A Study of the Physiological and Neuromuscular Demands on Female Nurses Working in Geriatric Wards in Hong Kong

By

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Statement of Source

The idea of the present investigation and planning of the study results from discussions between the author and Dr. Gabriel Ng.

The data collection in the present investigation was completed solely by the author.

The author declares that the work presented in this thesis is, to the best of the author's knowledge and belief, original, except as acknowledged in the text, and that the material has not been submitted, either in whole or in part, for a degree at this or any other university.

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List of Abbreviations:

Caritas Medical Center (CMC)

Discrete Fourier Transformation (DFT)

Electrocardiography (ECG)

Electromyography (EMG)

End Plate Potential (EPP)

Erector Spinae (ES)

Fast Fourier Transformation (FFT)

Intraclass correlation coefficients (ICC)

Initial Median Frequency (IMF)

Low Back Pain (LBP)

Manual Material Handling (MMH)

Motor Unit Action Potential (MUAP)

Median Frequency (MF)

Nuclear Magnetic Resonance Spectroscopy (NMR)

Occupational Safety and Health Council (OSHC)

Self-Rating of Perceived Exertion (RPE)

Standard Deviation (SD)

Standardized Residual (SR)

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Abstract of thesis entitled 'A Study of the Physiological and Neuromuscular Demands on Female Nurses Working in Geriatric Wards in Hong Kong' submitted by Ling Hui for the degree of Master of Philosophy at The Hong Kong Polytechnic University in (December 1998).

Abstract

In order to study the physiological and neuromuscular exertion levels of front-line female hospital nurses working in geriatric wards in Hong Kong, twenty one nurses (study group, mean aged: 27.33±4.99) and eighteen sedentary workers (control group, mean aged: 28.39±3.22) were tested. The physiological and neuromuscular exertion levels of the two groups were assessed with continuous heart rate recording during a whole work shift and by comparing the fatigability of the back muscles before and after the work shift with surface electromyographic (EMG) measurement. The nurses recorded their activity profile at work for comparing with the heart rate data. A Borg's self-rating perceive exertion (RPE) questionnaire of nursing duties was filled in before the tests by the nurses. Results showed that there were significant difference in the physiological and neuromuscular demands between nurses and sedentary office workers in their daily work. The nurses demonstrated reasonably high heart rates (>90 beats per minute in 56% of the working hours) throughout their work shift, which reflects the physical demanding nature of their work. Solo patient transfer, showering and patient turning was found to be the most physically demanding duties in the heart rate recording and the RPE scale. The EMG data showed significant difference in the nurses' back muscles before and after work, which provided another index to confirm the accumulative neuromuscular exertion of their back muscles. Both the heart rate and EMG data were significantly different from the control group. It was suggested that the most demanding duties should be performed with extreme care by the nurses and it may be better to schedule these duties not at the end of a workday, in order to minimized injuries at work.

Relevant Publications

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Chapter 1

Introduction

1.1 Background

Hong Kong is one of the most fast-growing cities in the world. The rate of development has been particularly fast in the past 20-30 years. The highly efficient workforce is an important factor for the economic growth of Hong Kong. In 1997, the total labor force reached 3.1 million, and the unemployment rate was 2.2%, which was comparatively lower than many western developed countries, such as the United Kingdom, France, Holland, Germany and Spain (Ilg and Clinton 1998).

In the past 30 years, Hong Kong has emerged from a fishing port to an international financial and commercial center. Notwithstanding the international recognition of the efficiency of the workforce in Hong Kong, the heavy workload and overlooking of the importance of safe working environments by employees and employers have led to an increase in occupational injuries and accidents in different professions. In 1997, there were a total of 43,305 cases of reported occupational accidents and injuries in Hong Kong, which had increased by 7.59% when compared with 1996. Among them, 6,567 cases were caused by handling without machinery, which ranked second for industrial accidents by causes, following fall of person (Annual Departmental Report, Department of Labor, 1997). Actually this figure of occupational injuries and accidents is not trivial. It raises the concerns of the employees, employers, health care practitioners, Occupational Safety and Health Council (OSHC) and the Hong Kong Government. Therefore, investigating the neuromuscular demand for manual handling is important to understand the mechanism of injury, so that it helps to prevent and decrease the number of such work-related accidents.

According to the Hong Kong Monthly Digest of Statistics of May 1997, nursing has been ranked as a high-risk profession in terms of incidence of occupational injuries. It closely followed the three highest risk professions, namely catering, construction and manufacturing.

Data from the Association of Hong Kong Nursing indicated that there are about 30,000 nurses (enrolled and registered) in Hong Kong. According to the Annual Report of Hong Kong Government in 1997, the number of hospital-nurses employed by the Hospital Authority was 17,829. The ratio of employed nurses to population is approximately 1:200, which is lower than the average in other developed countries such us the US, where the ratio is 1:100-150 (Walsh 1997). The workload of local nurses could therefore be heavier than that of their overseas counterparts.

In Germany, the prevalence rate of work related injuries in nurses during a lifetime was reported to be 35%-90%, a twelve-month prevalence rate was reported as 35-80% and a present prevalence rate was 10-39% (Moens *et al.* 1993). Clinically, many nurses have complaints of work-related injuries and some are severe enough to render them to leave the profession. Actually, back injury, particularly low back pain, is one of the most common problems for industrialized nations of the world, and many nurses suffer from back pain (Yassi *et al.* 1995, Lusted *et al.* 1996, Owen 1989).

1.2 Back Problem in a Global Perspective

Back problem in the general population has been reported globally by local and overseas figures and surveys. In Finland, there was 50-80% of their populations reported that they suffered from back problem at some times during their lives (Riihimäki 1996). In the USA, results of epidemiological studies showed that the prevalence of low back pain varied from 7.6% to 37% in different populations in the past twelve months (Borenstein 1997). Hurwitz and Morgenstern (1997) reported that 60% of the participants of their study claimed that the back pain had led them to consult their general practitioners. Whilst about 25% of them consulted a specialist, and 15% of them consulted a chiropractor. In Denmark, 928 men and women aged from 30 to 60 years old completed a questionnaire, that lasted for twelve months. At the end of the twelfth month follow-up, results showed that the lifetime prevalence rates for low back pain were 68-70% for men and 62-81% for women. The one-year incidence of first attack of low back pain was 11% among 30 year-old subjects including men and women. A portion between 23-31% of them had such symptoms daily or at least once a week (Biering-Sorensen 1983). In a local survey, 39% of adults being interviewed reported that they had at least one attack of low back pain since birth (Lau *et al.* 1995).

Back injury and respiratory infections are the most frequent reasons for claiming for sickness benefits (Westrin 1993). Back pain is one of the most expensive health care problems for the industrialized nations of the world, and the most expensive musculoskeletal malady. For example, the Liberty Mutual Insurance Company paid one million US dollars each day in medical and compensation costs for back problems (Leamon 1993). In the United Kingdom, the cost of back pain in relation to hospital services, family practitioners, community services, and drugs had been estimated to reach at least 90 million US dollars (Wood and Badley 1990). In Denmark, the direct expenses in the health sector amounted to an approximate average of three hundred US dollars per patient in a follow-up year for those who consulted their general practitioners for a new onset of low back pain. On a national scale, the total cost of this patient category alone would cost about 37 million US dollars per year, although only 7% of the patients were hospitalized (Cohen-Manfield *et al.* 1996). In Hong Kong, demands for medical treatment for back pain is enormous. There were over 30% of monthly adult referrals for treatment in physiotherapy outpatient departments, which are attributable to back problems (Lau *et al.* 1995).

Heavy lifting, twisting and trauma were the most commonly stated causes of back injury. About 52-60% of the participants claimed that the causes for injuries were work-related (Kraus *et al.* 1997). Since back problems most commonly occur during the most productive years of life, great attention had been given to the prevention and treatment of back injury among industrial workers (Battié *et al.* 1989). Construction workers, garbage collectors, machine operators and nurses are having higher prevalence rates of back pain and a higher incidence of back injuries than most occupational groups in the industrial and health care sectors (Yassi *et al.* 1995).

1.3 The Job Related Health Incidence Among Nurses

Nurses had been reported to have high incidence of worker's compensation claims for sickness (Personick 1990) and high prevalence of back pain (Cust *et al.* 1992, Dehlin *et al.* 1976), resulting in high loss of income (Gibson and Dewhires 1986, Harber *et al.* 1985). In a study by Jensen (1990), he referred to several studies in Australia, which showed that the nursing population was a major occupational group affected by back injury. The same phenomenon had also been reported in the UK. The Health and Safety Commission in the United Kingdom reported over 70,000 injuries were related to manual handling tasks in 1992. In Australia, a survey on nearly 1,000 female nurses revealed that 87% of the respondents had experienced one or more episodes of low back pain, whilst 42% of them had experienced low back pain within the previous month or at the time of the survey. The majority of these nurses were registered nurses. In another survey being conducted to 386 Australian nurses, 60% of the respondents reported that they suffered back problems, while 10% of them had serious back pain (Arad and Ryan 1996). A report from Workcover Authority of New South Wales in 1993 also showed that female workers in the health industry had the highest incidence of back injuries among female workers in all industrial groups.

The problem is that the severity and frequency of back problems, as well as the cost incurred remained uncontrollable (Garg and Owen 1992). Gilsan (1993) stated that as many as 12% of nurses in the United States might have considered leaving the profession because of back injuries. A survey of 3,912 British nurses revealed that 750,000 working days were lost annually as a result of back pain. One in every six of these nurses attributed the onset of back pain to issues relating to patient handling (Stubbs *et al.* 1983). This may have a serious social impact because of the possible worsening of the shortage of nursing and care-providing staff (Corlett *et al.* 1992).

The number of sick leaves being taken by nurses due to musculoskeletal disorders was increasing, especially for long term absence of over four weeks (Buckle and Stubbs 1990, Harber *et al.* 1985). In the fiscal year of 1991-1992, a report from Workcover Authority of New South Wales showed that there were 3,492 reported cases for job related injuries which required more than five days of sick leave in the Health Industry in New South Wales of Australia. Among these cases, approximately 84% were classified as workplace injuries, 7% were journey claim and 9% were occupational diseases. Forty-seven per cent of these injury cases were related to the back and 25%

were related to the neck and upper limbs (Workcover Authority of New South Wales 1993).

Nursing personnel had higher prevalence of back pain and associated back injuries than other occupational groups in all health care industries (Jensen 1987). The Canadian Health and Disability Survey showed that back pain resulted in almost 30% more days of sick leaves annually in nurses than in the general population (Pheasant and Stubbs 1992). One example is the Health Science Center in Manitoba of Canada, which is a teaching hospital with 1,100 beds. There was an average of 225 back injuries being reported annually by nurses during 1990-1995. The report showed that back injury was in 12.9% of all reported injuries and 42.5% of the total working-hour lost in nurses (Yassi *et al.* 1995).

It is possible that the actual number of incidence of low back pain experienced by nurses may be greater than the published statistics. Some nurses might have suffered the back pain for a long time due to their daily heavy workload. Perhaps they have got used to it and never taken sick leave or reported their cases to their in-charge officers.

Some nurses perceive back pain as an inevitable part of nursing practice (Garg *et al.* 1991). If this was true, it would seriously affect the younger generation contributing themselves to this lofty profession. Actually, there is evidence that there have been a gradual loss of 7.6% in both registered and enrolled nurses each year in the USA (Gibson and Dewhires 1986), which could well be partly due to the above reasons. It is suggested that our recommendations in the study could reduce the back injuries and dispel the belief that back pain is an inevitable occupational hazard of nursing.

1.4 Characteristics of Nursing Duties in Geriatric Wards

Among all the occupational injuries, Manual Material Handling (MMH) injury happens most frequently in nurses (Personick 1990). It is common for nurses to sustain injuries particularly to their backs during daily work duties such as turning, bathing, transferring and lifting of patients. These are also the most common duties for nurses working in rehabilitation and geriatric wards.

In geriatric wards, some elderly patients are highly dependent and some may be uncooperative due to dementia. Nurses working in geriatric wards may have more physically demanding duties such as making beds, showering, turning, lifting, transferring, cleaning and tidying. Most of these duties need frequent trunk bending and stooping. Patient transfer is considered to be the most physically demanding activity of their work, yet this is the major nursing activity for geriatric ward nurses (Collins and Owen 1996).

The chances of nurses working in geriatric and rehabilitation wards to perform patient transfer would be inevitably higher than their counterparts of other specialties. The prevalence rate for injury had been reported to be 92% for nurses in geriatric wards, and actually, these nurses are at highest risk of injuries amongst the nursing profession. This may be related to the physical demand of their job nature (Lusted *et al.* 1994).

Some investigators reported that the heaviest workload was associated with the duties in geriatric and rehabilitation wards in hospitals (Lo *et al.* 1993, Mital *et al.* 1993). The following editorial was an extract from a report of Lancet in 1965, about 30 years ago:

"The adult human form is an awkward burden to lift or carry. Weighing up to 100 kg or more, it has no handle, it is not rigid, and it is liable to severe damage if mishandled or dropped. In bed, a patient is placed inconveniently for lifting, and few industrial workers would tolerate the placing of

a load in such a situation. Therefore, there is clearly much that can and should be done, since nursing stresses seem likely to increase as the population ages and the shortage of nurses continues"(Collins and Owen 1995).

The message is still valid despite being published 30 years ago and it remains all the more important today (Collins and Owen 1995).

It is generally believed that the weight of a patient, the frequency of lifting or transferring, and the level of co-operation of patients determine the level of risk of injury among nurses (Ku *et al.* 1987, Owen and Garg 1989, Tuffnell 1987).

Injuries caused by high physical demands particularly to the back are a threat to the ability of nurses to carry out proper patient care. According to the report of the U.S. National Institute of Health in 1995, more than 44% of all hospital beds in the USA were occupied by adults aged 65 years or more, the number of elderly patients rose increasingly each year. It was believed that the number of dependent patients had been increasing and the problem would worsen with an aging population (Mital *et al.* 1993).

In Hong Kong, according to the annual report of Hong Kong in 1997, the average life span of citizens has reached 81 years old. The city is faced with the same problem of an aging population. This will inevitably strain geriatric care in the local hospital system. It is disappointing that a series of annual reports of the Hospital Authority from 1992 to 1997 have never mentioned the need to increase the workforce in local geriatric wards. Therefore, the workload of these workers is likely to become heavier each year.

In light of the high incidence of injuries among nurses working in geriatric wards, and the likely increase in workload, it is vital to investigate the level of physical demand of these workers, and hence to implement suitable training for them or plan necessary measures to prevent injuries.

Therefore, understanding the nature of the work demand of nurses, particularly local hospital nurses, is important. This could help to prevent injuries at work and to enable injured nurses to return to the work force.

1.5 Identification of the Nursing Profession

The nursing profession is recognized as having a unique perspective on people, environment and health.

"It is the application of nursing knowledge from the physical, biological, behavioral, social and medical sciences to the promotion, maintenance and restoration of health for the individual and family through stressful events, which may include death and bereavement" (Joan and Mike 1992).

In order to provide the best nursing to clients, a nurse needs to apply concepts and theories from nursing, biological, physical, behavioral sciences, and humanities, a rationale for making decisions, judgments, interpersonal relationships and actions can be formulated. In the nursing process, there are five essential components, namely assessment, nursing diagnosis, planning, implementation, and evaluation (Hill and Howlett 1997).

Assessment is the first phase in the nursing process. It consists of the systematic and orderly data collection and analysis of data pertaining to and about the health status of the patients for the purpose of making the nursing diagnosis.

Nursing diagnosis is the second phase of the nursing process, which is defined as the identification of the human responses and resource limitation of the patient for the general purpose of identifying and directing nursing care.

The next phase is planning. It is the plan for providing nursing care, including various means to assist the clients, setting the goals and designing methods to resolve actual or potential problems.

Implementation follows the planning, which includes the action or actions initiated to accomplish the defined goals and objectives. It is often considered as the actual application of nursing care. The present research project concerns more on this phase in the nursing process for investigation of their physical demands.

Evaluation is the final phase of the nursing process. It is the appraisal of the patients' behavioral changes due to actions of the nurses.

The above descriptions of the nursing processes indicate that nursing, particularly in the implementation phase, draws heavily on the intellectual, interpersonal, and technical skills of the nurses (Torres and Stanton 1982). Therefore, many nursing activities happened on the implementation phase falls into the broad categories of work duties. They contain multifaceted activities including the following key areas:

1) to provide input and participate in the implementation of patient's treatment plan,
2) to formulate and carry out patient's nursing care plan,
3) to keep documentation of patient's condition and inform related parties when necessary,
4) to provide health care and advice to patients and patients' relatives,
5) to keep a safe custody of drugs,
6) to participate in the planning and organization of ward activities to ensure smooth running of the ward, and
7) to provide basic patients' care including a lot of manual effort such as turning, feeding, showering, transferring, lifting, holding, dressing and

undressing patients, making beds, changing pads, cleaning, tidying up, and dispensing medications, etc. (Lusted *et al.* 1994).

The workload of nurses is often very heavy. Some reports had found that nurses were as likely to sustain compensation on back injury as workers in physically demanding occupations such as construction and garbage collection (Personick 1990). Klein *et al.* (1994) reported that the lifting frequency for nurses was similar to that of construction site workers. Jensen (1987) reported in a survey that the weight of lifting and incidence of back injuries amongst garbage collectors, warehouse workers and nurses were similar in terms of prevalence percentage. Several studies had also identified high prevalence rate of low-back pain in nurses (Muir 1994). Musculoskeletal strain to the back was considered to be one of the most widespread occupational hazards for the nursing profession, with one out of six nurses likely to suffer back injury each year (Stubbs *et al.* 1983).

Many studies have identified patient handling activities as the major causes of musculoskeletal injuries in nurses (Corlett *et al.* 1992, Garg and Owen 1992). However, these studies were from overseas, and there could be difference in the physical demand of the nurses between local and overseas hospitals due to the different workload and patients profile. There is as yet no local data available on the physical demanding level of nurses working in hospital settings.

1.6 Work Nature of Local Hospital Nurses

The description of job nature for ward nurses of the Queen Elizabeth Hospital of Hong Kong in 1997 provides some details of local nursing duties as follows:

1. participate in the basic nursing care and ward routine,

2. carry out doctors' prescriptions,
3. provide systematic and individual care to patients,
4. collect and dispatch specimens for laboratory examination,
5. sort and file laboratory and X-ray results,
6. formulate and carry out patients' nursing care plan,
7. perform comprehensive assessment of patients on admission,
8. identify patients' bio-psychosocial and educational problems,
9. keep alert observation on patients' conditions and report any changes to doctors and seniors,
10. keep accurate documentation of patients' progress on nursing card,
11. serve patients with appropriate diet and medications, etc.

Besides, nurses sometimes play the role as health consultants to provide health care advice to patients and their relatives.

1.7 Evaluation of Job Physical Demands of Nurses

Some studies have reported that nursing profession requires heavy physical demand especially for those working in geriatric wards (Corlett *et al.* 1992, Garg *et al.* 1991, Hignett 1996, Lo *et al.* 1993, Owen *et al.* 1992). Different types of studies were conducted to develop the epidemiological data and injury statistics on nurses. Lusted and colleagues (1994) collected data concerning the self reported symptoms in the back, neck and upper limbs among nurses. Yassi and colleagues (1995) conducted a longitudinal study for two years to gather data of injury rate, time and common injury sites in a 1,100-bed acute and tertiary care hospital. Hignett (1996) was interested in the postural analysis of nursing work through ergonomics theory. Lo and colleagues (1993) observed the nurses working in geriatric wards on work site. Juha and colleagues (1996) conducted a survey of physical work exposures in the Ontario Health Center of Canada and reported the prevalence of long-term back problems in occupational group.

However, these studies did not investigate the actual physical demand of front line workers of this profession. No studies or reports could be found reporting the level of physical demand of nurses in Hong Kong and the workload of nurses working in geriatric wards. Without objective data, it would be difficult to assess the problems of work related injuries and the problem may perpetuate. Therefore, the aim of this study is to evaluate the actual physical demand of nurses working in geriatric wards. The project will address two issues of physical demands, which include physiological and neuromuscular aspects of routine daily nursing duties of hospital nurses. The following section discusses the commonest approach used in the evaluation of physiological and neuromuscular demands at work.

1.7.1 Evaluation of Physiological Demand

Physiological measurements of physical activities have a long history. They provide indications of the dynamic effort people exert, with well-recognized and reliable limits, which can be used to ensure that people are not overloaded (Kilbom 1990). Different classification systems exist for rating the strenuousness of physical activities. These include ratings based on the ratio of energy cost at the task to that at rest, oxygen requirement per minute or multiples of the resting metabolic rates. Many of the studies of exercise physiology involve the measurement of physiological demand, which includes direct and indirect methods (McArdle *et al.* 1996).

One of the most common methods of direct measurement is to evaluate the uptake of oxygen per minute in the body during dynamic exercise with large muscle groups. Oxygen uptake is calculated after the analysis of expired air for its content of oxygen and carbon dioxide. It provides basic data for determining respiratory gas exchange and oxygen uptake, and inferring the body's rate of energy expenditure. Measurement of oxygen uptake requires relatively expensive and complex instrumentation. It needs a system, which measures airflow and temperature, current barometric pressure and humidity, ventilation rate and concentrations of oxygen and carbon dioxide in the expired air. Therefore, a mouthpiece will be fitted to the subject's mouth, while a nose clip will be used to eliminate leakage from the nose (Kilbom 1990, Skoldstrom 1987). This method will cause inconvenience and is not suitable for the present study, because the subjects needed to carry out their daily nursing duties as usual during the data collection period.

The direct measurement requires an extensive laboratory and special equipment as well as considerable subject motivation. Consequently, these tests are not suitable for measuring large groups of untrained subjects, such as those in the present study. Therefore, measurement of heart rate during exercise would be conducted to evaluate physiological demand. The test is easy to administer and it can be used with large subject group. The subjects can perform their usual working when the tests are proceeding (McArdle *et al.* 1996).

Besides the heart rate recording, there are still several indirect methods for measurement of physiological demands, such as lactic acid concentration in blood, venous blood return, oxygen content of arterial blood, and blood pressure. The lactic acid concentration, oxygen concentration of arterial blood and blood pressure all tend to be linearly related with oxygen uptake throughout a wide range of exercises, which are the same as heart rate recording (McArdle *et al.* 1996). However, all these measurements involve some levels of invasion and hindrance to the normal work routines of the subject. Therefore, they would not be suitable for the present study.

Since heart rate increases during exercise, heat exposure and under psychological stresses, an increase of heart rate is an unspecific cardiovascular response. Therefore, the interpretation of heart rate recordings must be made against the background knowledge of the circumstances of the recording (Åstrand and Rodahl 1986).

During dynamic exercise at a constant workload, heart rate increases during the first three minutes and then reaches a steady state. Steady state heart rates are linearly related to workload or oxygen uptake, which reflects the exertion of workload. The continuous measurement of heart rate during work is a common method to evaluate cardiovascular strain. The measurements are relatively simple to perform and results are usually reliable. The impulse registered via chest electrodes is transmitted to a receiver, which displays and records the heart rate data. This is the most commonly used system for continuous heart rate recording. The receiver identifies the waves of the signal and stores them in a microprocessor, where the number of beats is counted for a given time period. The receiver can be positioned on the wrist of the subject, where the signals can be stored. The circuitry of the receiver can be constructed to identify the wave with good accuracy so that no artifacts are recorded (Kilbom 1990).

As stated earlier, heart rate is an unspecific measure of cardiovascular strain, therefore measurements must be supplemented with activity recording, i.e. the type of physical activity, psychologically stressful situations, simultaneous heat exposure, etc., must be noted.

The analysis of heart rate recording during work includes several parts:

1) The average heart rate can be calculated, which will provide an estimation of the level of physiological exertion at work.
2) The most demanding tasks will be identified which should correspond to the highest heart rate recorded.
3) The different activities performed can be analyzed and compared by the distribution of mean heart rate.

These analyses can be used to estimate the severity of the work tasks in terms of both calculated proportions of maximal oxygen uptake and cardiovascular strain. Heart rates during prolonged work up to 90 beats per minute are considered as light cardiovascular strain, 90-110 beats per minute is moderate cardiovascular stain, 110-130 beats per minute is heavy cardiovascular strain, 130-150 beats per minute is very heavy cardiovascular strain, and 150-170 beats per minute is extremely heavy cardiovascular strain (Kilbom 1990).

1.7.2 Evaluation of Neuromuscular Demand

Neuromuscular measurement is an important aspect in the evaluation of physical demand. Since back strain and injury has been reported to be one of the most common musculoskeletal disorders that affects nurses in many countries (Gagnon *et al.* 1987, Garg *et al.* 1992, Stubbs *et al.* 1983), therefore the measurement of back muscles strength and fatigue pattern may be useful means to evaluate the neuromuscular demand of muscles.

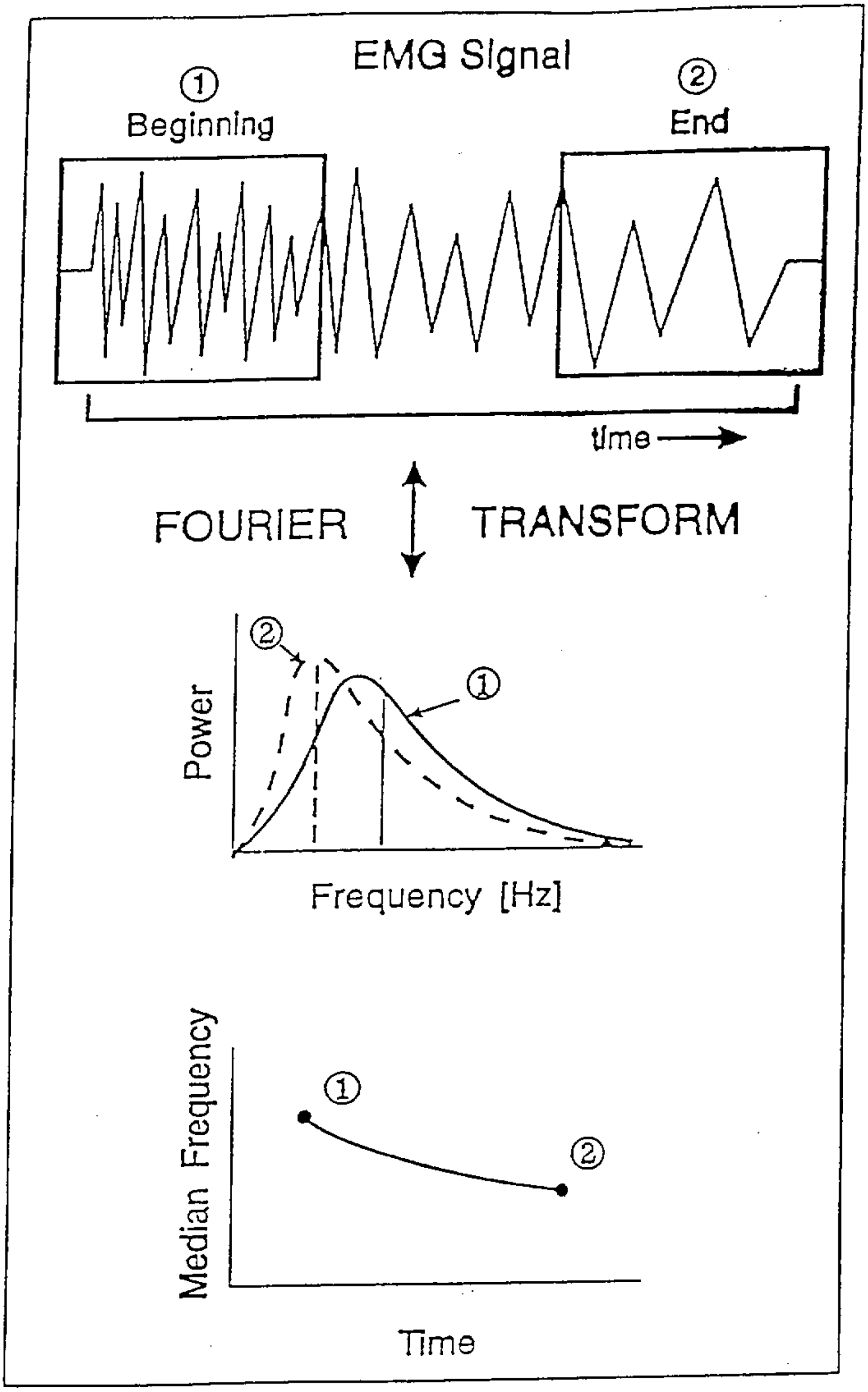
Surface electromyography (EMG) is a common, convenient and well-established method for evaluation of muscle activities (Ng *et al.* 1997, Ng and Richardson 1994). One of the earliest applications of EMG technique to back muscle studies was in 1964 by Morrioka. The EMG signals represent the spatial and temporal summation of action potentials originated from muscle fibers located in the vicinity of the recording electrodes (Basmajian and De Luca 1985). EMG in studies of static isometric contractions has been widely used. It has been shown that the mean rectified EMG signal is linearly proportional to the muscle force (Hof 1980).

Muscle tissues can conduct electrical potentials similarly to the way axons transmit action potentials. When nerve impulses arrive at the postsynaptic membrane, depolarization of the postsynaptic membrane happens, which is called an end plate potential (EPP). In normal circumstance, the EPP is large enough to reach a threshold level, and causes the adjacent muscle fiber membrane to depolarize and then repolarize subsequently. Throughout this process, a muscle action potential is formed. The spatiotemporal summation of individual muscle fiber action potential is called motor unit action potential (MUAP). The MUAPs can be "seen" by using surface electrodes accompanying with muscle contraction. The MUAPs are the signals of EMG. Actually, the change of detected EMG signals reflects the change of the MUAPs during muscle activities, and any factors that affect the MUAPs will change the EMG waveform (Hof 1980).

Many factors can affect the EMG signals, which include physiological, anatomical and technical aspects. The more understanding and control of these factors, the more confidently one can develop the fidelity of the EMG signals. Technically, attention should be paid to electrode configuration, location and orientation as well as skin preparation. The same electrode configuration and dimensions must be used every time for repeated measurements. The air temperature can also affect the surface EMG signals (Bell *et al.* 1993). It is therefore necessary to maintain approximately the same ambient temperature during EMG measurement. The spatial filtering must be considered, such as tissue filtering which includes the skinfolder layer (Biolodeau *et al.* 1995) and skin preparation (De Luca 1997), can also influence the EMG signals.

Unprocessed EMG signals obtained from the amplifier are known as raw signals. They can not be used to compare the activities among various muscles or the same muscle in different measuring situations. Therefore, in order to quantify the EMG signals, different processing procedures are used. These include integration and root mean square. They both quantify the electrical charges and power of the signals (Hof 1980). Another processing method is to look at the frequency of the signals using Fast Fourier Transform (FFT) technique. Analysis of the frequency domain for EMG signals has been generally used in the study of muscle fatigue (Ng *et al.* 1997). The raw EMG data are expressions of electrical signals against a time continuum, through FFT technique, the electrical energy is expressed against the frequency, which is known as the power spectrum. Median frequency (MF) is the important and frequently used parameter for analyzing the power density spectrum of the EMG signal. Median Frequency is defined as the frequency that divides the power of the EMG spectrum into two equal halves. It is considered to be more sensitive to show the biochemical and physiological processes, which occur within the muscles during sustained contractions. Furthermore, MF has been chosen to be a common parameter because it is less sensitive to noise and signal ailment (Basmajian and De Luca 1985, De Luca 1997). During fatiguing isometric contraction, its decrease in MF is generally observed. The MF/time

Figure 1.1: Drop in MF with time (Roy *et al.* 1995).



slope and initial MF are two important indices in muscle fatigue assessment of EMG measurement (De Luca 1997, Roy *et al.* 1995) (Figure 1.1).

EMG analysis of the back muscles was not popular in the 1970's because it failed to isolate trunk extensor muscles and relied upon cumbersome methods of spectral analysis. These technical problems were solved in the 1990's when Thompson and Biedermann (1993) established a protocol to place a standardized electrode for measuring EMG on back extensors. An early study (Morrioka 1964) reported increase in the lower frequency component of back extensors EMG while subjects were performing static lifting with increasing load. A later study confirmed this frequency shift accompanied with an increase in EMG signal amplitude (Andersson *et al.* 1979).

The reason of this increase in EMG activity during the fatiguing process may be due to:

1) During the period of sustained muscle contraction, many action potentials remain ineffective and do not induce a twitch in the muscle fiber. In order to compensate this decrease in force, either additional motor unit is recruited or the action potential firing rate is increased (Basmajian and De Luca 1985).
2) Since the muscle tissues act like a spatial low-pass filter, low frequency components are attenuated less than high frequency components. The spectral shift in the motor unit action potentials is expressed in the EMG signals as increase in amplitude (De Luca 1979, Basmajian and De Luca 1985).

1.7.2.1 Electromyographic Study of Back Extensor Endurance

Back muscles can be divided into three main groups: 1) the superficial muscles associated with the shoulder girdle, 2) the intermediate muscles involved with respiration, and 3) the deep muscles belonging to the vertebral column. Deep muscles of the back are important in maintaining normal postural curves of the vertebral column in standing (Snell 1994).

Erector spinae is the main muscle group, which maintains the posture in many positions, and is the longest and most superficial muscle in the deep group. For surface EMG measurement of erector spinae, it was suggested that the electrodes should be placed at 3-6 cm lateral to the L4 lumbar spinous process of the dominant side (Ng and Richardson 1994). This is because of the fact that ES is relatively thin and generally absents at the L4-L5 space. This can minimize electrical interference from other muscles. Repeatability test using the above electrode placement has been conducted (Thompson and Biedermann 1993) and long term (3 months) test - retest reliability results have shown that the EMG recordings were very reproducible.

1.7.2.2 Standardization of Trunk Holding Position

People differ in their muscle strength such as the back extensions. Hence, it is suggested that during EMG measurement of the back, it should be conducted in a fixed and standardized pain free position. Biering-Sorensen (1983) demonstrated that a subject could maintain a horizontally unsupported upper body holding posture (a measure of mechanical capability) for one minute. This test has been considered as one of the standardized tests for measuring back endurance. The study showed that the horizontally unsupported posture was equal to a sustained load of approximately 50-60% of the subjects' maximal voluntary effort of the trunk extensions (Mannion and Dolan 1994).

There are relatively few studies (Ng *et al.* 1997, Ng *et al.* 1998) on the investigation of initial MF and MF slopes even on normal subjects. For nurses, there is no published data concerning their back muscle strength or back muscular fatigue status at work. Therefore, it is essential to have some data on the back muscles' fatigue status during work to evaluate their musculoskeletal demand.

1.7.3 Psychophysical Measurement

A lot of reports (Hignett 1996, Lo *et al.* 1994, Lusted *et al.* 1994, Stubbs *et al.* 1983, Videman *et al.* 1989, Yassi *et al.* 1995) have stated that the workload for nurses is heavy. How can one relate the difference between their own perception of work intensity and the real physical workload? There is actually a highly reproducible relationship between the actual workload and the perceived exertion (Borg 1985).

The self-rating of perceived exertion (RPE) had been used in previous studies to rate the exertion level of tasks. The scale for rating of RPE or Borg's scales (Table 1.1) is constructed as a simple tool to aid a person in estimating and regulating exercise intensity for most physical activities. The scale steps have been adjusted so that the ratings, number from 6 to 20, correspond to a HR-variation from 60-200 beats /min. Beginning with 6 as the starting point, which means that the measurement is not in ratio scale with an absolute zero starting point.

The scale of 6 represents no exertion at all, 11 represents light exertion, 13 is somewhat hard work, 15 equates to heavy workload, 17 is considered very hard work, 19 is extremely hard work, and 20 is equivalent to maximal exertion (Borg 1985, Kilbom 1990). The instrument is an ordinal scale constructed to function as an interval

Figure 1.2: The pathway between physical and self rating exertion (Borg 1985).

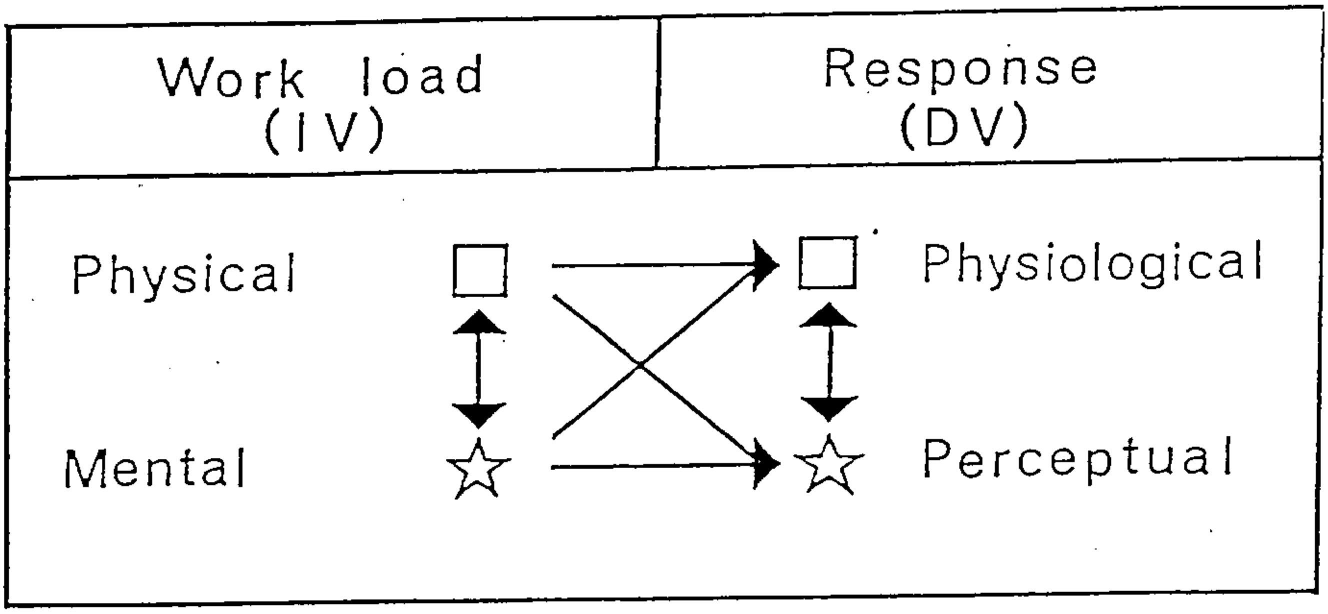


Table 1.1: Borg's RPE scale (Borg 1985).

Borg's RPE-Scale

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

scale covering the total perceptual range from an extremely light exercise to extremely hard ones.

This scale can be used to supplement physiological measurements during exercise testing and occupational work task (Figure 1.2). They often provide the valuable additional information about subjective perception, especially when the heart rate response is unreliable due to other environmental or physiological reasons. This idea of substituting physiological measurements by subjective rating is attractive, as rating does not require any instrumentation.

The use of RPE for evaluation of the workloads in heavy physical tasks is very common. The RPE - scale can be used not only to identify which aspects of the work are particularly hard, but also to quantify approximately how heavy the strain is. Heart rate is a practical measurement of physiological strain together with the RPE - values. Evaluation of the work demand according to heart rate only, can be deceptive because other environmental factors may affect the heart rate. This strain one feels is actually important indicator of the real degree of exertion. The combination of heart rate and Borg's scale can combine the physiological and psychophysical factors in the assessment, thus giving less biased results. Therefore, we will use the RPE scale to be a complementary part in evaluation of physical demand on nurses.

1.8 Objectives of Study

After reviewing the literature, it is clear that nurses have high physical demands at work, particularly when the clients are dependent, such as geriatric patients. Previous studies have revealed the high incidence of back problems in nurses, but these studies did not assess the actual physical demanding nature of the nurses. As far as local hospitals are concerned, there is no available data on nurses of Hong Kong for their work demanding profile. Particularly, on the levels of physiological and neuromuscular exertions, there are still no papers published on the actual bodily demand of local female nurses working in geriatric wards.

Therefore the present study has three aims:

1. To measure the physiological exertion level of nurses working in geriatric wards of a local hospital.
2. To measure the neuromuscular exertion level of nurses working in geriatric wards of a local hospital.
3. To develop the work profile of the nurses in this study and to correlate the physiological data with the self-perceived exertion data.

A group of normal sedentary office workers will be tested as the control in order to contrast the above testing parameters between the nurses and the control subjects.

1.9 Null Hypothesis

1. The work demand of nurses is not high and there is relatively low physiological strain on them.
2. There is no difference in the physiological demands at work between the nurses and control subjects.
3. The neuromuscular demand at work for the nurses is not high and there is no increase fatigue of back muscles in the nurses after one day of work.
4. There is no difference in the neuromuscular demands on the back muscles between the nurse and control subjects.
5. There is no correlation between the physiological data of heart rate with the self-perceived exertion level for the nursing duties.

Chapter 2

Method

2.1 Subjects

Twenty-one female nurses from the geriatric or rehabilitation wards of the Caritas Medical Center (CMC) in Hong Kong were recruited as subjects of the study group. Eighteen female sedentary office workers of similar age, body weight, height and working years as the nurses were recruited as the control group.

The recruitment criteria were:

- On voluntary basis.
- Female nurses aged between 18-35 years working front line in the geriatric or rehabilitation wards of CMC.
- Female clerical workers aged between 18-35 years.
- No cardiorespiratory problems.
- No musculoskeletal discomfort of the body requiring treatment in the last month.
- No regular exercise training at sports club level or above.

The subjects read the research protocol (Appendix 1) and information sheet (Appendix 2) of this study, and they gave their written consent (Appendix 3) before being tested. This study was approved by the Ethics Committee for Human Experimentation of the administering institutions (Appendix 4).

The study included three parts:

1. Physiological measurement;
2. Neuromuscular measurement; and
3. Work-related questionnaires.

2.2 Equipment

The equipment used in this study included:

- A Polar heart rate tester system (Polar Electro, Kaytto 4000, Finland) (Figure 2.1).
- A Bagnoli-2 electromyographic system (Delsys Inc., U.S.A.) (Figure 2.2).
- A DataQ data acquisition unit (DataQ Instruments Inc., U.S.A.) (Figure 2.3).
- An IBM compatible personal computer (Pentium MS 5133, AST, U.S.A.).
- Two electric manipulative plinths (Akron, Model 8250, Japan) (Figure 2.4).
- A job profile questionnaire (Appendix 5).
- A questionnaire of work history, injury profile, demographic information, and Borg's scale in nursing duties (Appendix 6).

2.3 Measurements of Physiological and Neuromuscular Demands

This study measured the physiological demands and neuromuscular demands of 21 nurses and 18 clerical workers during a normal workday. Each of the measurements is explained below.

Figure 2.1: The Polar heart rate tester system (Polar Electro, Kaytto 4000, Finland).

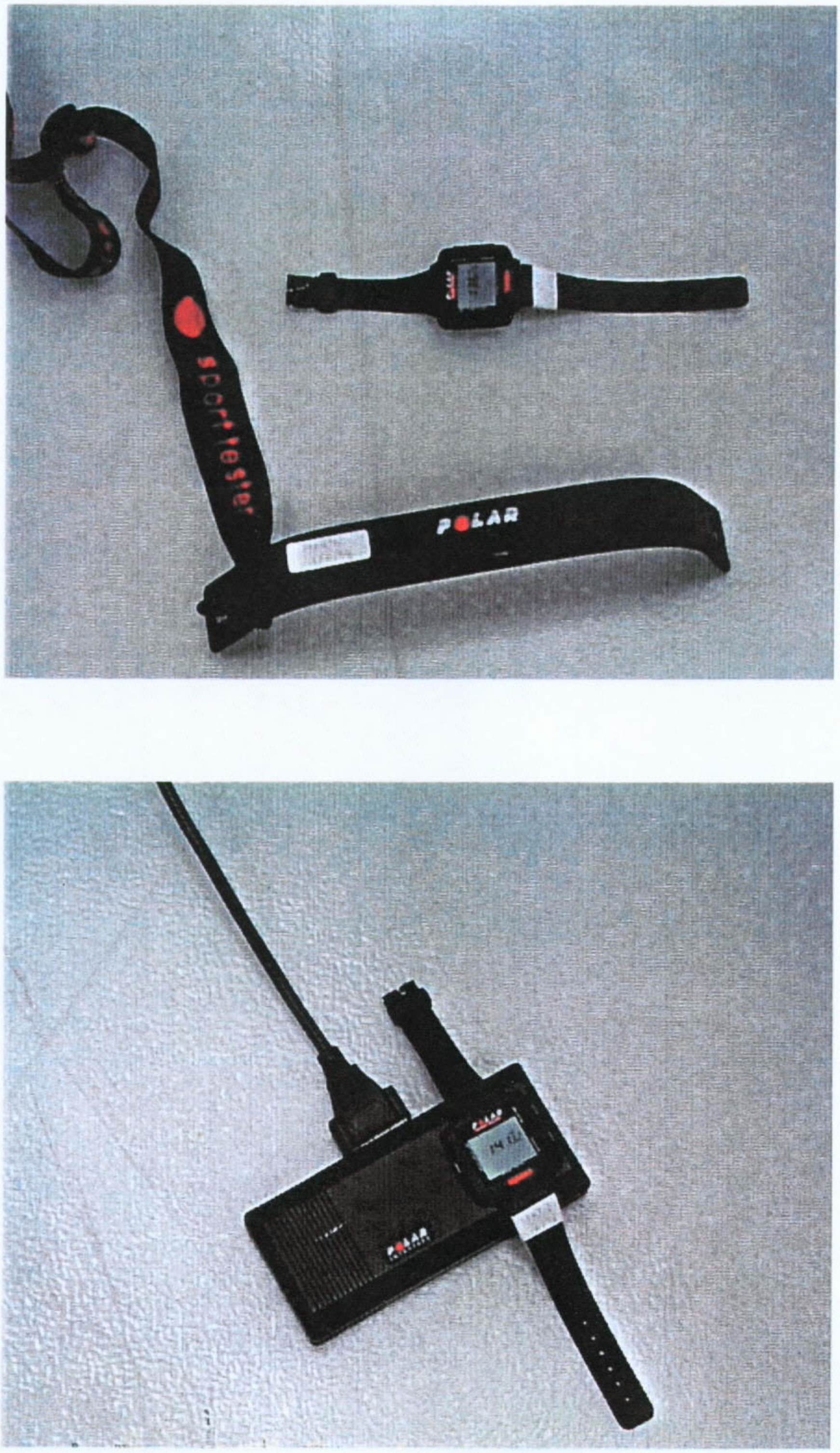


Figure 2.2: The Bagnoli-2 electromyographic system (Delsys Inc., U.S.A.).

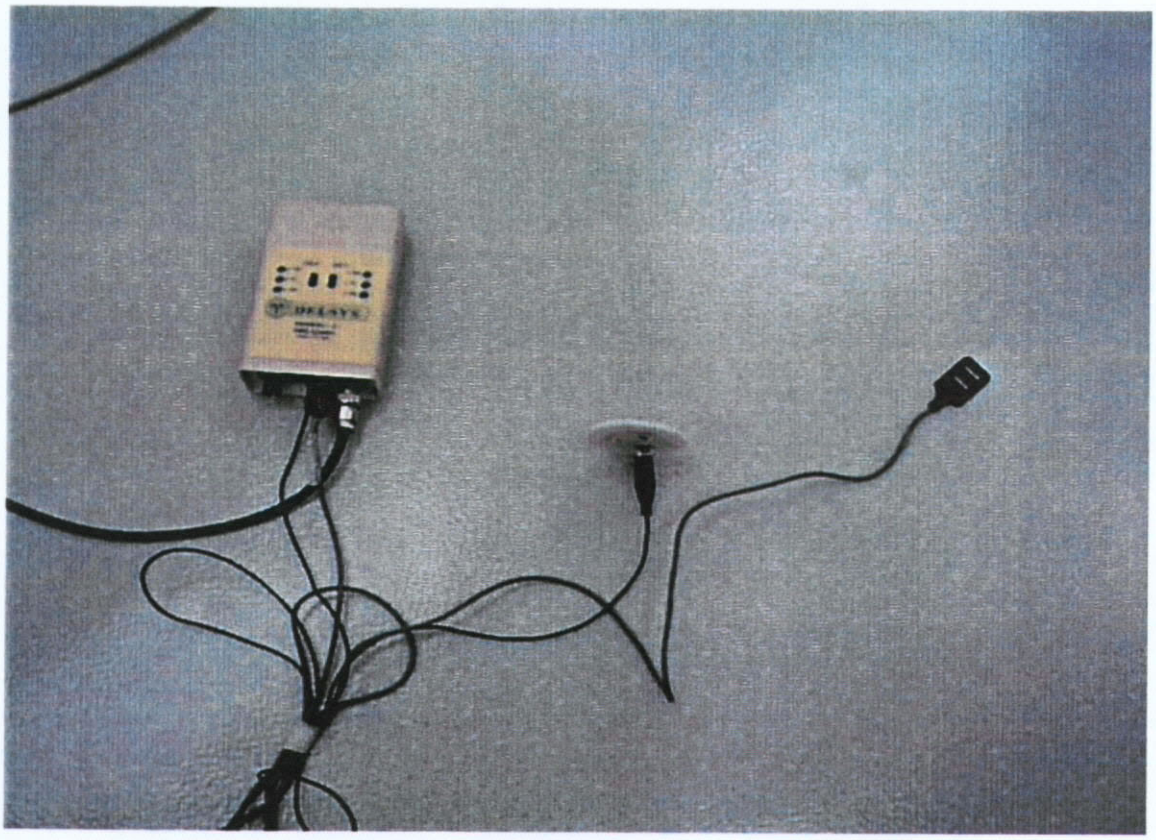


Figure 2.3: The DataQ data acquisition unit (DataQ Instruments Inc., U.S.A.).

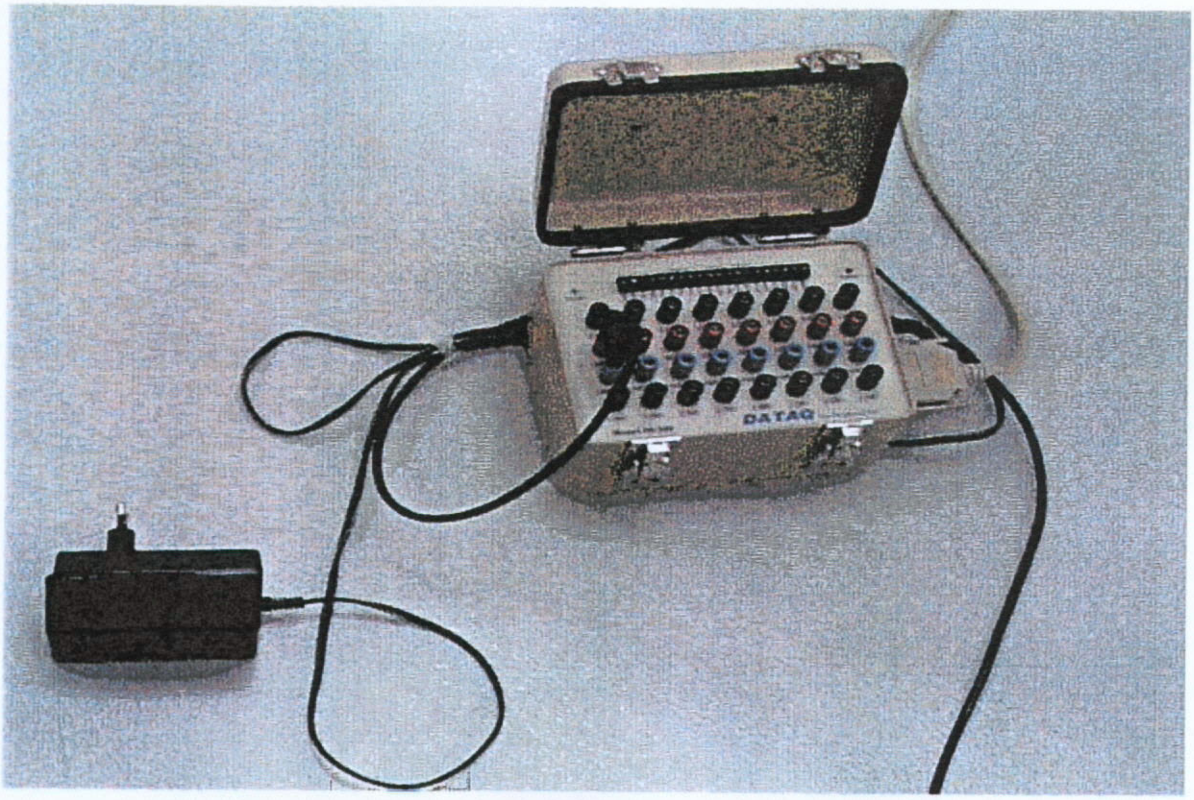
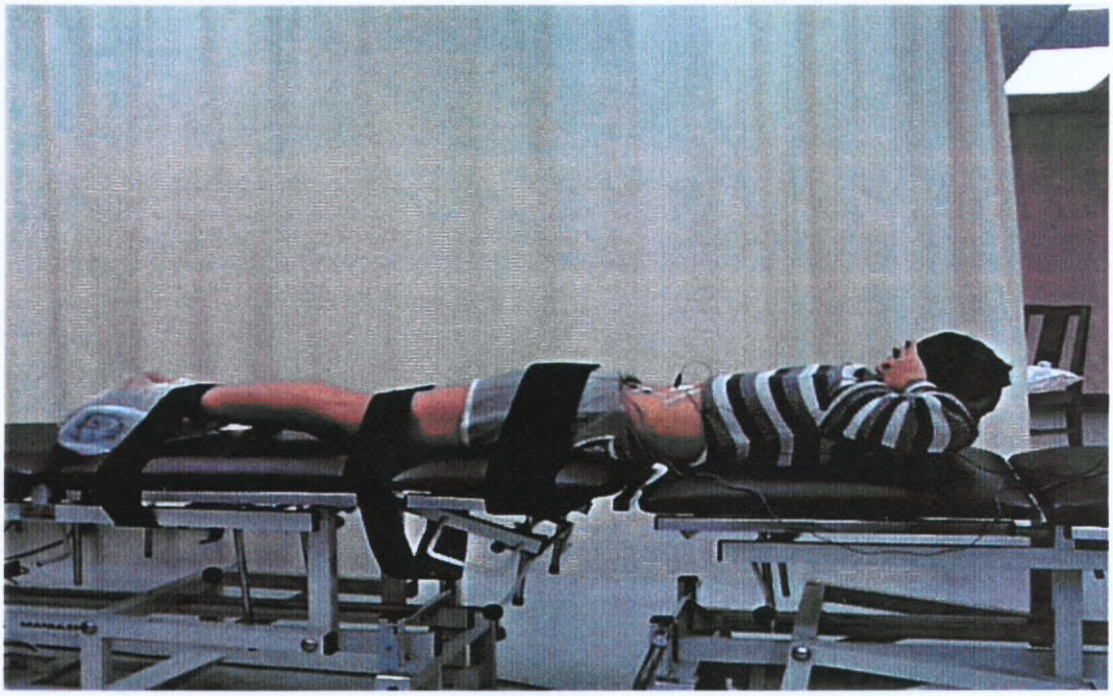


Figure 2.4: Subject was on two electric manipulative plinths used for the trunk holding test (Akron, Model 8250, Japan).



2.3.1 Physiological Measurement

The heart rate was measured to reflect the physiological demands of the subjects (Kilbom 1990). The Polar heart rate monitor was used to record the heart rates of the subjects during a workday.

Subjects were asked to record their radial pulse at their wrist early in the morning of the test day when they woke up. This was taken as the resting heart rate (baseline) of each subject. Before a subject started the workday, she would put on a Polar heart rate sensor on the chest, and the heart rate data would be transmitted telemetrically to a monitor, which the subject wore on the wrist. This equipment monitored and recorded the heart rate at one-minute intervals throughout the normal workday of eight hours.

In order to control the circadian effect, the nurses participated in this study were all tested in their daytime work shift only. This matched with the normal working hours of the control subjects.

Since the Polar heart rate sensor was applied directly to the skin and covered with clothes on the outside, other people would not notice that the subjects were being tested. Also, the wrist monitor is like a watch worn by the subjects. The size is small and therefore would not affect the subjects' normal duties at work.

Besides taking the heart rate data, the nurses were also asked to fill in a work sheet at thirty-minute intervals (Appendix 5), which recorded their work profile in the last thirty minutes. These data would be used to compare with the heart rate data so as to identify the level of physiological demands of each routine nursing duty.

At the end of the test day, all heart rate data collected would be downloaded to a personal computer through the computer interface of the Polar heart rate tester. Since the heart rates were taken at one-minute intervals throughout the eight-hour work shift, there would be a total of 480 heart rate data points for each subject. In order to examine the overall change in heart rate throughout the workday and to compare that with the work profile, the distribution percentage of heart rate in different ranges and the percentage change of heart rate from the baseline in different duties were calculated and analyzed.

2.3.1.1 Reliability of the Polar Heart Rate Recorder

A test-retest reliability study of the Polar heart rate monitor was conducted prior to the actual testing of the subjects. Six female university students wore the Polar heart rate monitor for two to eight hours on two different days, and they were instructed to maintain similar activities on the two testing days. The data obtained were analyzed with Intraclass Correlation Coefficient (ICC) (3,1).

The ICC is a reliability index that is calculated using variance estimates obtained through an analysis of variance. Therefore, it reflects the degree of correspondence and agreement among ratings. It is an index that overcomes the limitation of Pearson correlation as a measure of reliability (Portney and Watkins 1993). Shrout and Fleiss (1979) suggested that ICC model (3,1) is appropriate for testing intrarater reliability of a group for one specific data collection experience, since it is generally not reasonable to generalize one rater's scores to a larger population of raters. Therefore, this ICC model was used for assessing reliability in this study.

2.3.1.2 Data Analysis

The heart rate data in the entire experimental period were plotted against time and the work profile (Figure 2.5). The most demanding duties, those relatively light duties and the least demanding duties were all identified in terms of the heart rate data. These heart rate data were compared with the subjective questionnaire of self-perceived exertion scale (Appendix 6) completed by the subjects prior to the tests. The demanding natures of the nursing duties were therefore determined based on both the objective and subjective data.

The percentage of heart rate increases over the baseline is another indicator of physical exertion (McArdle *et al.* 1996). It is the difference of heart rate between the working hours and baseline expressed as a percentage of the baseline.

2.3.2 Neuromuscular Assessment

One of the most frequent complaints of nurses is low back pain (Personick 1990). This part of the study aimed to test the endurance and fatigue pattern of the back muscles of nurses and compare with the clerical control group. Surface electromyography (EMG) of the erector spinae (ES) muscles was recorded in this study. A pair of surface EMG electrodes (Bagnoli-2, Delsys Inc.) were applied at the level of L4-L5 on each subject along the muscle fiber direction of erector spinae, three centimeters from the midline on both sides (Ng and Walter 1995). The common ground electrode was applied over the spinous process of T12 (Figure 2.6). These sites were labeled by skin markers, in order to enhance accurate repositioning of the electrodes.

Figure 2.5: **The heart rate data in the entire experimental period were plotted against time and the work profile.**

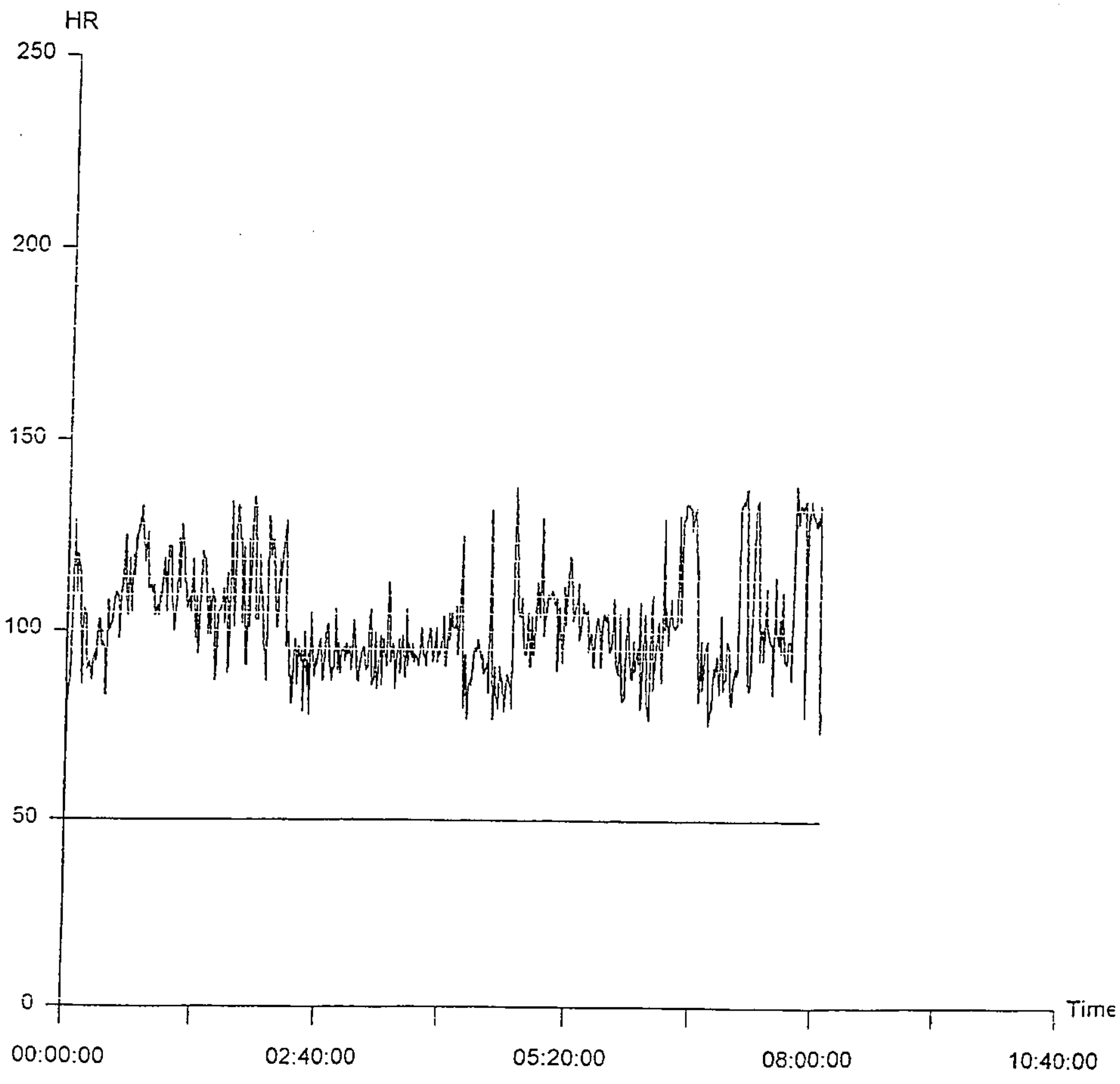
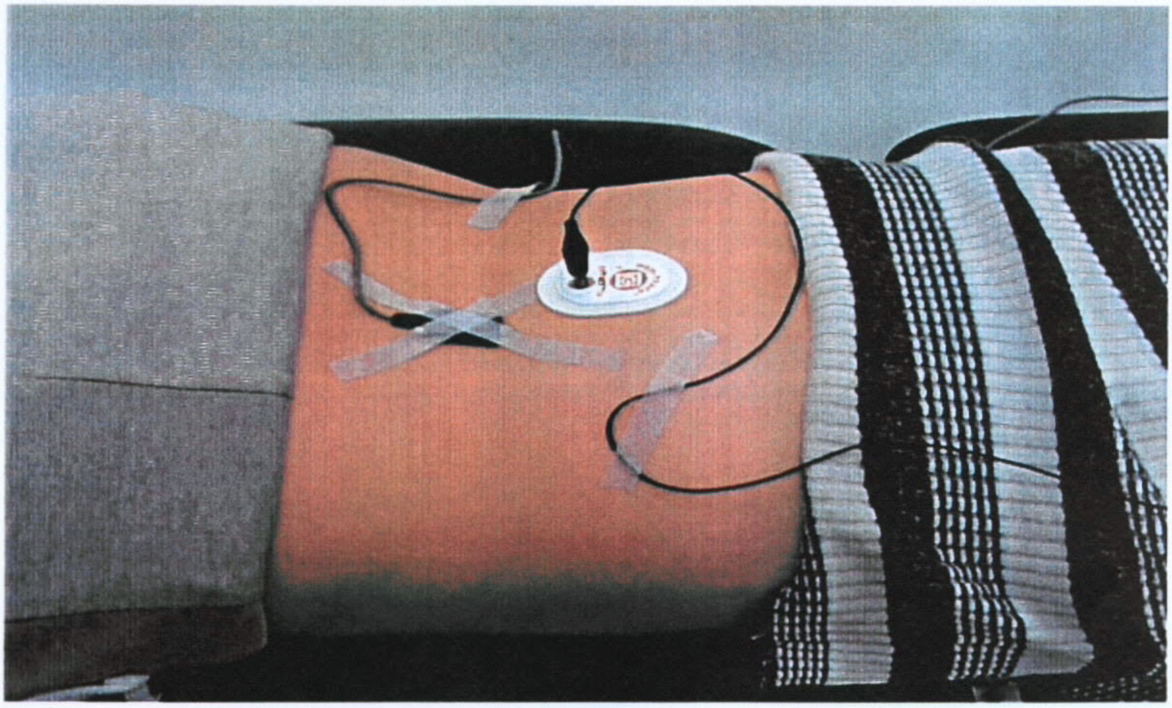


Figure 2.6: Location of the electrodes in the tests.

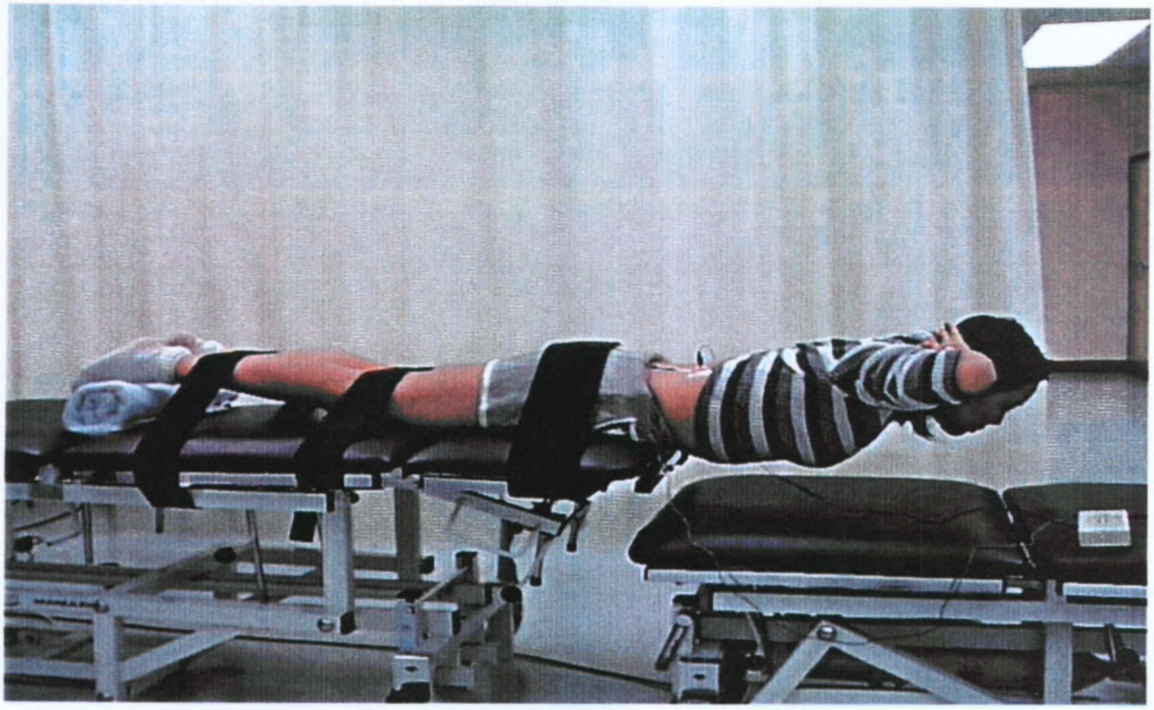


Skin preparation prior to the placement of electrodes included light shaving of the skin, scrubbing with medical skin scrub gel (Offset Dx, Graphic Controls Co.), and cleaning with 75% alcohol to reduce skin resistance. Surface electrodes were applied to the skin and secured with adhesive tapes to prevent relative movements during the tests.

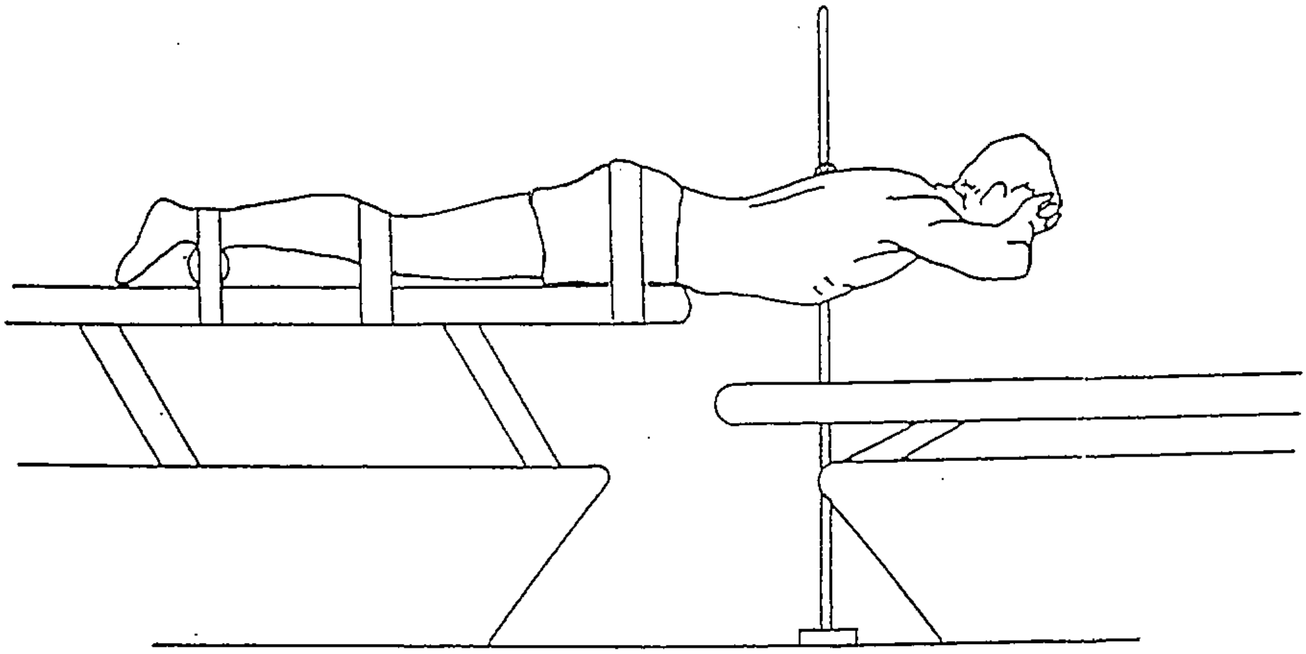
The testing procedures required each subject to perform a horizontal trunk holding manoeuvre immediately before and after the work shift. The subject was positioned in prone lying over two electric manipulative couches of equal height. The first couch supported the upper body and the second supported the pelvis and legs. The anterior superior iliac spines were positioned over the edge of the couch that supported the lower body (Figure 2.7). Straps were used to stabilize the hip, knees and ankles onto this couch. After the lower body was firmly secured, the couch supporting the upper body was gradually lowered by 20cm, but the subject was asked to maintain her trunk in a horizontal position by contracting the back extensor muscles isometrically. A pointer was placed beside each subject to help her to maintain a horizontal position (Ng *et al.* 1997) (Figure 2.8). The subject was asked to maintain this trunk holding position for 60 seconds, and EMG of the ES muscles was recorded during this period.

The 60-second raw EMG signals were pre-amplified by 1,000 times and filtered through a bandwidth of 20-450 Hz. The EMG signals were A/D converted (DI 220, DataQ Instruments Inc.) with a sampling rate of 1,000Hz. Off-line data analysis was supported by WINDAQ software (WINDAQ, DataQ Instruments, Inc.).

<u>Figure 2.7</u>: The anterior superior iliac spines were positioned over the edge of the couch that supported the lower body.



<u>Figure 2.8</u>: The horizontal trunk holding position according to Ng *et al.* (1997).



2.3.2.1 EMG Signal Processing

The EMG signals of every "fifth" second (i.e. 5^{th}-6^{th} sec, 10^{th}-11^{th} sec, 15^{th}-16^{th} sec, 20^{th}-21^{st} sec, etc.) were extracted for further analysis. Twelve data points were thus obtained for one minute of recording. These EMG signals were transformed into the frequency domain by the Discrete Fourier Transform (DFT) technique supported by the WINDAQ software (WINDAQ Instruments, Inc.). The power spectra were exported as ASCII file to a personal computer and the median frequency (MF) was calculated with the Microsoft Excel program.

A scatter plot of mean MF against time was performed for the twelve MF recordings of subjects in each group. Linear regression was performed on these points and the slope (MF slope) and constant (initial MF) of the regression lines were calculated.

2.3.2.2 Reliability Test of EMG Recording

Since the EMG recording involved two measurements, a test-retest reliability study was performed. Six female university undergraduate students were tested. The testing procedures followed the description above. Each subject was given about two hours of rest between the tests in order to eliminate the effect of muscle fatigue. The MF slopes and initial MFs of the two tests were analyzed by ICC (3,1) to obtain the reliability of this measurement.

2.3.2.3 Data Analysis

Linear regression was used to study the changes of MF with time. Initial MF (IMF) and MF slope were then calculated from the regression line. Paired t-tests were used to compare the difference in IMF and MF/time slopes before and after the work shift. For the residual analysis, Cook's distance less than 4 and standardized residual (SR) less than ± 2 were taken as the indices to ensure that the regression equations significantly represented the MF data. The α level for all tests was set at 0.05.

2.3.3. Questionnaires

Subjects in the study group were required to fill in three questionnaires, which included a survey of work history, work profile, safety training and demographic data, a Borg's RPE scales in nursing duties, and a Nordic questionnaire (Appendix 6).

2.3.3.1. Survey of work history, work profile, safety training and demographic data

The first part of the survey was about their demographic data, work history, work profile, work safety training and history of work-related musculoskeletal problems of the subjects. It provides information on the personal history and work safety training, such as awareness of safe lifting of heavy objects and attendance of manual handling training courses offered by their employers.

2.3.3.2. Borg's RPE scale in nursing duties

The second part was related to their self-perceived exertion level of their duties according to the Borg's RPE exertion scale (Borg 1985). The nursing duties included in this questionnaire were selected after a few days of observation in the ward to identify the usual work duties of the nurses.

2.3.3.3. Nordic Questionnaire

Nordic questionnaire (Ekberg *et al.* 1994) was used to indicate subjects' uncomfortable site(s) in the past twelve months and seven days. Uncomfortable site(s) referred to different body area(s) suffering discomfort and/or pain. The twelve-month record represents relatively chronic suffering, and the seven-day record represents relatively acute suffering. The subjects were asked to circle their uncomfortable site(s) on the body chart before being tested.

Chapter 3

Results

3.1. Demographic Difference between Study and Control Groups

There is no significant difference in age, weight, and height distribution between the two groups (Table 3.1). Therefore, adjustment for these demographic covariates is not necessary for subsequent analysis.

3.2 Results of Physiological Measurement

3.2.1. Test-retest Reliability of Polar Heart Rate Recorder

The test-retest reliability of the Polar heart rate recorder was conducted on six female subjects with mean age of 21.3±2.1years, mean weight of 52.98±2.09kg, mean height of 158.85±8.13cm. Measurement of reliability was based on the ICC (3,1). An ICC of over 0.75 indicates high reliability, whilst 0.90 and above is considered to be a valid interpretation of clinical results (Portney and Watkins 1993). The ICC result of the Polar heart rate recorder was 0.911. That means the Polar heart rate recorder has very high reliability (Table 3.2).

3.2.2 Results of Heart Rate Records

Distribution of the heart rate records from all twenty-one subjects of the study group is shown in Figure (3.1). The figure indicates that over 50% (55.52%) of the heart rates is in the range of 90-130 beats/minute. In 56.19% of their total work hours, the heart rate of the nurses is above 90 beats/minute; and in 18.43% of the work hours,

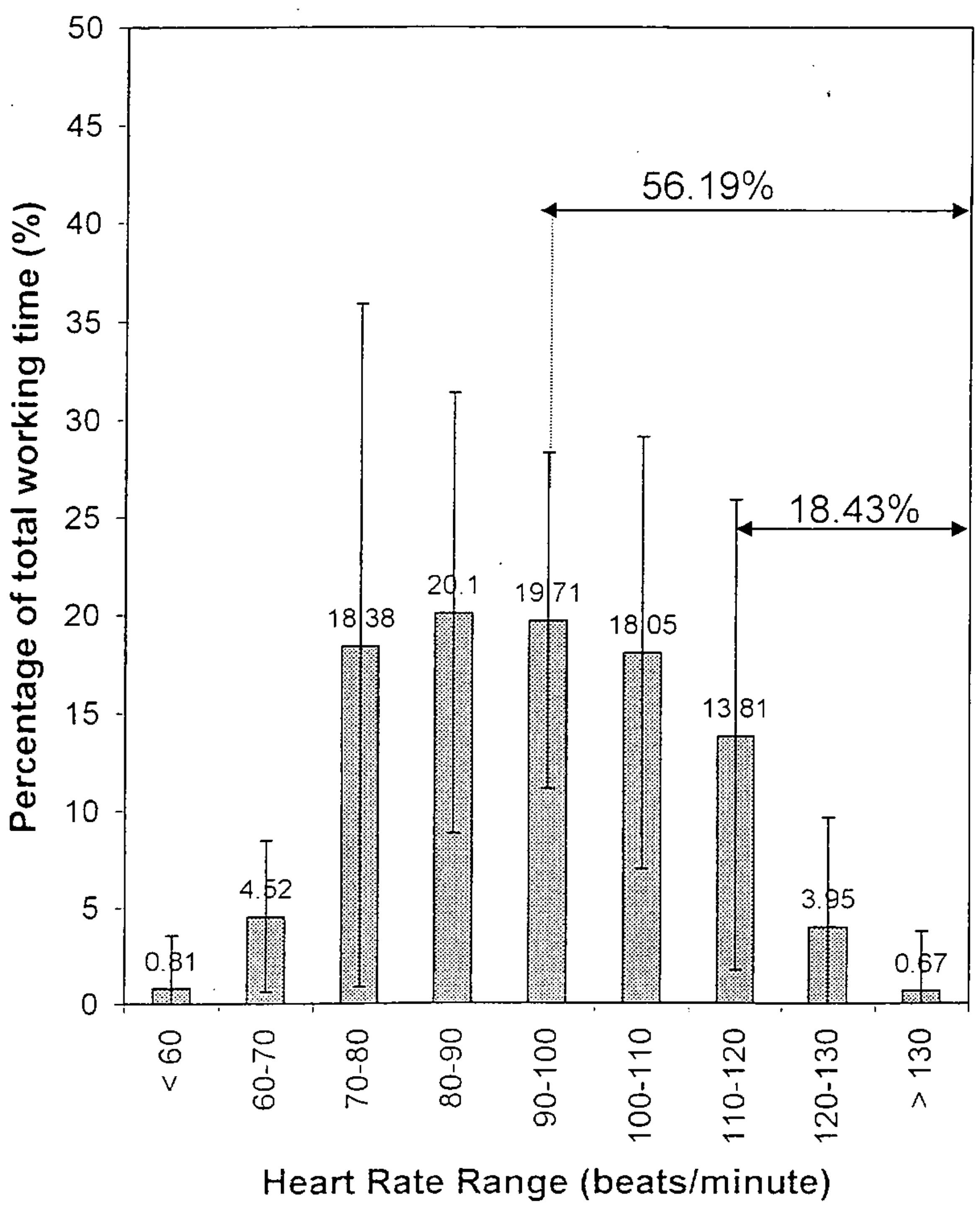
Table 3.1: Demographic data for subjects of this study.

	Study Group (Geriatric Wards Nurses)	Control Group (Sedentary Clerical Workers)
Sample Size	21	18
Age (years ± standard deviation)	27.33±4.99	28.39±3.22
Weight (kg ± standard deviation)	50.89±5.62	51.53±4.06
Height (cm ± standard deviation)	161.72±4.22	162.72±5.31

Table 3.2: Test re-test reliability of Polar heart rate recorder (N=6).

	Mean ± SD (Beats/min)	ICC (3,1)
Initial Test of Heart Rate by Polar Recorder	74.3 ± 6.02	0.911
Re-test of Heart Rate by Polar Recorder	75.3 ± 5.57	

Figure 3.1: Distribution of heart rate in a work shift in the study group (N=21).



it is above 110 beats/minute. According to the classification of cardiovascular strain level by Kilbom (1990), heart rates during prolonged work up to 90 beats per minute are considered to be light cardiovascular strain, 90-110 beats per minute is moderate cardiovascular strain, and 120-130 beats per minute is heavy cardiovascular strain. Therefore, the cardiovascular strain of the study group can be considered to be moderate to heavy in over 50% of their working hours.

The distribution of heart rate records from the control group shows that they acquired heart rate of above 90 beats/minute in 18% of their total working hours (Figure 3.2). Therefore, according to the classification of Kilbom (1990), the clerical workers had light cardiovascular strain in 82% of their total work hours.

The nurses filled in a work duty sheet to record their work profile at 30 minutes interval throughout a day shift. The work profile was then compared with the respective subject's heart rate records, so as to study the physiological strain for different nursing duties (Table 3.3). Results indicated the heart rates increased substantially when the subjects performed solo transfer, showering and turning. The nursing duties with lightest cardiovascular strain were paper work and feeding.

The various nursing duties did not occur exactly at the same time, because the nurses were recruited from four geriatric wards in the same hospital. Even in the same ward, the nurses in different groups finished the nursing tasks at different time. Normally, the nurses had reporting and paper work at the beginning and end of a workday. They performed patient transferring and showering in the morning, which was between the 1st to 3rd hours of a daily work shift. Patient turning was finished in the afternoon, which was one hour to thirty minutes before the end of a work shift. Patient feeding was scheduled at noon, which was followed by nurses' lunchtime.

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Table 3.3: The percentage of heart rate change (The fluctuation of heart rate) and heart rate record in different nursing duties (N=21).

Percentage of heart rate change was defined as the increase in heart rate over the baseline level and expressed as percentage of baseline.

Nursing duties	Heart Rate Record (Beats/min)	Percentage of heart rate change (Heart rate fluctuation)
Solo transfer	129.38±10.951342	92.31±10.95
Turning	127.64±7.361466	90.24±7.36
Showering	127.15±11.11263	89.77±11.11
Share transfer	117.67±17.06324	75.64±17.06
Bed making	95.28±13.57113	42.21±13.57
Observation	94.96±9.613891	41.73±9.61
Administration	93.70±11.44909	39.85±11.45
Reporting	87.96±20.95221	31.28±20.95
Ward Round with Doctors	84.32±10.91918	25.86±10.92
Lunch	80.88±5.633989	20.72±5.63
Feeding	80.33±8.061667	19.90±8.06
Paper work	79.38±10.22066	18.48±10.22

Baseline heart rate of the study group is 65.05 ± 4.07 beat/min., and baseline heart rate of the control group is 67.06 ± 3.04 beats/min.

3.3 Results of Neuromuscular Measurement

3.3.1 Test-retest Reliability of EMG

Reliability of EMG recording of back muscles was tested in six subjects with mean age of 22.1±3.2years, mean weight of 51.40±1.54kg, and mean height of 155.45±6.10cm. The ICC (3,1) values of MF/time slope and initial MF of the test and retest trials were 0.971 and 0.957 respectively (Table 3.4), which are very high values to indicate that the measurements are reproducible.

3.3.2 Results of EMG for Back Muscles

The MFs of EMG measurement for back muscles of the study group (nurses) and control groups (clerical workers) are presented in Table 3.5.

The back extensor endurance patterns, before and after work, of the study and control groups are shown in Figure 3.3 and Figure 3.4.

Linear regression (SPSS 6.0 program) was used to study the relationship between the MF and time. The linear regression model that best fitted the data of the study and control groups are:

$Y=-0.6131X+132.93$ (nurses before work),

$Y=-1.0583X+115.83$ (nurses after work),

$Y=-0.5646X+133.44$ (clerical workers before work),

$Y=-0.5587X+125.73$ (clerical workers after work).

Table 3.4: Test re-test reliability of EMG in MF/time and initial MF (N=6).

Each subject was given about two hours of rest between the Test 1 and Test 2.

	Test 1 Mean±SD	Test 2 Mean±SD	ICC (3,1)
MF/time slope	-0.298±0.144	-0.292±0.130	0.971
Initial MF	116.85±21.34	115.04±17.68	0.957

Table 3.5: The Median Frequencies (MFs) of the study group and the control group before and after work shift.

Time Duration	Test Group		Control Group	
	MF before work shift	MF after work shift	MF before work shift	MF after work shift
5^{th} - 6^{th} sec.	131.50±10.42	118.72±12.13	126.05±9.87	123.22±6.85
10^{th} - 11^{th} sec.	127.86±11.63	114.90±12.33	124.53±8.14	120.44±8.06
15^{th} -16^{th} sec.	122.56±10.64	93.81±13.76	125.39±9.35	118.86±7.25
20^{th} - 21^{st} sec.	123.23±9.83	88.71±19.36	124.14±7.69	112.56±7.71
25^{th} - 26^{th} sec.	114.02±12.61	81.63±17.43	122.34±8.76	110.89±9.18
30^{th} - 31^{st} sec.	117.46±9.00	75.15±18.11	119.24±10.14	107.88±8.02
35^{th} - 36^{th} sec.	110.63±9.09	81.81±23.37	116.35±8.21	106.87±8.80
40^{th} - 41^{st} sec.	101.49±9.21	74.87±18.70	113.79±6.60	103.87±7.87
45^{th} - 46^{th} sec.	103.58±8.17	65.25±14.68	111.02±7.28	101.64±7.12
50^{th} - 51^{st} sec.	103.08±8.36	66.83±14.70	102.11±8.22	98.11±7.42
55^{th} - 56^{th} sec.	103.54±7.90	61.91±13.07	99.86±6.48	94.91±6.32
60^{th} - 61^{st} sec.	97.06±6.72	53.57±11.66	96.21±7.41	91.67±7.05

Figure 3.3: Change of median frequency of erector spinae during one minute EMG recording of the study group (N=21).

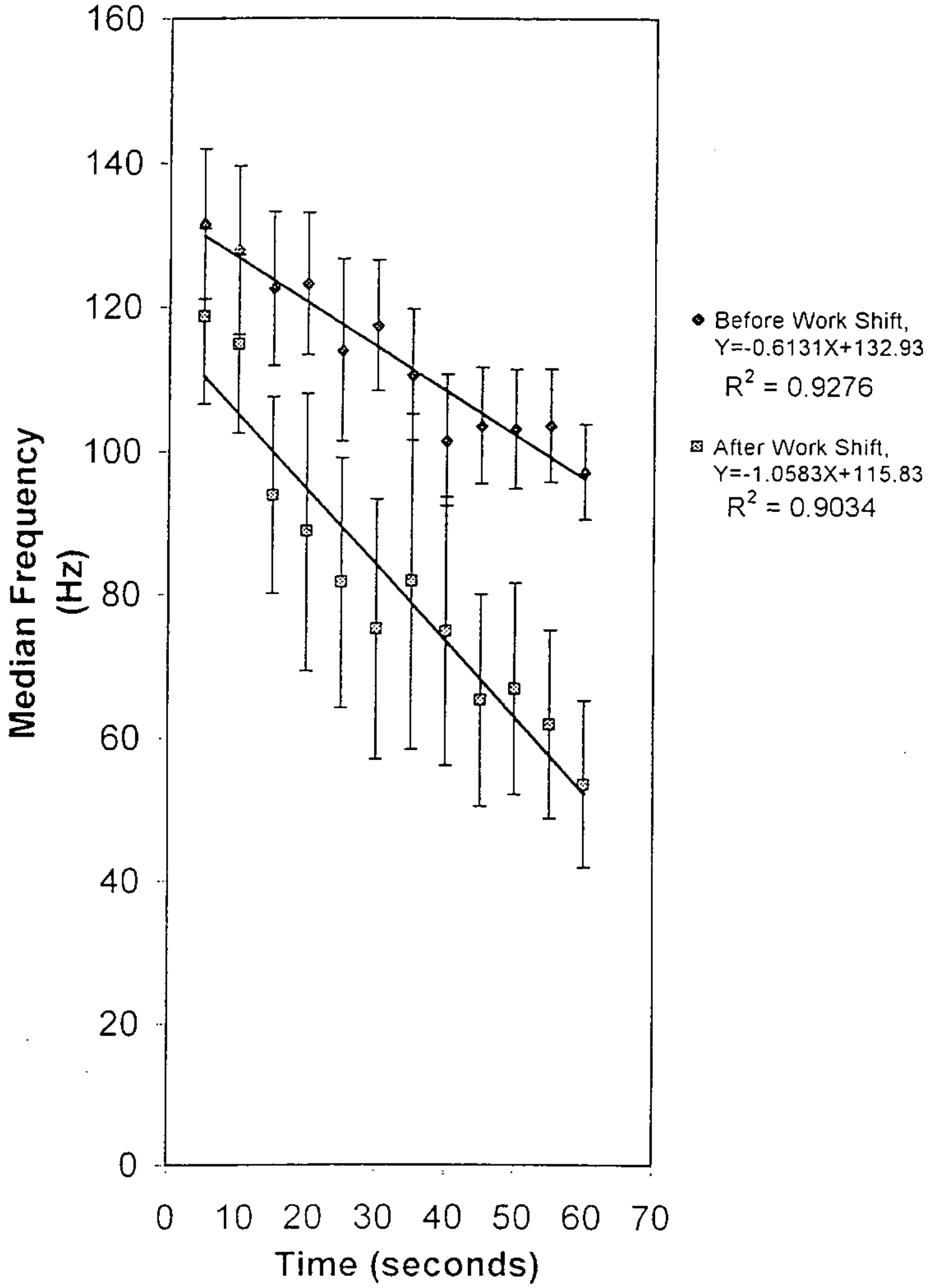
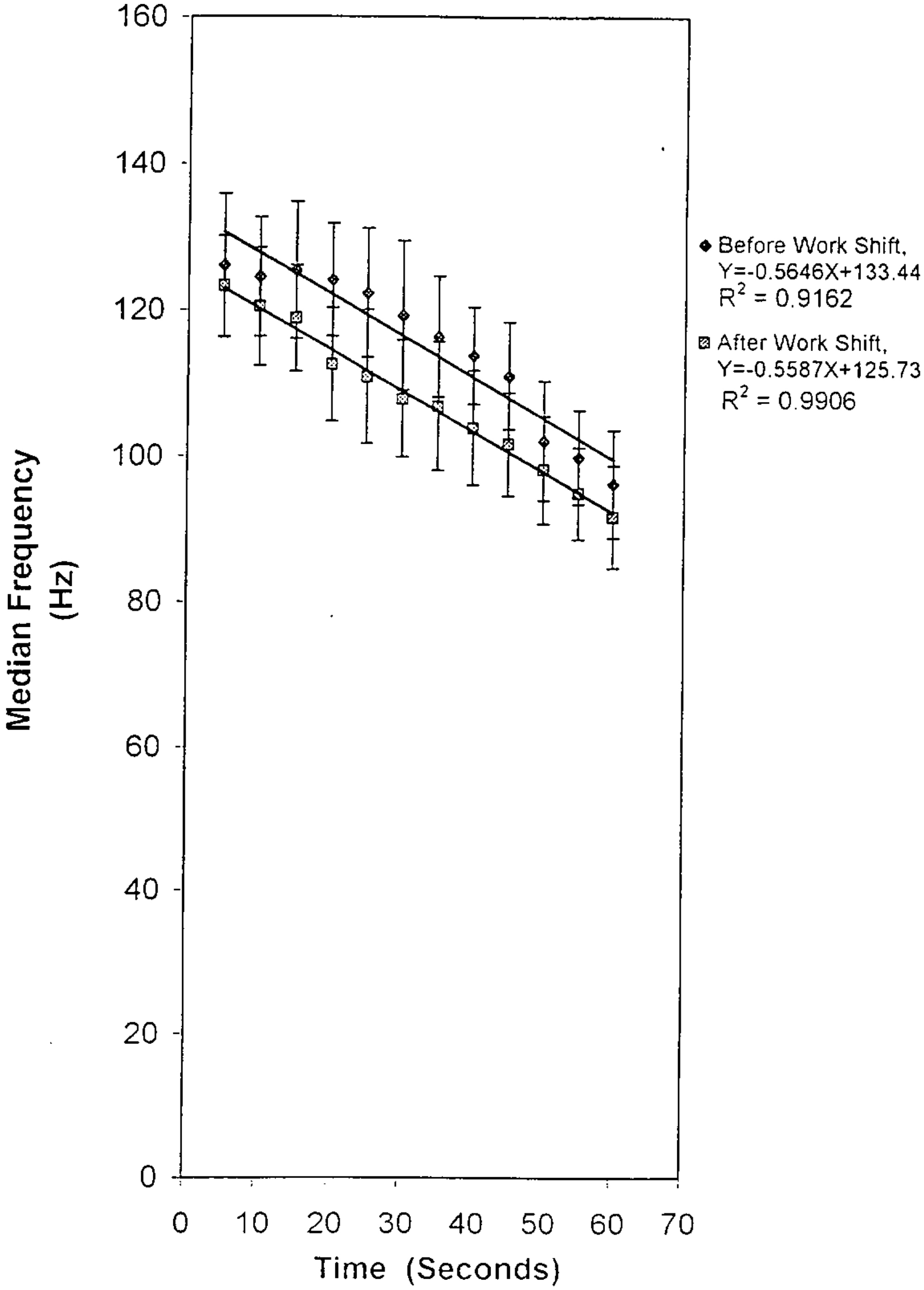


Figure 3.4: Change of median frequency of erector spinae during one minute EMG recording of the control group (N=18).



The models were subjected to residual analysis, and the results revealed that the Cook's distance was less than 4 and SR was less than ± 2. Moreover, the R^2 values of the equations were all over 0.90. These indicate that the MF/time slopes and initial MFs highly represented the MF data.

Results of paired t-tests indicated that there was a significant decrease in initial MF of the EMG measurements after the work shift for the nurses ($p<0.05$) (Table 3.6), and the MF/time slope was more negative and steeper after the work shift than before ($p<0.05$) (Table 3.6). This indicated that there was a significant difference in the back muscle fatigue rate and fatigue status between the two EMG measurements (before and after work shifts) in the study group. On the contrary, results for the control group showed no significant difference in initial MFs and MF/time slopes between the two recordings ($p>0.05$) (Table 3.6). This implies that the muscles become significantly more fatigable after the workday for the nurses but not for the clerical workers.

3.4 Results of the Questionnaires

The contents of the questionnaire included demographic data, work history and profile, training for manual handling and lifting, Borg's RPE scale, and Nordic questionnaire. The results are shown below.

3.4.1 Results of Survey in Work History, Work Profile and Safety Training

Survey of the study group and control group in work history, work profile and lifting training are listed in Table 3.7.

<u>Table 3.6</u>: The results of paired t-tests of MF/time slopes and initial MF.

Nurses Group

	Mean ± SD	**p**	**t**
MF/time slope (Before work)	-0.6131	0.008	2.975
MF/time slope (After work)	-1.0583		
Initial MF (Before work)	132.93	0.023	2.462
Initial MF (Before work)	115.83		

Clerical Workers Group

	Mean ± SD	**p**	**t**
MF/time slope (Before work)	-0.5646	0.509	0.675
MF/time slope (After work)	-0.5587		
Initial MF (Before work)	133.44	0.216	1.286
Initial MF (Before work)	125.73		

Table 3.7: The survey of work history, safety lifting training and work profile in the study group (N=21) and the control group (N=18).

	The Study Group	The Control Group
Years in the profession	6.93±4.57	4.88±2.61
Years in the current post	2.82±1.88	2.39±1.04
Percentage of attendance in safe lifting training	66.67%	83.30%
Frequency of lifting in each working hour	7.75±7.29	0.44±0.59
Average weight of lifting load (kg)	53.85±4.56	0.3±0.67

The study group comprised of 11 enrolled nurses and 10 registered nurses, who are all front-line nurses working in geriatric wards. In the control group, there were 18 sedentary clerical workers, with 7 clerks, 9 executive officers, and 2 administrative officers. Such a mix of work posts was believed to be highly representative of their professions.

3.4.2 Results of Borg's Scale in the Nurses

Borg's scale was used to evaluate the self-perceived exertion in the nursing duties and its results are compared with the heart rate data during the same period that the nurses were involved in these duties (Table 3.8).

Results of Borg's scale revealed that the most demanding and the relatively less demanding duties matched well with the results of heart rate recording. Apparently, turning, showering and patients transfer were the most exhausting tasks in both self-perceived scale and objective cardiovascular measurement. The heart rate records of dressing and tidying up were blank because the nurses did not perform these activities at the time of testing.

3.4.3 Results of the Nordic Questionnaire

Nordic questionnaires were used to indicate subjects' uncomfortable sites in the past twelve months and seven days, which respectively represented chronic and acute uncomfortable areas of the body. Results of the study group and control group in the past twelve months are shown in Figures 3.5 and 3.6, and that for the past seven days are shown in Figures 3.7 and 3.8, respectively.

Table 3.8: The results of Borg's RPE Scale and heart rate record in nursing duties (N=21).

Nursing duties	Heart-Rate Record	Borg's RPE Scale
Turning	127.64±7.36	17.00±2.41
Solo transfer	129.38±10.95	15.31±3.18
Showering	127.15±11.11	14.62±3.61
Share transfer	117.67±17.06	12.42±2.68
Dressing	---------------	11.23±2.33
Changing pads & bed sheets	95.28±13.57	10.81±2.75
Tidy and cleaning	---------------	10.73±2.70
Paper work	79.38±10.22	9.76±1.58
Feeding	80.33±8.06	8.55±3.13
Lunch	80.88±5.63	7.85±1.24

Figure 3.5: Suffering percentage of uncomfortable sites over the past 12 months in the study group (N=21).

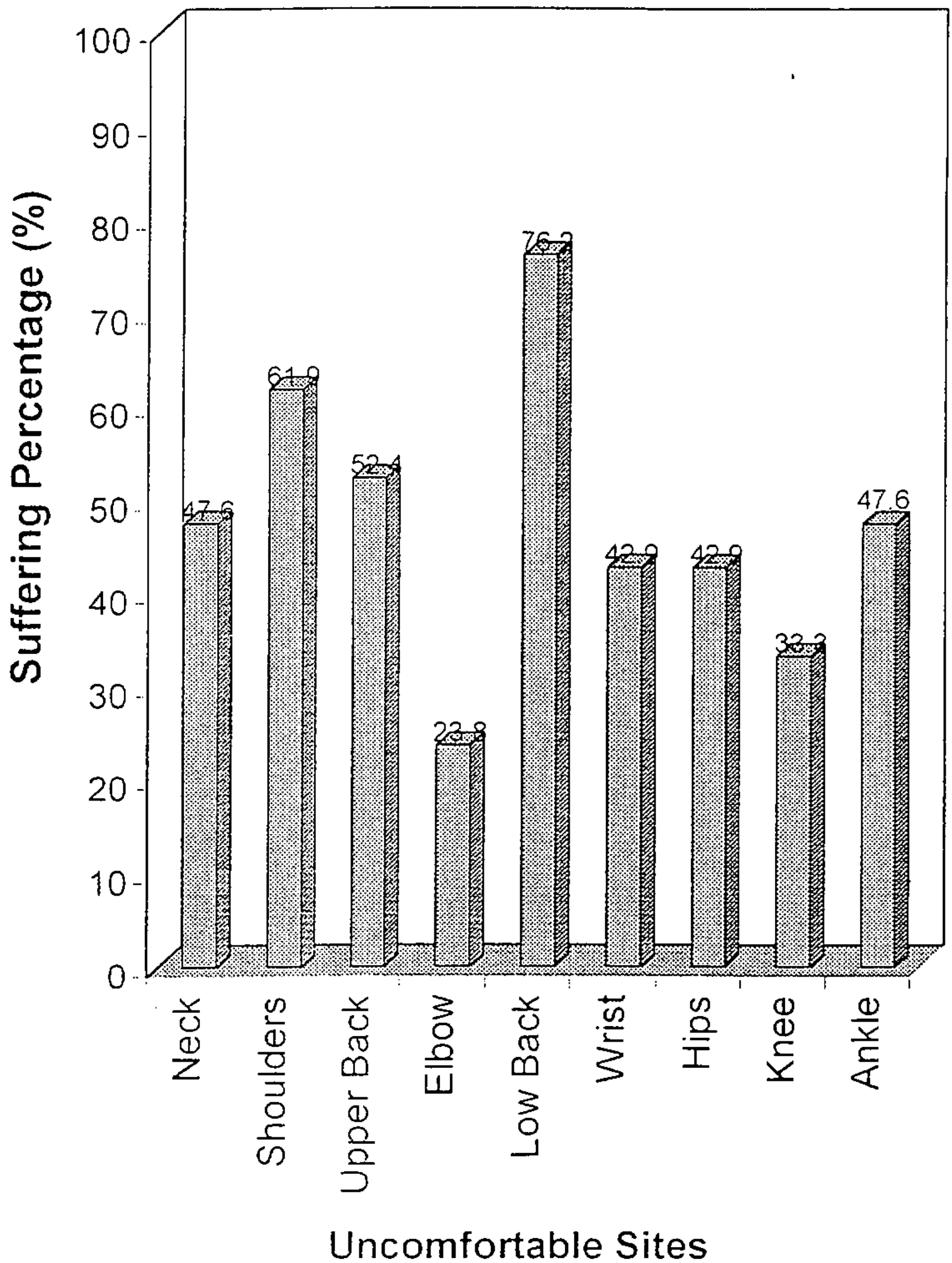


Figure 3.6: Suffering percentage of uncomfortable sites over the past 12 months in the control group (N=18).

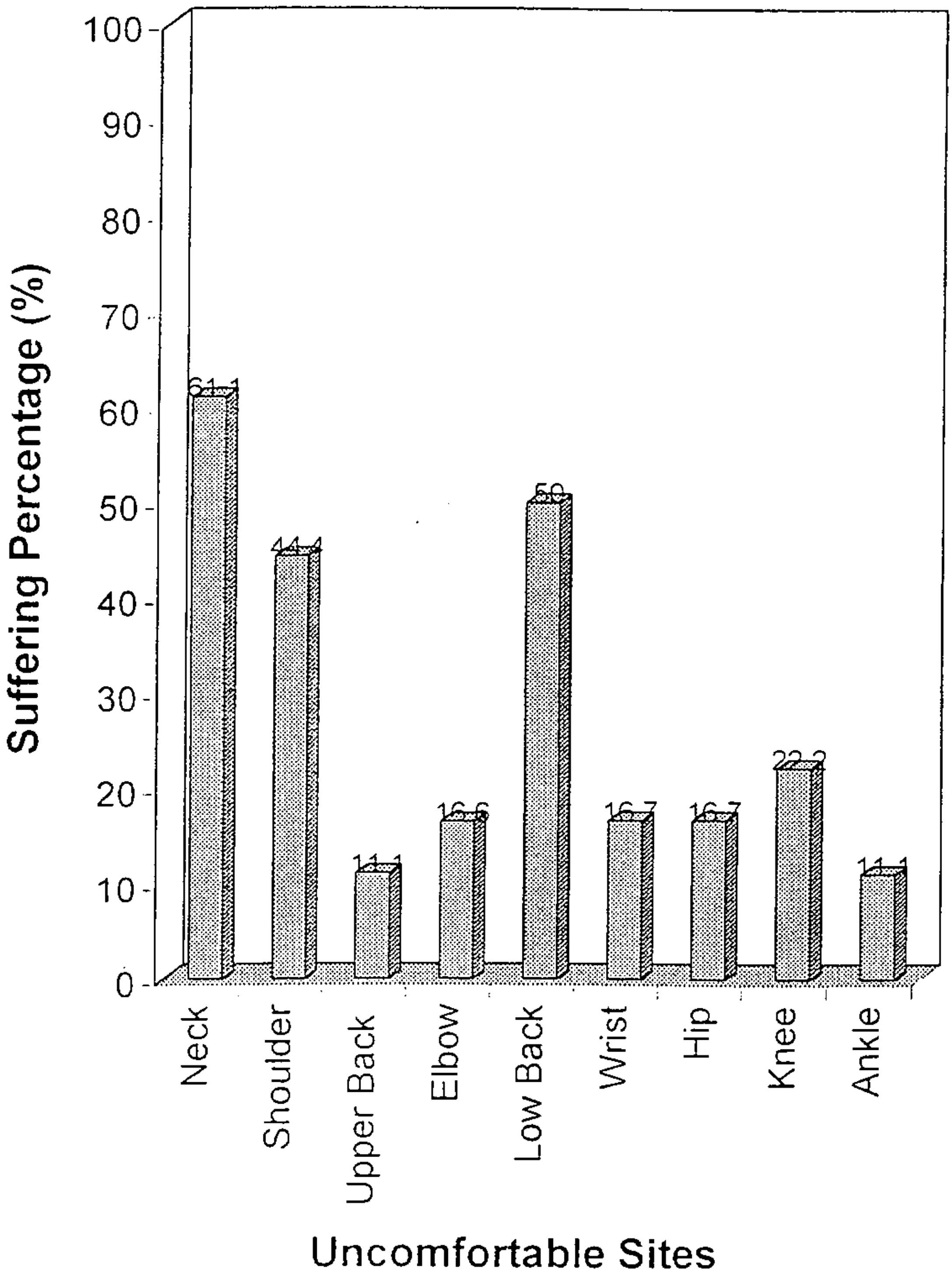


Figure 3.7: Suffering percentage of uncomfortable sites over the past 7 days in the study group (N=21).

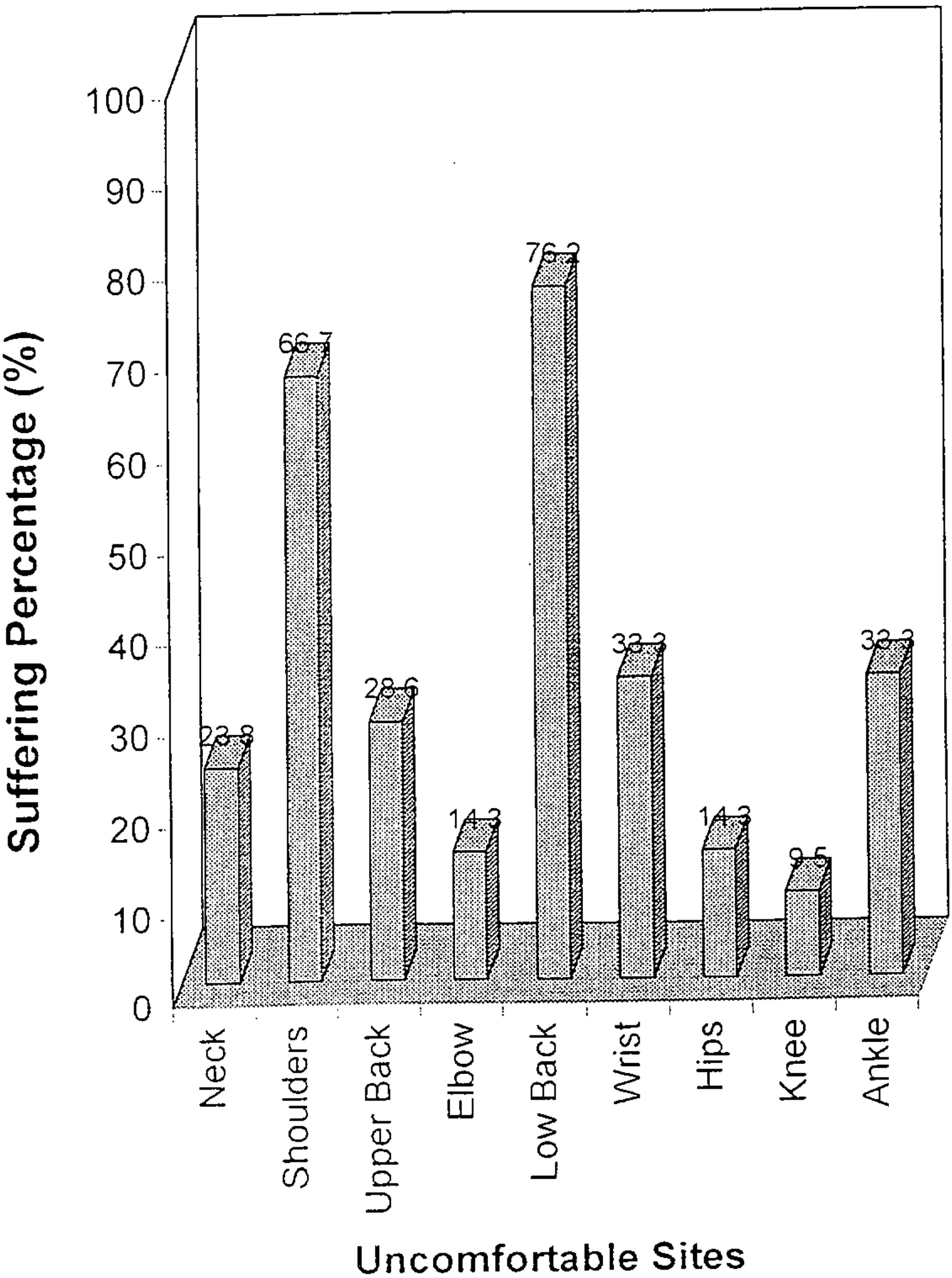
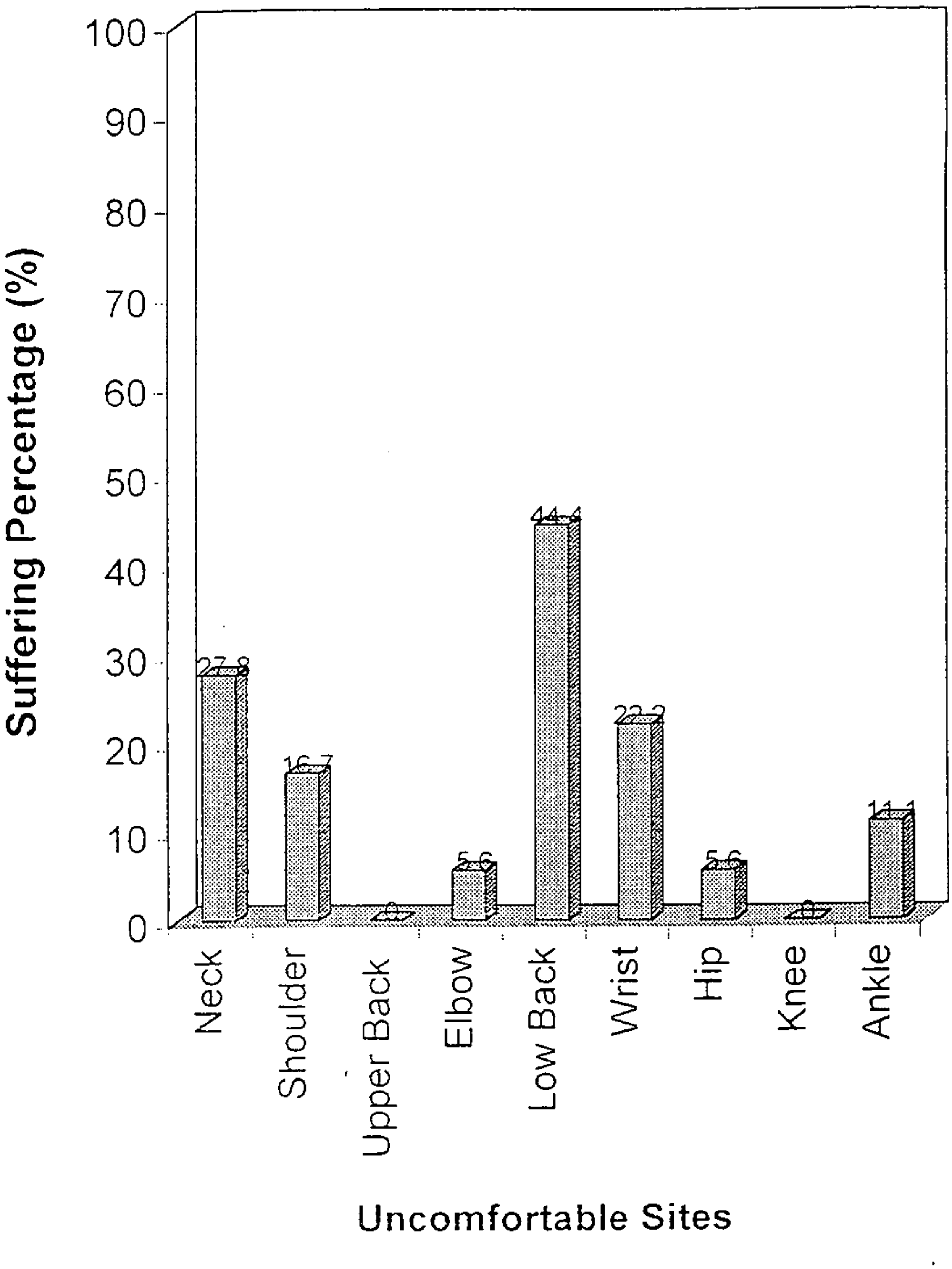


Figure 3.8: Suffering percentage of uncomfortable sites over the past 7 days in the control group (N=18).



The three most common uncomfortable sites of the test group in the last 12 months were low back (76.19%), shoulders (61.90%), and upper back (52.38%). Results of the control group were neck (61.11%), low back (50%), and shoulders (44.44%).

The three most common uncomfortable sites of the test group over the last seven days were low back (76.19%), shoulders (66.67%), wrist, knees and ankle (33.33%). The results of the control group were low back (44.44%), neck (27.78%), and wrist (22.22%). Results indicated that the low back was the most common site of complaint for the nurses.

Chapter 4

Discussion

The objectives of this study were to investigate the levels of physical exertion of hospital nurses working in geriatric wards and to compare these with a group of sedentary clerical workers. Physical exertions were assessed through heart rate recording, subjective self-perceived exertion, and work profile evaluation during a whole day-time work shift and comparing the fatigability of the back muscles before and after the work shift with EMG measurements.

In this study, twenty-one hospital nurses working in four geriatric wards of a local hospital and eighteen sedentary office workers were recruited as the study group and control group respectively. Subjects of both groups were comparable in terms of age, weight, height and years in the post (Table 3.1), in order to increase the homogeneity between the two groups.

The present results indicate striking differences in the physiological and neuromuscular demands between nurses and sedentary clerical workers in their daily work. The geriatric ward nurses demonstrated reasonably high heart rate (90-130 beats/minute) throughout most of their work shift, which reflects the physical demanding nature of their work. The EMG data provided another index to show the accumulative neuromuscular exertion of the back muscles, and level of fatigue after work, which may shed some light to explain why there are high rates of back pain amongst nurses.

4.1 Choice of Subjects

Regarding the subject selection of female hospital nurses working in geriatric wards as the study group and sedentary office workers as the control group, the predominant reason for testing only female nurses is because majority of the nurses working in geriatric wards is female. Only two male nurses worked in the four geriatric wards of CMC at the time of this study. Another reason for choosing single gender is to eliminate the gender related physiological difference amongst the subjects, because it has been shown that gender effects significantly the physiological cost (heart rate) and perceived exertion (RPE) (Drury and Deeb 1986).

The original plan was to study the physiological and neuromuscular exertion level of nurses in their working day and during day off, in order to compare the exertion levels at work and during leisure activities. However, the plan was aborted because none of the subjects agreed to be tested on their day off, and it was not easy to schedule and standardize activities for individuals, particularly during day off. In order to compare the nurses with a known profession that has predominantly light physical demand working nature, sedentary clerical workers were chosen as the control group.

4.2 Physiological Exertion Level of Geriatric Ward Nurses

The nursing profession has generally been recognized as having reasonably high physical demands at work. The present results revealed that the mean heart rate of nurses at work was quite high. In 56% and 18% during their work time, their heart rates exceeded 90 and 110 beats per minute respectively (Figure 3.1). This level of heart rate has been classified as moderately heavy cardiovascular strain or above by Kilbom (1990). This study substantiated the finding by Klein (1994), in which the author reported that nurses working in geriatric wards were in a fairly heavy exertion level, close to that of construction site workers in terms of lifting frequency and load (Klein et al. 1994).

Among the various nursing duties, the heart rate records of turning, solo transfer and showering were 127.38 ~ 129.38 beats/minute, which was very close to the level of "very heavy" cardiovascular strain (130 beats/minute). For the relatively light nursing duties, the heart rate data of feeding, paper work and changing pads, were recorded respectively as 80.33, 79.38, and 95.28 beats/minute. Even in the lunchtime, the nurses' heart rate was still in 80.88 beats/minute (Table 3.8). It reflected that between the demanding activities, the physiological stress of their body was still in a light cardiovascular strain level. The physical stress could not be recovered to the level of the beginning of the work shift. The stress on their cardiovascular system may be accumulated towards the end of work shift, thus causing signs of bodily fatigue.

Subjects in the control group showed that their mean heart rate was under 90 beats per minute in 82% of their working hours (Figure 3.2). The given heart rate of 90 beats per minute is considered to be light cardiovascular strain, this result indicated that subjects in the control group sustained only light cardiovascular exertion in 18% of their working hours. In most of the work hours of the control subjects, their heart rate was maintained at relatively low level.

Continuous heart rate recording has been used extensively to monitor physical exertion during work (Dehlin 1974). It had been used by other investigators to determine the workload during work. Grieve (1972) studied the activities of housewives with young children using continuous heart rate recording, and found that cleaning windows and floor was one of the most demanding duties for them. Kilbom (1990) reported continuous recording of heart rate could be used to study various occupational groups. The beauty of continuous heart rate recording is that it gives a good indicator of workload level during continuous physical work, and an estimation of the whole day workload level can be produced.

In the present study, a portable heart rate monitor was used to record the heart rate data. The accuracy and precision of the monitor were important consideration. A study by Seaward *et al.* (1990) proved that portable heart rate monitor and direct electrocardiography (ECG) were equally reliable for measuring heart rate in subjects performing various aerobic activities at varying intensities. Twenty-four subjects were studied at rest, light, moderate, and high endurance activities (walking, running, aerobic dancing and skiing) by the ECG and portable heart rate monitor. Differences between data obtained by the two approaches were very small and not statistically significant, with correlation coefficient values ranging from 0.998 to 0.999. The portable heart rate recorder was proved to be as accurate as ECG sampling for monitoring heart rate at rest and during a variety of endurance exercise activities at different intensities.

However, it has been recognized that there are some limitations with the use of this technique. Environmental factors, psychological states and various medications have been shown to influence heart rate. It must be stated that the actual heart rate may not be a sensitive measure of physical exertion, due to difference in individual fitness level. In the study by Koltyn and Morgan (1992), the heart rate responses to an aerobic dance training session were monitored and compared with that during treadmill jogging at the same VO_2. There was a significantly higher heart rate response to aerobic dance than jogging, but the percentage change in heart rate over the baseline was more comparable. Therefore, the per cent change of heart rate may be a more reliable measure for evaluation of physical exertion in terms of oxygen uptake. It was found that the mean heart rate of the nurses increased by 45.2% at work, while the control group increased by 21.3% as compared to their baseline heart rate during works. Therefore, the fluctuation of heart rates in the nurses' was two times of that in the control subjects. This result indicates that the normal physical exertion of nurses at work was much higher than the exertion of the control group.

4.3 Psychophysical Evaluation of Physical Exertion for Geriatric Ward Nurses

Psychophysics is commonly defined as the quantitative branch of the study of perception. It investigates the correspondence between the magnitude of stimulus properties assessed by instruments and the scale of perceptual system assessed by people (Deeb 1997). Objective measurements of physical exertion, such as measured by continuous heart rate recorder, could not present the whole picture of actual physical stress.

Limitations associated with the use of heart rate had led to the use of perceived exertion rating to evaluate physical work level. The most commonly used scale for the assessment of psychophysics evaluation was Borg's ratings of perceived exertion (RPE), which can be used in the prescription of exercise to measure strenuousness. It was believed that RPE was not only related to the heart rate response at sub-maximal exercise levels, but also to other important measures of exercise strain, such as lactate accumulation, oxygen uptake and glycogen depletion (Wilmore *et al.* 1986). In fact, the guideline of the American College of Sports Medicine has listed RPE to be an accurate, valid and reliable indicator of the level of physical exertion during exercise testing and prescription. The theory of Borg's RPE reflects that effort sense is a configuration of many inputs, therefore, it should be a more accurate predictor of strain than any single input variable, and a perfect complement of heart rate recording in both subjective and objective evaluations (Koltyn and Morgan 1992).

Results of Borg's exertion scale indicated that three of the daily nursing duties had high exertion level of over 14. They were turning (17.00), solo transfer (15.31) and showering (14.62). It indicated that these three nursing duties were the most physically demanding tasks as noted by the nursing staff. The nursing duties with values ranging from 10-13 were shared transfer (12.43), dressing (11.22), changing pads and bed sheets (10.81) and cleaning up (10.73). The relatively light physical demanding jobs were feeding (8.55) and paper work (9.76). These results were then compared with the actual heart rate data. It was found that the heart rate recordings of the three duties, turning, showering and solo patient transferring, had an 90%-92% increase as compared to the baseline levels when the subjects performed these duties. The Borg's questionnaire and the heart rate recording represent the subjective psychophysical and objective physiological measures respectively. The results seem very consistent in these two aspects. Both physiological and psychological factors may play important roles in the formation of effort sense; it is reasonable that the heart rate recording and RPE have the similar findings.

It was revealed that the RPE scales of nursing duties when multiplied by ten were higher than the actual heart rate recorded during these duties (Table 3.8). This may be presumably due to the subjects rated their exertions on the basis of local muscular fatigues more than their cardiovascular loads. This was in line with the finding by Koltyn and Morgan (1992), in which they reported that the RPE values when multiplied by ten was higher than the heart rate data in a dynamic task. One possible explanation may be because rating of perceived exertion have been shown to be the senses of total bodily inputs. Heart rate just represents one component of this perception, but it has not involved the psychological inputs.

The combination of physiological and psychophysical measurements gives a good reflection of the work task, which includes both objective and subjective data. Physiological measures have the advantage that they can grade the strain for each subject, because of the continuous nature of these data, such measurements are, however, constrained by the contextual nature of work task to be studied. When considering the relative strain on an individual, the perception of exertion is as reliable and relevant as physiological measures in many cases (Borg 1985). In the present study, evaluation of physiological and psychological demands may be able to give a more comprehensive overview of the nursing profession.

Nurses working in geriatric wards have a lot of chances to deal with old and uncooperative patients. They may need to lift, transfer and shower the patients frequently due to urinary or bowel incontinence. This would increase the neuromuscular as well as cardiovascular demands on the nurses.

4.4 Neuromuscular Demand of Geriatric Ward Duties on Nurses

Neuromuscular demand was objectively evaluated with EMG in the present study, which was commonly used for muscular fatigue investigations. Muscle fatigue can be attributed to processes beyond the neuromuscular junction; the central nervous systems could also be involved. Fatigue is an acute response of the neuromuscular system to exercise. It is most often observed during physical activities that require high-sustained force, high power short-term repetitive contractions, or low power long-term repetitive contractions (Faulkner and Brooks 1993).

The level of muscle fatigue can be determined by many approaches, such as the maximal sustainable power, calcium concentration, optimum velocity for power, and energy delivery (Vollestad 1995). In this study, all of these measures are relatively difficult to apply on the nurses without affecting their normal working routine.

A new approach, Nuclear Magnetic Resonance Spectroscopy (NMR), was applied to healthy humans to study neuromuscular fatigue level and its metabolism. It has been increasingly used as an objective evaluation tool of fatigue. The major advantage of NMR is that continuous biochemical data can be obtained from human muscle without causing discomfort or altering the exercise condition in any way. At the same time, there are some limitations in this technique, such as it involves more than a single muscle; it is very expensive; and the subject must sleep on the testing bed (Miller *et al.* 1994). In CMC, there was not a NMR machine in the hospital, thus we could not use this new technique to investigate neuromuscular demand of the nurses in the present study.

Surface EMG is a good and objective evaluation tool of back muscle fatigue and is suitable for this study, because of its non-invasive nature and relative ease of application. The reliability and validity of this technique has been evaluated by testing chronic low-back-pain (LBP) patients and normal subjects, and the results were found to be good (Thompson and Biedermann 1993).

Reliability of the spectral parameters, MF, initial MF and MF/time slope, is important in determining the applicability of these for the study. Reports from Miller *et al.* 1994 showed that the initial MF of ES during repeated contractions, with five or more repeated measures, has excellent reliability (ICC>0.8). Results of the present study in reliability of EMG parameters substantiated this finding (Table 3.4). Therefore, the EMG parameter tested in the present study is reproducible and reliable.

One of the early studies of back muscle fatigue was performed by Morrioka (1964), who investigated the relationship between the EMG signals of the lumbar musculature during static contractions. The author observed a decrease in EMG signal amplitude and an increase in low frequency potentials while subjects performed static lifting. A few years later, Troup and Chapman (1972) reported total change of the integrated EMG signal increased with fatigue. Furthermore, Andersson *et al.* (1979) measured the changes in EMG amplitude and spectral parameter concurrently during sustained contractions. They observed significant EMG power spectrum shifted towards the lower frequency end. An increased level of EMG activity was always accompanied by an increased rate of change of the EMG power spectrum. These studies relied on the amplitude of the EMG signal as an indicator of muscle fatigue (De Luca 1985). EMG frequency analysis may be able to quantify the different fatigue rates of the individual muscles in the back extensor group during the trunk holding test (Ng *et al.* 1997).

Roy and his colleagues (1989) established a method to monitor the modifications to the frequency domain properties of the EMG signals that are associated with fatigue. This method has gained wide acceptance in studies alike in the recent few years. Analysis of the time-dependent modification to the EMG signal has led to the characterization of muscle fatigue as a continuous process, rather than a single-point event related to failure of force production. It is because fatigue is a time-dependent continuous process that EMG power spectrum analysis is so useful.

The device that calculates the median frequency (MF) of EMG signals in real-time using analog circuitry is well documented by De Luca (1985). Median frequency is defined as the frequency that separates the power density spectrum into two halves of equal power. Median frequency parameters, including median frequency slope and initial median frequency, are muscle fatigue monitors. These parameters have been proven to be reliable, consistent and unbiased measures of the frequency shift of the EMG signals associated with muscle fatigue during sustained and constant-force contractions (Ng *et al.* 1997, Thompson and Biedermann 1993).

Mayer *et al.* (1995) used EMG to analyze muscle fatigue in normal subjects. The subjects were tested by monitoring the changes in the MF of EMG of back muscles during an unsupported trunk exercise. They were required to complete two sessions of ten trials with each trial consisted of unsupported trunk extension for 15 seconds followed by 10 seconds of rest. The slope of decline in MF was significantly greater after the trunk holdings. This significant drop in MF (i.e. more negative) meant that the back muscle fatigue rate had increased. A study by Mannion and Dolan (1994) reported significant correlation between MF parameters and trunk extension endurance during static paraspinal muscle contractions. It would be logical to state that EMG change indicating muscle fatigue is associated with changed in muscle force development. The muscle fatigue has associated with changes in MF parameters of back muscles as well as other muscle groups. The decrement of initial MF and MF slope was evident for level of back muscle fatigue after the fatigue-inducing task, such as heavy lifting or transferring (Thompson and Biedermann 1993).

EMG measure also has some disadvantages. Sometimes the noise is not easy to eliminate; it is easily influenced by many factors such as interference; and so on.

Although it has some disadvantages, so far, EMG is still a good tool for evaluation of single muscle fatigue (Roland 1994).

In the present study, the neuromuscular demand was determined by measuring the surface EMG of erector spinae muscle (main back muscle) of each subject, before and after the work shifts that lasted for eight hours. The MF of the EMG signal was calculated at five-second intervals, and it served as an index of fatigability of these muscles. The pre- and post- workday EMG results provided further evidence to support the contention that nurses working in geriatric wards had heavy physical demand in terms of musculoskeletal exertion.

The trunk holding test (Figure 2.7) resembled isometric contraction of the back muscles to develop a constant force level, thus the EMG signal would be more stable and reliable (De Luca 1985). Results showed a decrease in IMF and a more negative MF slope of the test group. The change in MF slope of the back muscles' EMG recording in the nurses revealed that their back muscles were more fatigable after the work shift. This implied that the muscles might not develop as much force and also decrease in endurance as the work shift progressed. Such a decrease in muscle performance may lead to heavier load in their spinal joints and other soft tissues. The muscle fatigue could then cause an accumulative musculoskeletal strain on front-line nurses.

Results of the control group showed no significant difference between the two recordings (before and after work shift), that indicated the back muscles were not more fatigable after work shift. The EMG recording of the back muscles in the two groups reveals that the nurses had significant changes in the neuromuscular parameter after work. The steeper drop in Median Frequency of the back muscle EMG of the nurses during isometric trunk holding test after work is an indication of increase fatigability of these muscles.

Results showed considerable difference between the study group and control group. Analysis of their work profile could explain this very well. In each working hour, the mean frequency of lifting was 7.75±7.29 for the study group and 0.44±0.59 for the control group, and the mean weight lifted was 53.85±4.56 kg for the study group and 0.3±0.67kg for the control group. The high frequency of lifting and the heavy load would inevitably cause higher muscular exertion on their bodies.

Muscles containing a greater percentage of fast twitch fibers demonstrate higher initial MF (Kupa *et al.* 1995). The greater initial MF could be an indication of the histochemical composition of the muscles. This may be due to a higher proportion of fast fiber action potentials, resulting in greater numbers of high-frequency components in the spectrum. Results of the EMG measures showed that the initial MF had significant difference after the work shift in the study group. It may reveal that the fast fibers of back extensor muscles were extremely fatigable after work. This can be a hint of heavy lifting exertion to the back of the nurses.

4.5 Patient Lifting and Transferring

Patient lifting and transfer were reported to be the two most demanding duties by the nurses in this study (Table 3.8). These two duties had also been found to be the major nursing duties involved in the mechanisms of work related injuries (Feldstein *et al.* 1993, Garret *et al.*1992).

An ergonomic intervention program such as using mechanical devices for lifting and transfer could be a means to avoid these injuries (Garg and Owen 1992). However, most nurses do not prefer to use these devices because they are less efficient and most devices have unclear instructions. Ironically, the two-year prospective study by Yassi *et al.* (1995) found that manual lifting or transferring of patients with assistance had the highest risk of injury to the operator. The same study found that nurses had fewer problems if appropriate lifting and transferring equipment were available and they operated these devices following the instructions. It has been found that more than half of the work-related injuries in nurses was training-related because the untrained nurses seldom work under the guideline of safe lifting, therefore, they were relatively more susceptible to injury. It is reasonable that suitable modification of the training program could be a means to prevent injury.

While training nurses for patient handling and lifting has previously been noted as an effective prevention for back injuries, the poor attendance by the nurses in these education sessions has been a problem (Feldstein *et al.* 1993, Yassi *et al.* 1995). The percentage of attendance in training courses on lifting and material handling by the nurses of the present study is 67%, even though the hospital did provide these courses to all the nurses. Although this figure is slightly better than that of Yassi *et al.*'s (1995) finding of 47%, still, one third of the nurses had not attended lifting training. Most of the nurses in this study expressed that it is not worth leaving their busy hospital wards to attend these classes and that the skills taught are often not practical. Feldstein *et al.* (1993) found the same problem in the education session of safe lifting. They reported that the attendance was only 59%, although they provided extra nurses to complement those who were at the work shift. Because of the poor participation in the training sessions, strong commitments from nursing managers are needed.

In the period of testing, the nurses said that the nursing managers actually did not support them to participate in the study as well as the safety educational session. The managers may worry the study and training could influence their routine nursing duties because of the shortage of nursing staff. Without the cooperation of nursing managers, who are in charge of their work units, it is impossible to schedule the work shift for ward nurses to attend the training sessions. Training the nurses in the wards may perhaps increase their participation, rather than asking them to go to a classroom for such training. A feedback-oriented on site training program is more practical than giving lectures in the classroom, because the nurses can ask questions pertinent to their needs. Only if the nurses find that the training could really help their needs, it would be difficult to improve their participation rate.

As found by Feldstein *et al.* (1993), successful prevention of back injuries was primarily based on training nurses in either patient-handling techniques or reducing the incidence of excessive manual handling. In a study by Heap (1987) on 3,778 nurses, it was found that the lowest injury rate happened was on fully trained nursing staff. Those undertaking their training had lower injury rate, and the highest rate of injury was found in the new recruits of nursing schools. Training nurses in patient-handling skills has been proved to be an effective strategy for prevention of back injuries (Feldstein *et al.* 1993, Heap 1987, Videman *et al.* 1989). However, the rigid teaching methods, management of hospital wards, and motivation of the nurses may lead to poor attendance to these courses. Further investigation on how to increase participation by nurses in these sessions may be required in the future.

A higher rate of injuries was found in the later hours of an eight-hour shift on the highest risk wards, such as geriatric ward (Ryden *et al.* 1989). This is consistent with the increasing demand of risk-related activities such as lifting and transferring performed during this period in these wards (Love 1997). In the present study, it was found that the nurses had to turn patients, which was rank as the most exhausting nursing activity, at the seventh hour of an eight-hour work shift. This may explain why nurses were easily injured at the end of a shift. In order to prevent work related musculoskeletal strain on their backs, rearranging the nursing activities in the optimal period of a work shift might be a means.

4.6 Injury Factors of the Nurses

As it was addressed before, patient lifting and transferring were the most exhausting nursing activities. The lifting load and frequency for nurses working in geriatric wards was reported to be higher than the normal workers (Kelsey and Gitkens 1986). Therefore, patient lifting was one of the predominant factors of injury among nurses. It was supported by the research data from Ryden *et al.* (1989), that 55.4% of injury cases were from lifting followed by bending and stooping (15.7%).

Many nursing duties need bending and stooping, such as making beds, tidying up, feeding, taking blood pressure, etc. Therefore, even if they did not need to lift patients, these postures also exert their backs. It should be noted that patient lifting is demanding, but nurses do not need to lift patients for long time periods. The other nursing activities, such as bed making, tidying, dressing patients, assisting patients for feeding could last for a long time. That means they spend a substantial period of their work hours in either stooping or bending postures, which are potentially vulnerable to their backs.

A few days of observation in a hospital ward by the author, revealed the normal working routine and schedule of the nurses. In the morning, the nurses lifted some dependent patients out of beds to sit on chairs, then they proceeded to make beds, shower patients, change pads, and feed patients if they could not eat by themselves. They took one or two hours to finish these tasks, in most of the time, they were in a stooping posture. It was also found that even the nursing staff wanted to use leg-lift in transferring patients, the space between the beds was not enough for them to do that. In the afternoon, the nurses helped patients with urinary and bowel incontinence to change pads and turning, which took about thirty minutes to one hour. This period was the last hour of a work shift.

It would be better if the heavily demanding duties were spaced out evenly throughout the whole shift. Ryden *et al.* (1989) reported that most of the injures among nurses happened in the day shift, because the most demanding nursing duties, such as patient lifting, turning, and showering, were mostly performed in the morning and afternoon. Therefore, to choose day shift as testing period for the investigation of nurses' physical exertion was very meaningful.

Wrong evaluation of their actual abilities and the shortage of hospital ward nurses are two other predisposing factors to injury. The extent of fatigue may not be noticeable by the nurses and that may result in mismatch of the nurses' subjective perception of work capacity with their actual ability (back strength and endurance). This may then result in back injuries.

In the few days of observation by the author in a hospital ward, it was found that only six nurses were working in the day shift and two nurses in the night shift. There were 56 beds in the ward and most of the patients were very dependent, and without relatives to help them. It is not surprising that the nurses were very busy and some had overlooked the safety precautions for themselves when they performed the tasks. Therefore, to increase the hospital ward nurses should be an ideal approach to lighten the workload.

Owen and Damron (1984) found a greater percentage of injuries happened to nurses, who have more working experience. However, this may be related to the accumulative strain rather than the risk of sustaining injury in a single episode. Studies carried out by Feldstein *et al.* (1993) and Garrett *et al.* (1992) showed that student nurses with less than two years of training were more frequently injured than qualified nursing staff. However, almost all agreed that inadequate training of inexperienced nurses was the main reason for this difference. In the present study, the years of working experience for the nurses is relatively short (mean working years: 2.83±1.88). Therefore, the relationship of working experience and injury rate has not been examined in this study.

4.7 Recommendations

Results of the present study showed that the nurses working in geriatric wards have reasonably high physiological and neuromuscular demand. The change in MF parameters (initial MF and MF/time slope) of the study group indicated their back muscles became more fatigable after a work shift. This could lead to a higher chance of musculoskeletal strain towards the end of a work shift, if the nurses have to perform heavy duties such as patient transfer or turning.

The slower lifting speed and the use of leg-lift strategy was found to be an effective way to decrease injury (Boston *et al.* 1993). According to the position related to load and lifting speed, nurses might use more coordinated lifting pattern that could decrease back injury. Love (1997) reported that nurses, who were assisted during a lift, would have high chance of injuries than solo lifting manoeuvre. That finding was unexpected, but a possible explanation could be because the lifters lack coordination and agreements amongst themselves, thus resulting in jerky movements that may predispose the lifters to unprepared loading. Therefore, it is vital that when lifting patients with more than one operator, a well-coordinated action between the lifters and good agreements among them is essential.

Training in back education program, such as safe lifting training and patient handing skills (particularly for assisted lifts and transfers), should preferably be provided to all nurses on site. It would be appropriate for them to attend these training courses as soon as they were recruited into the working sites that require lifting and transfer skills, such as the geriatric wards. It is also recommended that suitable facilities to aid lifting should be considered. After the equipment has been set up, all nurses in the ward should be trained on the operation of these devices. The instruction of the equipment should be displayed on the machine or accessed easily by all workers in the wards.

Rescheduling of tasks, such as spacing out the physically demanding duties throughout the work shift may reduce the intense loading to the nurses in a short period of time. There is evidence that back injury is cause by the cumulative effects of lifting, as Kelsey and Gitkens (1986) found a three-fold increase in the rate of prolapsed intervertebral disc if workers were lifting 11.5kg more than 25 times a day in a stooped posture and 4.5kg 25 times a day if the posture was stooped and twisted. The nurses were expected to lift loads that were over five times of these figures as a normal part of their work. The accumulative loading could be a direct reason for injuries, particularly at the end of a shift. Report from Ryden *et al.* (1989) showed that two peak times of injury cases in nursing staff are in the first hour of work shift and between the sixth and seventh hours. These could be related to the lack of warm up in the beginning of a shift and fatigue effect towards the end of a shift.

In the study of work related injuries on nurses, the subjects reported they had to lift beyond their physical capabilities due to lack of staff as well as working space (Gladman 1993). It was also reported that lack of space and human resources were identified as contributory factors or direct causes in more than 20% of injuries. To increase human resources for geriatric wards may provide some relief to the nurses and this could reduce the incidence of work related injury.

4.8 Limitations and Applications

The recruitment of subjects was from one local hospital. Even though it is quite common that nursing duties are very similar across hospitals, the present findings can not be directly applied to other hospitals. Furthermore, the nurses were all working in geriatric wards, it is not known if nurses of other specialties have similar physical work demands. Therefore, future studies could aim at wider collaborations with more hospitals or centers, and recruiting subjects from different specialties.

The methodologies developed in the present study may be applied to study other professions than nursing. It is known that ward assistants and physiotherapists have very high physical demands at work, but the former group is non-professional and non-skill based, whereas the latter group is professional with full knowledge of clinical biomechanics and ergonomic. It would be an interesting study to compare the physiological and neuromuscular demands *viz.* muscle fatigue profile or injury profile of the two groups, so as to examine the role of education in occupational health and safety.

Conclusion

The importance of evaluation of the physical demand on female nurses working in geriatric wards was addressed.

The present results indicated that nurses working in geriatric wards have high physiological output at work. Their back muscles developed signs of fatigue after a day shift of work. These findings contrasted significantly with the clerical control group.

One possible reason is the difference in work profile. The frequency of lifting and the lifting load of nurses are much higher than the control group. This caused a considerably higher exertion on their bodies. The increased fatigability of back muscles in the nurses implies a decrease in the muscle's reserves, which develop force to protect the spine when needed. This could lead to a higher chance of musculoskeletal strain towards the end of a work shift, when the nurses perform heavy work, such as patient transfer or lifting. After the work shift, back muscles become less fatigue resistant, but nurses may not notice these situations. This could result in mismatch of the nurses' subjective perception with their actual work capabilities. It can explain why there are more incidences of back injuries amongst nurses at the end of a work shift.

In order to change this phenomenon, training in back education program should be provided to all nurses on site, especially for the new recruits of nursing schools. When nurses lift patients, it is better for them to consider the following suggestions. Firstly, they should lift patients with slow speed, use the leg-lift posture to minimize back strain. Secondly, nursing tasks should be planned carefully such as the most exhausting duties should not be scheduled at the end of a work shift. Thirdly, it is better

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Appendix 1

Research Protocol

TITLE OF STUDY:
INVESTIGATION OF THE PHYSIOLOGICAL AND NEUROMUSCULAR DEMANDS OF FEMALE NURSES WORKING IN HOSPITAL WARDS OF HONG KONG

This study aims to evaluate and investigate the physiological and neuromuscular demands of local female nurses working in hospital wards. The study consists of two parts, one whole work shift heart rate monitor and two EMG tests of back muscle (before and after the shift). Subjects will fill in a questionnaire before the tests, which included a survey of work history, work profile, safety training and demographic data, a modified Borg's scales in nursing duties, and Nordic questionnaire. The study will be conducted in the physiotherapy department of Caritas Medical Center.

Part 1.
Participants will be required to wear a mini 'Polar' heart rate monitor throughout their daytime wok shift. This recorder collects their heart rate data at one-minute interval throughout the whole work shift.

Part 2.
The second part is back muscle fatigue evaluation. Participants will be positioned in prone lying on a treatment couch with their pelvis and legs stabilized on the couch. The anterior superior iliac spine will position at the edge of the couch supporting the pelvis and legs. Straps will stabilize the lower body over the hips, knees, and ankles. The participants will be instructed to place their hands over the head. During the test, the participants will hold their unsupported upper body at horizontal for 60 seconds. The EMG data will be collected through the surface electrode placed on their low back. The participants will be tested before and after the work shift.

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Appendix 3

DEPARTMENT OF REHABILITATION SCIENCES,
THE HONG KONG POLYTECHNIC UNIVERSITY.

PROJECT TITLE:
INVESTIGATION OF THE PHYSIOLOGICAL AND MUSCULOSKELETAL DEMANDS OF FEMALE NURSES WORKING IN HOSPITAL WARDS OF HONG KONG

Consent Form

I, ____, freely and voluntarily agree to participate in the captioned research project to be conducted at the Department of Physiotherapy, Caritas Medical Center.

The purpose of the study is to evaluate the physical demands (physiological and neuromuscular aspects) of local female nurses of Hong Kong working in hospital wards. The procedure of this study has been explained to me. In brief, I understand that I need to be recorded eight working hours heart rate by Polar heart rate monitor and be tested the back muscle with EMG before and after a work shift.

I am told that the procedures involved will have no risk and harm to me. In case of injury, please contact ____, telephone No.: ________________________.

I understand that participation is on voluntary basis: refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.

I authorize Dr. Gabriel Ng, Mr. Simon Yeung and Miss Ling Hui of Department of Rehabilitation Sciences, Hong Kong Polytechnic University to keep, preserve, use and dispose of the findings from this study with the provision that my name will not be associated with any of the results on publication.

I have been given chance to ask questions concerning this study. All questions have been answered to my satisfaction. I understand that my confidentiality and anonymity will be protected. I also understand that I have the right to terminate my involvement in this project at any time, without sustaining any form of penalty. I have read and understand the content of this form and have received a copy.

____ ________________

Signature of Participant Date

____ ________________

Signature of Participant Date

Appendix 4

The Approval of the Ethics Committee for Human Experiment of the Administering Institution

Appendix 5

Working Sheet in the Test Shift

Working Time	**Nursing Duties**
0 ~ 30^{th} min.	
30^{th} ~ 60^{th} min.	
1^{st} hr. ~ 1^{st} hr. 30^{th} min.	
1^{st} hr. 30^{th} min. ~ 2^{nd} hr.	
2^{nd} hr. ~ 2^{nd} hr. 30^{th} min.	
2^{nd} hr. 30^{th} min. ~ 3^{rd} hr.	
3^{rd} hr. ~ 3^{rd} hr. 30^{th} min.	
3^{rd} hr. 30^{th} min. ~ 4^{th} hr.	
4^{th} hr. ~ 4^{th} hr. 30^{th} min.	
4^{th} hr. 30^{th} min ~ 5^{th} hr.	
5^{th} hr. ~ 5^{th} hr. 30^{th} min.	
5^{th} hr. 30^{th} min. ~ 6^{th} hr.	
6^{th} hr. ~ 6^{th} hr. 30^{th} min.	
6^{th} hr. 30^{th} min. ~ 7^{th} hr.	
7^{th} hr. ~ 7^{th} hr. 30^{th} min.	
7^{th} hr. 30^{th} min. ~ 8^{th} hr.	

Appendix 6

<u>Survey on Female Nurses Working in Hospital Wards of Hong Kong</u>

Part I

Demographic Data (Individual data will not be exposed)

1. Code number (researcher use): ______
2. Name: ________________(in English), ____________________(in Chinese)
3. Age: ______
4. Weight (lb.): ______
5. Height (inch.): ______
6. Hand Dominance: _____ a) right, b) left
7. Number of Children: _____ a) nil, b) 1, c) 2, d) >2.
8. Date of Test: ______________
9. Address: ____
10. Contact Number: _______________ (Office), _______________ (Home).

Part II
Work History & Work Profile

1. Ward: __________
2. Post: ____________
3. Year(s) in nursing profession: _________
4. Year(s) in this post: _________
5. Working hours / week: _________
6. Hours of overtime per week (if any): ________
7. Frequency of break per shift: __________
8. Duration of each break (min.): _________
9. Frequency of lifting in each working hour: ____________
10. Average weight of lifting load (kg): ___________
11. Do you think you know how to perform heavy lifting safely? ___________
12. Has your employer provided training on how to perform safe lifting for you? _____
13. If yes, have you attended one? _______

Part III

Borg's Scale in Nursing Profession

Nursing duties	**Borg's Scale**
Turning	6-----------------------------------20
Solo transfer	6-----------------------------------20
Showering	6-----------------------------------20
Share transfer	6-----------------------------------20
Dressing	6-----------------------------------20
Changing pads & bed sheets	6-----------------------------------20
Tidy up and cleaning up	6-----------------------------------20
Paper work	6-----------------------------------20
Feeding	6-----------------------------------20
Lunch	6-----------------------------------20

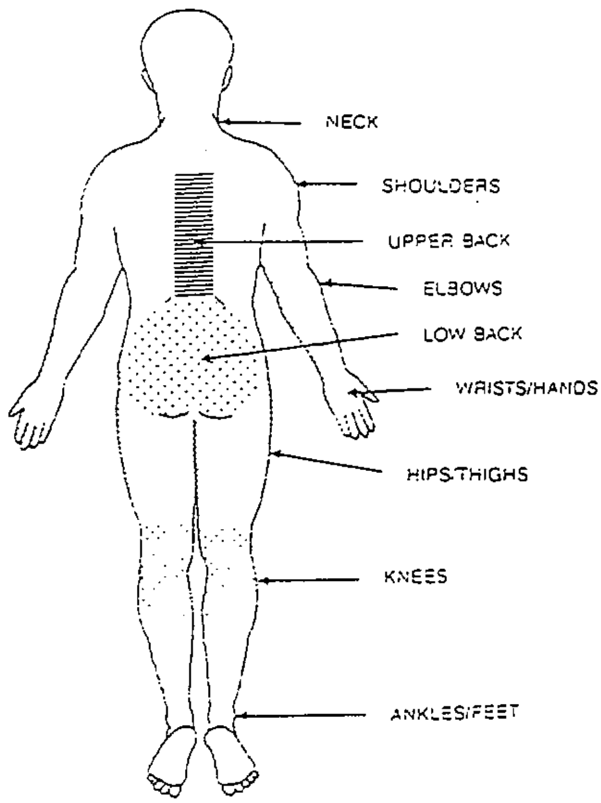
Part IV

Nordic Questionnaire (Ekberg *et al.* 1994)

In this picture you can see the approximate position of the parts of the body referred to in the questionnaire that if you had trouble at any time during the last 7 days and 12 months. Trouble is meant ache, pain, or discomfort in the shaded area.

Left

	Last 7 days		Last 12 months	
Neck	Yes	No	Yes	No
Shoulder	Yes	No	Yes	No
Upper Back	Yes	No	Yes	No
Elbows	Yes	No	Yes	No
Low back	Yes	No	Yes	No
Wrist	Yes	No	Yes	No
Hands	Yes	No	Yes	No
Hips	Yes	No	Yes	No
Knees	Yes	No	Yes	No
Ankles	Yes	No	Yes	No
Feet	Yes	No	Yes	No



Right

	Last 7 days		Last 12 months	
Neck	Yes	No	Yes	No
Shoulder	Yes	No	Yes	No
Upper Back	Yes	No	Yes	No
Elbows	Yes	No	Yes	No
Low back	Yes	No	Yes	No
Wrist	Yes	No	Yes	No
Hands	Yes	No	Yes	No
Hips	Yes	No	Yes	No
Knees	Yes	No	Yes	No
Ankles	Yes	No	Yes	No
Feet	Yes	No	Yes	No