩
通常你會在幾點飲最後一杯酒？_____

4. 你有沒有每天進食奶類食品的習慣？

❑ 無。
❑ 有。 這些奶類食品是：_____
每天會進食多少？_____
通常你會最後幾點進食這類食品？_____

5. 你有沒有每天做運動的習慣？

❑ 無。
❑ 有。幾時做？
早上（中午十二時前）／下午（下午六時前）／
晚上（下午六時後）
每天會做多久？_____分鐘/小時
在那裏做？ 户內／户外

6. 你有沒有每天到户外接觸陽光的習慣？

❑ 無。
❑ 有。 幾時到户外？
早上（中午十二時前）/ 下午 睡下午六時前）/ 晚上 下午六時後）
每天接觸陽光多久？_____分鐘/小時

7. 你通常幾點食晚飯？_____

8. 你睡前，有沒有食些東西才睡的習慣？

❑ 無。
❑ 有。

- 完 -

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Appendix 2

The Hong Kong Polytechnic University Date: _____
Department of Nursing and Health Sciences Code: _____

Questionnaire

Part I Sleep Habits

Please put a ✓ in the appropriate box.

1. What is your usual bedtime at night? _____

2. How long do you usually take to fall asleep at night? _____ minute(s)

3. How often do you usually wake up during the night? _____

   3.1. How long do you usually take to fall asleep again?

   ❑ A very short period of time (fall asleep again immediately)
   ❑ A short period of time
   ❑ A long period of time
   ❑ A very long period of time
   ❑ Once awake, can't fall asleep again
   ❑ I don't know/ No fixed mode

   3.2. What is/are the usual cause(s) of the awakening(s)?

   ❑ Go to toilet frequently
   ❑ Too Noisy
   ❑ Temperature: too cold or too hot
   ❑ Physical discomfort
   ❑ I don't know
   ❑ No cause
   ❑ Others: _____

   3.3. What will you usually do in the awakening(s)?

   ❑ Still rest on bed
   ❑ Get up to do something (eg go to toilet, etc) till sleepy
   ❑ Take sleeping pills
   ❑ Others: _____

4. What is your usual final awakening time? _____

5. What is your usual final arising time? _____

6. Do you go to bed in daytime?

❑ Frequently (Please answer 6.1 – 6.3)
❑ Sometimes
❑ Rarely
❑ Never

6.1. When do you usually go to bed in daytime?

❑ In the morning (before 1200 hours)
❑ In the afternoon (before 1800 hours)
❑ In the evening (after 1800 hours)
❑ No fixed mode

6.2. How long do you sleep each time? Lying _____ minute(s) / hour(s)
Asleep _____ minute(s) / hour (s)

6.3. Why do you go to bed in daytime?

❑ To kill time
❑ Being tired
❑ Poor sleep at night
❑ No reason
❑ I don't know
❑ Others: _____

7. Do you doze?

❑ Frequently (Please answer 7.1 – 7.2)
❑ Sometimes
❑ Rarely
❑ Never

7.1. When do you usually doze?

❑ In the morning (before 1200 hours)
❑ In the afternoon (before 1800 hours)
❑ In the evening (after 1800 hours)
❑ No fixed mode

7.2. How long do you usually doze?

- ❑ A very short period of time
- ❑ A short period of time
- ❑ A long period of time
- ❑ A very long period of time
- ❑ I don't know/ No fixed mode
- ❑ Others: _____

Part II Life style

1. Do you smoke every day?

   ❑ No.
   ❑ Yes. The last cigarette is usually at _____.

2. Do you consume any caffeinated food or drink every day?

   ❑ No.
   ❑ Yes. The caffeinated food or drink is/are: Chinese Tea, Coffee, Western Tea, Others: _____.
   I usually consume _____.
   The last time I usually consume such food or drink is at _____.

3. Do you drink alcohol every day?

   ❑ No.
   ❑ Yes. I usually drink _____ cup(s) / tael.
   The last drink is usually at _____.

4. Do you consume dairy product(s) every day?

   ❑ No.
   ❑ Yes. The dairy product(s) is/are: _____.
   I usually consume _____.
   The last time I usually consume dairy product is at _____.

5. Do you do exercise every day?

   ❑ No.
   ❑ Yes. I usually do exercise: in the morning (before 1200 hours), in the afternoon (before 1800 hours), in the evening (after 1800 hours).
   I usually do exercise for _____ minute(s) / hour(s).
   I usually do exercise in: indoor, outdoor.

6. Do you have outdoor sunlight exposure everyday?

   ❑ No.
   ❑ Yes. I usually expose to sunlight: in the morning (before 1200 hours),
   in the afternoon (before 1800 hours),
   in the evening (after 1800 hours).
   I usually expose for _____ minute(s) / hour(s).

7. When do you usually have your dinner? _____.

8. Do you eat snack every night before bedtime?

   ❑ No.
   ❑ Yes.

- The End -

香港理工大學　　日期：　/　/97 Day__
護理及醫療科學系　　編號：_____

睡眠狀況記錄

1. **晚上**(下午六時後)，你有否上床瞓？

☐ 無。
☐ 有。多少次？_____次

時間	躺了多久	眞正瞓了多久
_____	_____分鐘	_____分鐘
_____	_____分鐘	_____分鐘

2. **晚上**(下午六時後)，你有否瞌睡？

☐ 無。
☐ 有。多少次？_____次

時間	瞌了多久
_____	_____分鐘
_____	_____分鐘

3. 晚上，你幾點鐘熄燈？_____

4. 晚上，你幾點鐘上床瞓？_____

5. 你需要多少時間才能入睡？_____分鐘/小時

6. 你有否難於入睡？

☐ 無。
☐ 有。爲什麼？_____

7. 入睡之後，你半夜有沒有醒？

☐ 無。
☐ 有。多少次？_____次

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半夜醒的原因：

☐ 要去廁所
☐ 太嘈
☐ 太凍或太熱
☐ 身體不適
☐ 不清楚
☐ 其他：_____

半夜醒後，做了些什麼？

☐ 仍在床上休息
☐ 起身做其他事(如去廁所等)，等想睡才再上床
☐ 食安眠藥
☐ 其他：_____

半夜醒的時間	醒了多久
_____	_____分鐘
_____	_____分鐘
_____	_____分鐘
_____	_____分鐘
_____	_____分鐘

8. 你幾點鐘瞓醒？_____

9. 你幾點鐘落床？_____

10. 你晚間睡得好嗎？

☐ 很好
☐ 好
☐ 普通
☐ 差
☐ 很差

11. 朝早起身時，你精神好嗎？

☐ 精神奕奕
☐ 普通
☐ 精神不足
☐ 重係好想睡

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12. 你有否服食任何藥物？請列明。

_____

13. 你有否因身體不適以致影響睡眠？請列明。

_____

14. 你有沒有抽煙？

☐ 無。
☐ 有。你在幾點抽最後一支煙的？_____

15. 你有沒有進食含咖啡因的食品？

☐ 無。
☐ 有。　這些含咖啡因的食品是：中國茶、咖啡、奶茶、其他：_____

昨天進食了多少？_____
你最後在幾點進食這類食品？_____

16. 你有沒有飲酒？

☐ 無。
☐ 有。　飲了多少杯/兩？_____杯/兩
你在幾點飲最後一杯酒？_____

17. 你有沒有進食奶類食品？

☐ 無。
☐ 有。　這些奶類食品是：_____
每天會進食多少？_____杯
你最後在幾點進食這類食品？_____

18. 你有沒有做運動？

☐ 無。
☐ 有。

幾時做？	做了多久？	在那裏做？
早上(中午十二時前)	_____分鐘	户内/户外
下午(下午六時前)	_____分鐘	户内/户外
晚上(下午六時後)	_____分鐘	户内/户外

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19. 你有沒有到户外接觸陽光？

☐ 無。
☐ 有。　幾時？　接觸了多久？
早上(中午十二時前)　_____分鐘
下午(下午六時前)　_____分鐘
晚上(下午六時後)　_____分鐘

20. 你幾點食晚飯？_____

21. 你有否在睡前食些東西才睡？

☐ 無。
☐ 有。

22. **上午**(中午十二時前)，你有否上床瞓？

☐ 無。
☐ 有。多少次？_____次

時間	躺了多久	眞正瞓了多久
_____	_____分鐘	_____分鐘
_____	_____分鐘	_____分鐘

23. **上午**(中午十二時前)，你有否瞌睡(瞌眼瞓)？

☐ 無。
☐ 有。多少次？_____次

時間	瞌了多久
_____	_____分鐘
_____	_____分鐘

24. **下午**(下午六時前)，你有否上床瞓？

☐ 無。
☐ 有。多少次？_____次

時間	躺了多久	眞正瞓了多久
_____	_____分鐘	_____分鐘
_____	_____分鐘	_____分鐘

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25. **下午**(下午六時前)，你有否瞌睡？

☐ 無。
☐ 有。多少次？_____次

時間	瞌了多久
_____	_____分鐘
_____	_____分鐘

*26. 你認爲一晚你要睡多少小時才足夠？_____小時

*(請在實驗的最後一日才填寫第二十六題)

- 完 -

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Appendix 3

The Hong Kong Polytechnic University Date: _____
Department of Nursing and Health Sciences Code: _____

Sleep Log

Please put a ✓ in the appropriate box.

1. Did you go to bed in the evening (after 1800 hours)?

   ❑ No.
   ❑ Yes. How often? _____

Time	Lying	Asleep
_____	_____ min(s)	_____ min(s)
_____	_____ min(s)	_____ min(s)

2. Did you doze in the evening (after 1800 hours)?

   ❑ No.
   ❑ Yes. How often? _____

Time	Asleep
_____	_____ min(s)
_____	_____ min(s)

3. When did you turn off the light? _____

4. When did you go to bed? _____

5. How long did you take to fall asleep? _____ min(s) / hour(s)

6. Did you have any trouble in falling asleep?

   ❑ No.
   ❑ Yes. Why? _____

7. Did you awake during the night?

   ❑ No.
   ❑ Yes. How often? _____

   What was/were the cause(s) of the awakening(s)?

   ❑ Go to toilet frequently
   ❑ Too noisy
   ❑ Temperature: too cold or too hot
   ❑ Physical discomfort
   ❑ I don't know
   ❑ Others: _____

What did you do in the awakening(s)?

- ❑ Still rest on bed
- ❑ Get up to do something (eg go to toilet, etc) till sleepy
- ❑ Take sleeping pills
- ❑ Others: _____

Awakening Time	Duration
_____	_____ min(s)
_____	_____ min(s)
_____	_____ min(s)
_____	_____ min(s)
_____	_____ min(s)

8. What was your final awakening time? _____

9. What was your final arising time? _____

10. How did you describe your sleep?

- ❑ Very good
- ❑ Good
- ❑ Acceptable
- ❑ Poor
- ❑ Very poor

11. How did you feel upon arising?

- ❑ Refreshed
- ❑ Acceptable
- ❑ Still tired
- ❑ Sleepy

12. Had you taken any medication(s)? Please describe.

_____

13. Did you have any physical discomfort that affected your sleep? Please describe.

_____

14. Did you smoke?

- ❑ No.
- ❑ Yes. The last cigarette was smoked at _____.

15. Did you consume any caffeinated food or drink?

- ❑ No.
- ❑ Yes. The caffeinated food or drink was/were: Chinese Tea, Coffee, Western Tea, Others: _____.

  I had consumed _____.

  The last time I consumed such food or drink was at _____.

16. Did you drink alcohol?

- ❑ No.
- ❑ Yes. I had drunk _____ cup(s) / tael.
  The last drink was drunk at _____

17. Did you consume dairy product(s)?

- ❑ No.
- ❑ Yes. The dairy product(s) was/were: _____.
  I had consumed _____.
  The last time I consumed dairy product was at _____ .

18. Did you do execrise?

- ❑ No.
- ❑ Yes.

	Time	Duration	Place
In the morning (before 1200 hours)	_____	min(s)	Indoor / Outdoor
In the afternoon (before 1800 hours)	_____	min(s)	Indoor / Outdoor
In the evening (after 1800 hours)	_____	min(s)	Indoor / Outdoor

19. Did you have outdoor sunlight exposure?

- ❑ No
- ❑ Yes.

	Time	Duration
In the morning (before 1200 hours)	_____	min(s)
In the afternoon (before 1800 hours)	_____	min(s)
In the evening (after 1800 hours)	_____	min(s)

20. When did you have your dinner? _____

21. Had you eaten snack before bedtime?

- ❑ No.
- ❑ Yes

22. Did you go to bed in the morning (before 1200 hours)?

- ❑ No.
- ❑ Yes. How often? _____

Time	Lying	Asleep
_____	_____ min(s)	_____ min(s)
_____	_____ min(s)	_____ min(s)

23. Did you doze in the morning (before 1200 hours)?

❑ No.
❑ Yes. How often? _____

Time	Asleep
_____	_____ min(s)
_____	_____ min(s)

24. Did you go to bed in the afternoon (before 1800 hours)?

❑ No.
❑ Yes. How often? _____

Time	Lying	Asleep
_____	_____ min(s)	_____ min(s)
_____	_____ min(s)	_____ min(s)

25. Did you doze in the afternoon (before 1800 hours)?

❑ No.
❑ Yes. How often? _____

Time	Asleep
_____	_____ min(s)
_____	_____ min(s)

*26. How many hours do you prefer to sleep at night? _____ hours

* This question is completed at the end of the experiment (ie Day 6).

- The End -

Appendix 4

Instruction Sheet

I Caffeinated Products

1. Coffee
2. Tea
3. Cola drink
4. Chocolate

(Morin, 1993)

II Recording

During the experimental period, the following items should be recorded.

1. Room temperature
2. Any physical discomfort(s)
3. Prominent emotional changes or problems
4. Daily routine of the elderly home
5. Any changes in the subject's daily schedule (eg family's visit and so on)
6. Brightness of the light sources in the elderly home during daytime and night-time
7. Light intensity of the bright light applying on each subject during the period of bright light exposure period
8. Any complaint(s) or discomfort(s) related to the bright light exposure
9. Wear glasses during the experimental period (especially during the stage of bright light exposure)

III Symptoms of Sleep Disorders

1. Restless legs: Crawling or aching feelings in the legs (calves) and inability to keep legs still.
2. Periodic limb movements: Leg twitches or jerks during the night; waking up with cramps in legs.
3. Apnea: Snoring, pauses in breathing at night, shortness of breath, choking at night; morning headaches, chest pain, dry mouth.

4. Narcolepsy: Sleep attacks, sleep paralysis, hypnagogic hallucinations, cataplexy.
5. Gastro-esophageal reflux: Sour taste in mouth, heartburn; reflux.
6. Parasomnias: Nightmares, night terrors, sleepwalking/talking, bruxism.

(Morin, 1993)

IV Urine Collection

1. Before bright light exposure, the subjects are requested to void.
2. The first period of urine sample collection starts from 1800 hours to bedtime.
3. The second period of urine sample collection starts from bedtime to arising time (including the first morning voiding).
4. Clean bottles are provided for urine saving.
5. Urine samples are stored in the icebox before they are transferred to the laboratory.
6. Urine samples are collected and stored in the laboratory at -20°C each day after the end of morning session.

V Verbal Consent

1. The purposes of the study, the nature of the experiment, equipment and instruments used are explained clearly to the potential subjects.
2. The potential subjects are informed that they can withdraw at any time.
3. The potential subjects are informed that they will be invited to join the experiment if they meet the requirements.
4. The potential subjects are informed that data in this study are kept anonymously and confidentially.
5. The name and contact telephone number of the interviewer are given to all potential subjects for enquiry.

CIDtech Research Inc.

Chemistry
Immunology
Diagnostics

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May 1996

CIDtech 6-SULPHATOXYMELATONIN RIA KIT INSTRUCTIONS
CIK104H human, CIK104R rat

1. Intended use

CIDtech 6-sulphatoxymelatonin (aMT6s) RIA kit is intended for the quantitative measurement of aMT6s in urine.

2. Summary and explanation of the test

6-sulphatoxymelatonin is the primary urinary metabolite of the pineal hormone melatonin. Measurement of 6-sulphatoxymelatonin in urine has been validated for a variety of species including human and rat. Measurement of aMT6s in urine is an alternative for measurement of blood melatonin in the study of pineal gland activity.

3. Principles of the procedure

aMT6s determination by radioimmunoassay depends upon competition of aMT6s in urine and ^{125}I-labelled aMT6s for a limited number of high affinity binding sites on CIDtech ultraspecific aMT6s antiserum. The amount of radioactivity bound to the antiserum is inversely related to the amount of unlabelled aMT6s present in the urine. When the system is in equilibrium, the antibody free aMT6s is absorbed with charcoal. The precipitate is counted in a gamma counter. Quantitation of unknowns is achieved by comparing their activity with a response curve prepared using known standards.

4. CIDtech Ultraspecific antiserum

CIDtech ultraspecific aMT6s antiserum is intended for research purposes only. Sufficient antiserum is supplied to assay 150 tubes which is equivalent to 60 samples assayed in duplicate. Lyophilized antiserum is shipped at room temperature but should be stored at 4°C after receipt.

5. Assay procedures

5.1 Reagents supplied with the kit

Concentrated Assay Buffer
Ultraspecific Anti-aMT6s Serum
aMT6s Standard
Charcoal-stripped Urine
Internal Control; value of control is on label
^{125}I-aMT6s, 2.0 μCi
Dextran-coated Charcoal

5.2 Facilities for assay

Racks
Glass test tubes (12x75 mm)
Pipets
Vortex mixer
Refrigerated centrifuge
Gamma counter
Magnetic stirrer
Distilled or deionized water

5.3 Dilution of urine samples

Urine samples for analysis are stored at -20°C until assayed. aMT6s is stable for at least two years in urine stored at -20°C, for at least one week at 4°C and for at least two days stored at room temperature. Centrifuge cloudy urine specimens before use. Urine is diluted 1:250 with buffer prior to assay by pipetting 10 µl of urine into 2.490 ml assay buffer.

5.4 Reagent Preparation for assay

Assay Buffer

The bottle supplied contains 50 ml of concentrated buffer. Store at 4°C. If the concentrated buffer is crystallized, warm to 37°C to redissolve the crystals. For use in the assay, transfer the concentrated assay buffer to a 250 ml container, add 200 ml of double distilled water and mix thoroughly. After dilution, adjust the pH to 5.5 with 1 M HCl. When stored at 4°C, the diluted buffer is stable for 2 months.

Antiserum to AMT6s

Sheep anti-aMT6s is supplied lyophilized and should be stored at 4°C. Add 150 µl double-distilled water, then add 30 ml of assay buffer, mix well, let stand for 30 min. and mix again. Stable for 1 week when stored at 4°C.

Charcoal Stripped Urine (CSU):
(aMT6s free). This is supplied lyophilized and should be stored at 4°C. Add 25 ml of assay buffer to give a working dilution of 1:250. Diluted CSU is stable for one week when stored at 4°C.

Internal Control

Reconstitute with 100 µl double distilled water and mix well. Dilute 1:250 with buffer prior to assay by pipetting 10 µl of internal control urine into 2.490 ml assay buffer.

Standard

The supplied displacement standard should be stored at 4°C. It contains 500 pg in 2.5 ml charcoal stripped urine.
Prepare further standard curve dilutions according to Table 1.

Dextran-coated Charcoal

The supplied vial contains 2% Charcoal and 0.02% Dextran when reconstituted with 32 ml assay buffer. Stir for at least one hour on ice prior to use in the assay. It is stable for one month at 4°C after dilution.

^{125}I-aMT6s

2.0 µCi of tracer is supplied in 5 ml of assay buffer in an amber vial. It should be stored at 4°C. For use in the assay, dissolve with more of assay buffer to provide a working solution of 5000 cpm / 100 µl (5000 cpm/tube).

Table 1

Tube Numbers	Totals	NSB	Standards (pg/tube)									Controls and Samples
			0	1	2	4	8	14	20	40	100	
	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-100
Tricine Buffer (µl)	800											
CSU (µl)		700	500	495	490	480	460	430	400	300	0	Diluted Urine Sample 500 µl
Standards (µl)			0	5	10	20	40	70	100	200	500	
Anti-aMT6s Serum (µl)			200	200	200	200	200	200	200	200	200	200
^{125}I-aMT6s (µl)	100	100	100	100	100	100	100	100	100	100	100	100
Vortex and Incubate for 15 to 18h at 4°C												
Dextran-coated charcoal (µl)		100	100	100	100	100	100	100	100	100	100	100
aMT6s (ng/ml) in urine			0	0.5	1.0	2.0	4.0	7.0	10.0	20.0	50.0	
Total final volume (µl)	900	900	900	900	900	900	900	900	900	900	900	900

5.5 RIA Procedure

1. Set up labelled 12 x 75 test tubes in duplicate according to the protocol in Table 1.

2. Add reagents as follows:
   a) Total count tubes
      Add 0.8 ml of assay buffer
   b) Non Specific Bound tubes
      Add 700 µl of CSU
   c) 0 standard tubes
      Add 500 µl of CSU
   d) Standard tubes
      Add CSU and standard as indicated in Table 1
   e) Internal control and sample tubes
      Add 500 µl of urine samples or controls at 1:250 dilution

3. Add 200 µl of CIDtech anti-aMT6s serum to each tube except total and non specific bound tubes.

4. Add 100 µl of ^{125}I-aMT6s to each tube.

Perform steps 5 to 9 for all tubes except the total count tubes.

5. Vortex all tubes gently then incubate for 15-18 hours at 4°C.

6. Add 100 µl Dextran-coated charcoal. The coated charcoal is stored at 4°C and stirred continuously on ice for 30 mins before and during addition to assay tubes. Vortex each tube for a few seconds. Charcoal addition and vortexing should be done quickly to reduce assay variation. Incubate for 15 min at 4°C.

7. Centrifuge at 2000 x g for 20 min at 4°C.

8. Aspirate or decant supernatant immediately after centrifugation. Blot rim of tubes to remove all aqueous phase.

9. Count the charcoal pellet in an appropriate gamma counter. Determine the aMT6s concentration from the dose-response curve.

6. Calculation of aMT6s Levels

$$\frac{\text{NSB tube count - Assay tube counts}}{\text{NSB tube counts}} \times 100 = \% \text{ bound}$$

aMT6s level in unknown sample is determined from the dose response curve. The molecular weight of aMT6s is 328.

Dose Response Curve

Value of Standards (pg per tube)	If urine is diluted					
	1:100		1:250		1:500	
	Urine Concentration		Urine Concentration		Urine Concentration	
	ng/ml	pmol/ml	ng/ml	pmol/ml	ng/ml	pmol/ml
0	0	0	0	0	0	0
1	0.2	0.61	0.5	1.53	1	3.05
2	0.4	1.22	1	3.05	2	6.1
4	0.8	2.44	2	6.1	4	12.2
8	1.6	4.88	4	12.2	8	24.4
14	2.8	8.54	7	21.3	14	42.6
20	4	12.2	10	30.5	20	61.0
40	8	~~48.8~~ 34.4	20	61.0	40	122
100	20	61.0	50	153	100	305

Normal Range Each laboratory must determine its own normal range.

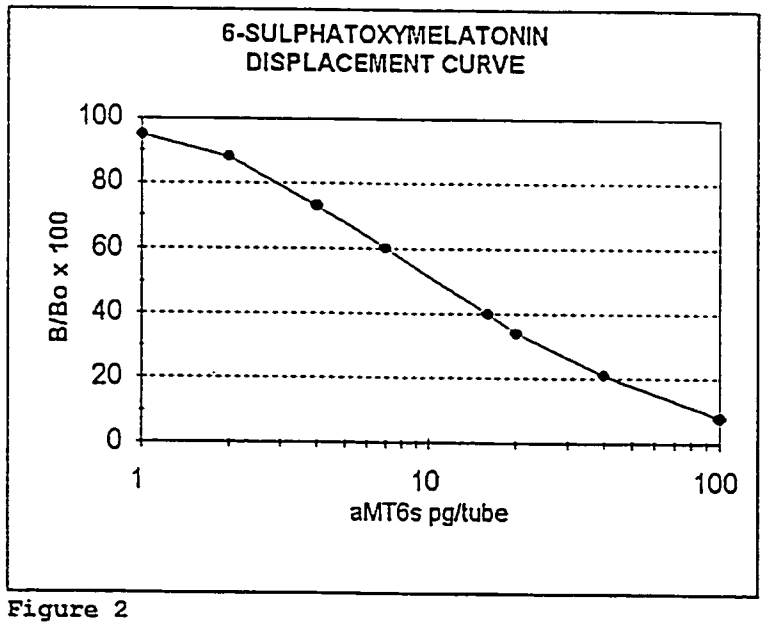

Figure 2

Do not use in place of actual curve.

7. Performance Data

The CIDtech ultraspecific antiserum provided was produced in sheep immunized with aMT6s conjugated to protein using formaldehyde.

CIDtech ultraspecific antiserum is highly specific as determined by crossreactivity studies (Table 2).

The dilution of sample curve is parallel with standard curve. Within assay variation and between assay variation were 8.6 and 12.5 respectively.

The sensitivity of the assay is 1 pg/tube.

Table 2

Compound	% Crossreactivity
6-sulphatoxymelatonin	100.0
N-acetylserotonin sulphate	2.0
N-acetylserotonin glucuronide	1.4
6-hydroxymelatonin glucuronide	0.5
6-hydroxymelatonin	<0.11
melatonin	<0.11
5-methoxyindole acetic acid	<0.11
5-hydroxyindole acetic acid	<0.11
N-acetyltryptamine	<0.11
N-acetylserotonin	<0.11
5-hydroxytryptophan	<0.11
N-methyltryptamine	<0.11
5-methoxytryptamine	<0.11
5-methoxytryptophan	<0.11
5-hydroxytryptamine	<0.11
5-methoxytryptophol	<0.11
5-hydroxytryptophol	<0.11
tryptophan	$<1.1 \times 10^{-3}$

crossreactivity is based on mass required for 50% displacement of ^{125}I-aMT6s.

References

Aldhous, ME. and Arendt, J. Radioimmunoassay of 6-sulphatoxymelatonin in urine using an iodinated tracer. Ann. Clin. Biochem., 25 (1988) 298-303.

Arendt, J., Bojkowski, C., Franey, C., Wright, J. and Marks, V. Immunoassay of 6-hydroxy melatonin sulphate in human plasma and urine: abolition of the urinary 24h rhythm with atenolol. J. Clin. Endocrinol. Metab., 60 (1985) 1166-1173.

香港理工大學
護理及醫療科學系

同意書

這是一個探討老人睡眠的研究，目的是要了解光線、褪黑激素與睡眠的關係。

這研究需要你填寫一份有關睡眠狀況的問卷和經歷一個爲期六日的實驗過程。參與者於研究期間需佩戴一個錶型的儀器、留取小便樣本和記錄睡眠狀況。研究期間，他們身處的活動室燈光會加以調節，以迎合研究的需要。此項研究的方法是沒有明顯的反效果。

閣下可自由參與這研究，甚或中途退出。所有個人資料，會絕對保密。

倘若你要進一步了解或詢問有關這研究的詳情，請致電給：-

何淑貞小姐	研究員	2766 6546
汪國成博士	研究導師	2766 6398
鄧泊澧教授	研究導師	2766 5606
彭美慈小姐	研究導師	2766 6409

你若自願參與此項研究及明白以上所述的內容，請在以下指定地方簽名。

_____ _____

參與者姓名　　研究員簽署

_____ _____

參與者簽署　　日期

Appendix 6

The Hong Kong Polytechnic University
Department of Nursing and Health Sciences

Consent Form

This is a study on exploring the relationships among bright light, excreted melatonin level and sleep in old people complaining of sleep disturbance. You will be requested to complete a questionnaire and undergo a 6-day experiment. During the experimental period, you will need to wear a watch-liked instrument, save urine samples and record your daily sleep state. Besides, the light condition of the room (not bedroom) will be adjusted according to the protocol. There is so far no reported cases related to any hazard caused by this kind of study.

Your participation is completely voluntary. You are free to discontinue participation at any time without prejudice. Any information obtained in connection with this study that can be identified with you will remain confidential and will be disclosed only with your permission. In any written reports or publications, only aggregate data will be presented. Should you have any enquiries, please feel free to contact:-

The Researcher, Miss Jacqueline Ho at 2766 6546
The Chief Supervisor, Dr Thomas Wong at 2766 6398
The Co-supervisor, Professor P. L. Tang at 2766 5606
The Co-supervisor, Miss Samantha Pang at 2766 6409

By signing this consent form, you indicate your voluntary participation in this study and you have understood the content of this consent form.

_____ _____

Subject's name Researcher's signature
(Jacqueline Ho)

_____ _____

Subject's signature Date

Appendix 7

Protocol of the Experiment

Day 1 Pre-Bright Light Exposure Stage (Adaptation)

Evening Session

1. Subjects are explained about the purposes of the study, the nature of the experiment, equipment and instruments used.
2. Subjects are instructed how to wear the wrist actigraph.
3. Subjects are instructed to note their awakening frequency, time and duration at night, collection time of urine samples, bedtime, awakening time and arising time.
4. Subjects are instructed how to collect urine samples.
5. Before the light exposure, subjects should void.
6. Subjects expose to red dim light from 1800 hours to 2100 hours.
7. First urine sample collection period starts from 1800 hours to bedtime.
8. Second urine sample collection period starts from bedtime to arising time including the first morning voiding.
9. During the light exposure period, the subjects are watching television and they should complete the questions 22 to 25 of the sleep log.

Morning Session

1. Questions 1 to 21 of the sleep log are completed as soon as the subjects awake.
2. Actigraphic data are downloaded.
3. Urine samples are brought back the laboratory, centrifuged and stored at -20°C.

Day 2 Pre-Bright Light Exposure Stage (Baseline)

Evening Session

1. Repeat the procedures 5 to 9 of Day 1.
2. Check the actigraph to ensure it is collecting data.

Morning Session

1. Same as Day 1.

Day 3 to 4 Bright Light Exposure Stage

Evening Session

1. Repeat the procedures on Day 2 except the light sources (white bright light) are replaced by the red dim light.

Morning Session

1. Same as Day 1.
2. Actigraph should be re-calibrated on Day 3 before it is used to collect data.

Day 5 to 6 Post-Bright Light Exposure Stage

Evening Session

1. Repeat the procedures of Day 2.
2. No evening session on Day 6.

Morning Session

1. Same as Day 1.
2. Actigraph should be re-calibrated on Day 5 before it is used to collect data.
3. Complete question 26 of the sleep log on Day 6.