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An ergonomic analysis of vacuum cleaning tasks using observational risk assessment tools

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An Ergonomic Analysis of Vacuum Cleaning Tasks Using Observational Risk Assessment Tools

A thesis submitted in fulfilment of the
requirements for the award of the degree of

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from

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by

Alison Bell

B. App. Sc. (O.T.)

Grad. Dip. Safety Sc.

Grad. Cert. Health Sc. (Education)

School of Health Sciences

2008

Certification

I, Alison Bell, declare that this thesis, submitted in fulfilment of the requirements for the award of Master of Science (Research), in the School of Health Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution. Copies of the original data analysed within this thesis are held by the School of Health Sciences, University of Wollongong.

Alison Bell

11 June 2008

Dedication

I would like to dedicate this thesis to my husband, Robert Edgar, and my children, Elizabeth and Callum, who have shown extraordinary patience, understanding and resilience through my perpetual quest for further study. Without their support, this thesis would never have been written. I would also like to dedicate this thesis to the memory of my mother, who always told me to do my best, and passed away before this thesis could be completed.

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Abstract

This research thesis examined the risk of upper limb musculoskeletal disorders for cleaning workers while performing vacuum cleaning tasks in the normal course of their employment. The cleaning workers in this study were from three sectors of the workforce – government schools, hospitality and commercial office space. The vacuum cleaning tasks were divided into those performed with a back pack style vacuum cleaning machine and those using a canister/barrel machine. Three observational risk assessment tools were selected to measure the risk of these tasks to cleaning workers. The selected tools were the Manual Tasks Risk Assessment Tool (ManTRA) version 2.0; the Quick Exposure Check (QEC) (Li & Buckle, 1998); and the Rapid Upper Limb Assessment tool (RULA) (McAtamney & Corlett, 1993).

Results of this thesis study demonstrated that vacuum cleaning is a risk to the musculoskeletal health of cleaning workers, with some variation between the tool ratings, reflecting the specificity and/or sensitivity of each tool. Differences were found between the three cleaning sectors in terms of overall risk posed by vacuum cleaning tasks. The sector with the greatest risk was found to be the government school cleaners, followed by the hospitality and then commercial office space cleaning sectors.

The 'risk experience' difference between the sectors cannot be attributed only to vacuum cleaner characteristics, but also, the environment and length of shift worked by the cleaning staff. Further research is required to determine the difference in risk exposure between the two types of vacuum cleaner (back pack and canister).

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Chapter 1
The Problem

1.1 Introduction

Despite rapid technological advancements and increasing mechanisation in the workplace to reduce loads imposed on the body, musculoskeletal disorders continue to be one of the main causes of occupational disorders in the developed world. For example, the European Agency for Safety and Health at Work (Benavides, 2000) conducted a survey of its members and found musculoskeletal disorders accounted for 30-46% of all work-related injuries. Australian statistics mirror this international experience with the latest workers' compensation data collated in 2002/03 (Office of the Australian Safety and Compensation Council 2006), reporting 52.1% of new workers' compensation claims being attributable to musculoskeletal injury, including sprains, strains and disorders of muscle tendons and other soft tissues. The cost of these injuries both in financial terms to business and the economy, as well as the personal cost caused by pain, loss of income and possible loss of employment, is a burden to every developed nation. Although emphasis in the past has focussed on musculoskeletal disorders of the back, increasingly, upper limb musculoskeletal disorders are emerging as a more frequent injury. That is, 24.6% of new claims in 2002/03 were for injuries to the back, whereas 27.8% of claims were for the upper limb (12.5% hands; 7.9% shoulder; 2.7% arm; 2.5% neck and 2.2% elbow; Office of the Australian Safety and Compensation Council, 2006).

Although many occupational tasks involve repetitive use of the upper limb, one occupational group known to incur an increasing number of upper limb musculoskeletal disorders is that of cleaning workers. The musculoskeletal health of cleaning workers was raised as an issue following the New South Wales (NSW) Safety Summit in 2002, where WorkCover NSW undertook to address specific issues related to the occupational health and safety of cleaning workers. For example, although cleaning workers represented only 1% of the employed labour force in Australia in 1999-2000 (Australian Bureau of Statistics, 1999/2000), the reported workers' compensation cases for musculoskeletal disorders for cleaning workers for the same period represented 4% of total claims (National Occupational Health and Safety Commission, unpublished data). Construction, mining and forestry are acknowledged as the industry sectors with the greatest cost of injury across Australian jurisdictions, yet the reported workers' compensation cases for musculoskeletal disorders for the same reporting period shows that this group also represented 4% of claims. Clearly, cleaning is a demanding repetitive occupation, which incurs a high level of musculoskeletal disorders. Additionally, the awareness of the risk of cleaning work in relation to work-related musculoskeletal disorder is low. The reasons for this lack of awareness and lack of attention is possibly due to the gender distribution in cleaning workers (mostly female), the nature of employment (precarious) and the socio-economic status of these workers (low; see Section 2.3.3).

A comprehensive review of the musculoskeletal health of cleaning workers in Britain (known as the Robens Report, 1999) found that cleaning tasks were linked with higher than average reports of musculoskeletal discomfort and disorders (Woods *et al.*, 1999). The Robens Report also identified work organisation factors, such as work speed and intensity, workload and time pressures, lack of job control, poor training and poor workplace support and recognition, as significant problems for cleaning workers as an occupational group.

In NSW, a survey of cleaning workers indicated that the most common musculoskeletal disorders incurred by these workers were upper limb related, with these upper limb disorders reported as frequently as low back pain (Gaudry, 1998). An ergonomic assessment of the physical demands of cleaning tasks (Aickin, 1998) identified repetitive bending of the back and shoulder actions as task characteristics of cleaning and established that these task characteristics predisposed cleaning workers to upper limb and low back pain. However, only limited research has been located which has assessed the upper limb physical demands of the most common cleaning task, that of vacuum cleaning, or how these demands may contribute to the increasing number of upper limb musculoskeletal disorders reported by cleaners.

1.2 Statement of the Problem

The primary purpose of this thesis was threefold:

(1) To examine the physical upper limb musculoskeletal risks to cleaning workers in the field while they perform vacuuming cleaning tasks; and

(2) Compare differences between these risks in three sectors of the cleaning workforce: government schools, commercial office space and hospitality; and

(3) Compare the risk posed by the use of back-pack vacuum cleaners and canister-type vacuum cleaners.

The ‘risk’ was measured using three different observational ergonomic assessment tools: Manual Tasks Risk Assessment; Quick Exposure Check; and Rapid Upper Limb Assessment (see Section 2.6). Vacuum cleaning was selected as the focus of this thesis, as this task is the most common task performed by cleaning workers and it is performed across most sectors of the cleaning industry (see Section 2.5).

1.3 Significance of the Study

Why is it important to study cleaning workers and their level of risk for work-related upper limb musculoskeletal disorders? Indeed, cleaning workers could be termed 'the invisible army' as their work is usually performed outside standard office hours and is largely unseen by the rest of the workforce. Cleaning workers perform work tasks in a variety of settings and in all types of workplaces, ranging from industrial manufacturing settings to office type environments. Commonly, cleaning workers can work alone and on split short shifts. As an occupation, cleaning involves repetitive actions of the spine and upper limbs; the work force is predominantly female; and, as the rest of society, ageing. (See Section 2.3.3).

Most workplaces, excluding hospitals, shops and factories (not included in this study), are carpeted and so vacuuming is one of the most common tasks performed by cleaning workers across all sectors. Vacuuming is a core cleaning task and two main types of vacuum cleaning machines are used in all sectors, back packs and canister/barrel machines. As all cleaning workers need to use a vacuum cleaner, it is useful and relevant to determine the relative risk of upper limb musculoskeletal disorder for each type of machine. For these reasons, this thesis will focus on the physical upper limb musculoskeletal risks to cleaning workers during the specific task of vacuuming.

1.4 Hypotheses

Based on the background literature, it was hypothesised that:

(1) Vacuum cleaning tasks would be associated with high levels of upper limb musculoskeletal risk;

(2) There would be no difference in the risk rating of vacuuming tasks between the three cleaning sectors (government schools, commercial office space and hospitality); and

(3) There would be no difference in the risk rating of vacuuming tasks between the two types of vacuum cleaning machines (back pack and canister).

1.5 Limitations and Delimitations of the Study

1.5.1 Limitations

This study was limited by several factors:

(1) This study examined a cohort of 24 workers derived from a sample of 66 workers who participated in a larger scale study in 2005. This field-based study was undertaken by Health & Safety Matters Pty Ltd for WorkCover NSW and the cleaning industry, in which the candidate was part of the study team. The purpose of this larger study was to examine repetitive work tasks performed by cleaners. This larger study reviewed all cleaning tasks, but did not examine vacuum cleaning in detail. All the data collection and data analysis presented in this thesis were undertaken by the candidate.

(2) Sites for the study were selected by the cleaning industry from a major city and major regional centre in NSW and, as such, were not randomly selected.

(3) Subjects were selected by the cleaning company overseeing the individual worksite. Subjects were therefore not randomly selected.

(4) Subjects were restricted to those who were at work when the researcher visited their worksite. Therefore, the results of this study were restricted to those who were at work and do not include other workers who may have been on sick leave, holiday leave or workers' compensation at the time of testing.

(5) The filming process used to collect data, while as discrete as possible, might have altered the subject's normal working style and, as such, may not in all situations provide a true picture of the subject's vacuuming method.

1.5.2 Delimitations

There were also several delimitations imposed on this study:

(1) Only the physical upper limb work-related musculoskeletal risk factors were investigated in this thesis. It is acknowledged that there are psychosocial risk factors that impact on the incidence of upper limb work-related musculoskeletal disorder risk and these factors are discussed in Section 2.2.2.

(2) The measurement of risk of musculoskeletal disorder was confined to three selected observational risk assessment tools, and was therefore not exhaustive.

Other limitations and delimitations imposed on the thesis are discussed in Chapter 3.

Chapter 2
Literature Review

2.1 Introduction

Prior to commencing the experimental work, this literature review provides background information pertaining to the issue of work-related upper limb musculoskeletal disorders. It begins with an overview of the presentation of these disorders in injured workers, followed by a discussion of the known risk factors: physical, psychosocial and individual. Information is then provided on cleaning work, vacuum cleaning tasks, a description of the regulatory context of manual tasks within the jurisdiction of NSW, Australia, and finally an overview of the tools selected for this study.

2.2 Work-Related Upper Limb Musculoskeletal Disorders

2.2.1 Definition

The phrase "work-related upper limb musculoskeletal disorders" includes a variety of upper limb degenerative and inflammatory diseases and disorders, which result in pain and functional impairment. Affected areas typically include the neck, shoulders, elbows, forearms, wrists and hands (Buckle & Devereux, 2002). For the disorders to be work-related, work tasks and conditions must exacerbate or cause the disorders.

A difficulty with determining the work-relatedness of musculoskeletal disorders is the interplay between an individual purportedly suffering the injury and the work task(s), including psychosocial factors, psychophysical factors, pre-existing or co-existing musculoskeletal disorders, functional capacity and intensity of task demands.

In other words, the causation of musculoskeletal disorders is multifactorial and involves the interaction among a combination of occupational and non-occupational factors.

The United States National Institute for Occupational Safety and Health (NIOSH) conducted a critical review of the epidemiological evidence for work-related musculoskeletal disorders of the neck, upper extremity and lower back (Bernard, 1997) and were able to link specific work-related risk factors with musculoskeletal disorders. These factors will be discussed in Section 2.3.3.

2.2.2 Prevalence of Work-Related Musculoskeletal Disorders

On an international scale, the incidence of work-related upper limb musculoskeletal disorders is difficult to quantify as there has been no standardised diagnostic screening tool for the disorders, although several researchers have developed such tools (Health Council of the Netherlands, 2000; Sluiter, 2001). Buckle & Devereux (2002) reported that work-related musculoskeletal disorders accounted for anywhere between 15% and 70% of reported work-related disorders in the European Union, with variations in the estimates depending on the country (different reporting and compensation systems). The authors noted, however, that the number of compensable cases for work-related musculoskeletal disorders was increasing. In the United States, 13% of over-exertion injuries were related to the upper limb (Bernard, 1997). However, in Australia, the National Workers' Compensation Compendium (2001) reported that 31% of all injuries were related to the upper limbs. Therefore, understanding risk factors that predispose cleaning workers to work-related upper limb musculoskeletal disorders is imperative if the incidence of these disorders is to be minimised and the cost to the individuals, their employers, the economy and the community addressed appropriately.

2.3 Risk Factors for Work-Related Upper Limb Musculoskeletal Disorders

2.3.1 Physical Risk Factors

Work-related risk factors for musculoskeletal disorders have been identified and analysed in a comprehensive review undertaken by Bernard (1997). This document provided a critical review of 600 studies for causal relationships between work/task factors and the development of musculoskeletal disorders. The report identified that the key risk factors for work-related upper limb musculoskeletal disorders were the physical risk factors of repetition, force, posture and vibration. Similar findings were reported by Buckle & Devereux (2002), who also undertook a review of the literature, in combination with consultation, to demonstrate the relationship between work tasks and musculoskeletal disorders in the United Kingdom.

Cleaning tasks are highly repetitive in nature and the evidence for repetition being a major risk factor for upper limb musculoskeletal disorders is compelling. Latko and colleagues (1999) studied over 300 workers in three different manufacturing settings to assess the link between repetition and work-related upper limb musculoskeletal disorders. The study was cross-sectional and consisted of an expert ergonomics job analysis combined with a medical assessment of each subject. The authors found that repetitive work was related to upper limb discomfort, tendonitis and carpal tunnel syndrome in the population studied.

Frost *et al.* (2002) studied 4,000 Danish workers across a variety of manufacturing and retail sites, also finding repetition and aspects of force requirements being linked to shoulder tendonitis. However, the authors acknowledged the difficulty in isolating specific physical risk factors for upper limb musculoskeletal disorders in real work tasks.

English *et al.* (1995) undertook an epidemiological study of work-related musculoskeletal disorders in orthopaedic clinics in the United Kingdom. Their findings have particular relevance to the cleaning population in that cleaning workers were found to be over-represented in wrist/forearm disorders. Importantly, the height of the worker was associated with injury, whereby the shorter the worker, the greater the risk of injury. This finding is particularly relevant to this study, as it points to ergonomic design issues with work equipment and or tasks as being an issue for cleaning workers (see Section 2.5.1).

2.3.2 Psychosocial Risk Factors

Risk factors for work-related musculoskeletal disorders have traditionally been viewed from a purely physical perspective. However, recent literature has also considered the interaction of physical factors with other factors, specifically psychosocial issues, such as work-related stress (Work Environment Research Centre, 2003b). Factors leading to work-related stress include job-level factors (work organisation) and company-level factors (workplace organisation; Work Environment Research Centre, 2003b). Job-level factors consist of work organisation factors such as time pressure, workload, job schedules, training, colleague and managerial support (Work Environment Research Centre, 2003a), job control, work pace and opportunity for creativity (Waldenstrom *et al.*, 2002).

Psychosocial factors such as high job stress and high job demands, as well as non-work-related stress, have been found to be associated with work-related musculoskeletal disorders (Bongers *et al.*, 2002). Bongers *et al.* (2002) proposed a simple model to summarise the interaction of physical and non-physical factors in the development of work-related musculoskeletal disorders (see Figure 2.1). In this model it can be seen that physical and psychosocial loads impact on chronic musculoskeletal symptoms.

Please see print copy for Figure 2.1

Figure 2.1: Interaction between psychosocial load, physical load and individual factors and symptoms and signs of shoulder, arm or wrist injury (adapted from Bongers *et al.*, 2002, p. 316).

In a systematic review of psychosocial risk factors for neck pain, researchers found some evidence for a positive relationship between neck pain and high job demand, low social/co-worker support, poor job control, high and low skill discretion and low job satisfaction (Ariens *et al*, 2001). Interestingly, their review found inconclusive evidence for high job strain, low supervisor support, conflict at work, low job security and limited rest break opportunities. The task characteristics outlined by Ariens *et al.* (2001) are typical aspects of low status jobs, such as cleaning. Studies of overall population health have highlighted the relevance of socioeconomic status to general health status, with lower socioeconomic groups presenting with greater health issues (Marmot, 1994). The situation is put succinctly by Lundberg (1999) who stated:

“Conditions typical of many low status jobs, such as time pressure, lack of influence over one’s work, and constant involvement in repetitive tasks of short duration are known to cause work stress or strain” (p. 163).

Lee & Krause (2002) conducted a large survey involving hospitality cleaners (n = 258) in San Francisco. The survey revealed that cleaners had poor overall health, felt pressured at work due to workload/time constraints and had high levels of ‘work-related pain/disability’. It is therefore clearly evident that psychosocial risk factors can contribute to the prevalence of work-related musculoskeletal disorders.

In addition to physical and psychosocial risk factors, several individual risk factors must also be considered when addressing work-related musculoskeletal disorders.

2.3.3 Individual Risk Factors

Individual risk factors for work-related musculoskeletal disorders include gender, age and employment status. Each of these factors is discussed below.

***Gender*:** Several studies have examined the impact of gender upon the reporting of musculoskeletal disorders (Zetterberg & Ofverholm, 1999; Soares & Lundberg, 2000). For example, Fredriksson *et al.* (2000), in their longitudinal study of neck/shoulder disorders, found a gender difference in causal workplace factors and musculoskeletal disorders. Women’s reporting of neck/shoulder musculoskeletal disorders increased with adverse psychosocial factors; whereas for men, the reporting increased with greater physical demands and exposure to vibration. Treaster & Burr (2004) conducted a literature review to examine differences between the genders for upper limb musculoskeletal disorders. They found that women had a significantly higher prevalence of upper limb musculoskeletal disorders compared to men, even when the results were adjusted for age and work factors, whereby women are traditionally involved in jobs of repetitive upper limb work, and thus considered at greater risk of developing a musculoskeletal disorder.

In a review of studies conducted between 1985 and 2003 on the relationship between social support at work and musculoskeletal health, Woods (2005) found an increased risk of musculoskeletal disorders was associated with poor social support at work. Furthermore, in a large study of over 3,000 Swedish women, Jablonska *et al.* (2006) found a significant relationship between adverse psychosocial work conditions and pain. The study was particularly interesting as it examined several parameters including education level, whether the women were from a foreign background, location and characteristics of pain, their occupation and financial support. The highest levels of work-related pain and discomfort were in women of low socio-economic backgrounds. These women find themselves working in physically demanding, low skilled jobs, which are often repetitive in nature, such as cleaning work. A further finding of this study relevant to the topic of this thesis was that women who had foreign backgrounds were at higher risk of pain in the upper and lower limbs, and the entire body. It is postulated that this finding is probably due to the women being employed in jobs that were physically demanding and over which they had little job control.

It is important, however, to view these findings associating low socio-economic status and poor musculoskeletal health with regard to the wider context of society, socioeconomic status and health. That is, studies from Europe (Arber & Lahelma, 1993) and Australia (Mishra *et al.*, 2002) confirm that women with low socio-economic status have worse health than those of higher socio-economic status. This is attributed to poor health behaviours such as smoking and obesity, and these women are less likely to access preventative health services than other women.

Age: Another factor influencing musculoskeletal disorders is age. It is recognised that Australia's workforce is ageing. In June 2002, people aged over 65 years represented 13% of the population, whereas those under 15 years represented 20%. The projections for 2051 suggest these percentages will be reversed (Australian Bureau of Statistics, 2003). The ageing worker has a higher 'background level' presence of disease and pre-existing conditions, such as osteoarthritis, decreased cardiac capacity and lung function, which will impact on and with any newly acquired musculoskeletal disorders (Savinainen *et al.*, 2004; Garden *et al.*, 2005).

Research relating to ageing workers and type of occupation consistently highlights decrements in strength and aerobic capacity as workers age. For example, Savinainen *et al.* (2004) examined changes in physical capacity and ability to work in a food factory by female workers over 45 years of age. Over the 10 years that the workers were tracked, decreases in dynamic strength of the upper limbs, squatting and aerobic capacity were observed. The authors concluded that women in physically demanding work had a greater decrease in physical capacity than women in jobs with mixed cognitive and physical components. One of the issues highlighted by this longitudinal study was the propensity for workers to self-select occupation depending on strength and work capacity, the so called 'survivor effect' (Torgén, *et al.* 1999). This effect means that workers unable to cope with heavy physical work will find alternate work.

De Zwart (1997), in a repeated survey (4 years apart), found that exposure to heavy physical work was associated with work-related musculoskeletal disorders; whereby both younger and older workers experienced musculoskeletal symptoms. Viewed in light of the 'survivor effect', de Zwart recommended that preventative measures should be taken to protect all workers from work-related musculoskeletal risk. This view was reinforced by Cassou *et al.* (2002), who investigated the prevalence of chronic neck and shoulder pain, age and working conditions in a longitudinal study of 18,000 French workers. The recommendation was to establish strategies to prevent and manage work-related musculoskeletal disorders in the workplace and to determine appropriate work demands for older workers.

Precarious Employment: In addition to ageing, there is the phenomenon of the changing nature of employment in Australia, with an increased incidence of precarious employment and changes in job working conditions, such as increasing work hours and changing shift patterns (Work Environment Research Centre, 2003a). In an issues paper (Work Environment Research Centre, 2003) written as part of a review of the 1990 Manual Handling Standard and Code of Practice, risks associated with a changing working population are also highlighted; an ageing workforce, an increasing number of women in the workforce, and workers from non-English speaking backgrounds.

Work arrangements also impact as specific risk factors for the cleaning population. Internationally and nationally, there is a move away from direct employment to one of subcontracting. As an employment sector, micro, small and medium sized enterprises/businesses are growing as large organisations/businesses are outsourcing and subcontracting their cleaning work (Stromsvag, 1998; Caple, 2003; European Agency for Safety and Health at Work, 2002; Benavides, Benach, Diez-Roux, & Roman, 2000). Work arrangements are usually project/contract based, can be part time, temporary, and flexible in nature.

Only limited research has examined the ability of small and medium sized enterprises to manage their occupational health and safety (OHS) obligations in Australia, the United Kingdom and in the European Union. The findings of this limited research highlight poor risk management strategies in the small and medium sized enterprises studied and higher than average injury rates. For example, Mayhew (2002) listed the competitive nature of tenders for projects being based on cost, and ignoring OHS as a way to keep costs down. She also pointed out that smaller workplaces have physically fewer OHS resources and current regulations are designed for large workplaces and are commonly inappropriate for small workplaces. Mayhew & Quinlan (2001) also highlighted the problem of reporting OHS issues in small and medium sized enterprises, whereby employees may not be aware of their rights to workers' compensation, and/or fearful of losing their jobs if they report problems. Additionally, some small and medium sized enterprises or micro enterprises may not carry any workers' compensation cover, or have insufficient cover. If a sole trader or self-employed, it is almost impossible to continue the business if the operator is injured at work. As the workers' compensation system is the method of tracking workplace injuries/illnesses/disease in Australia, the prevalence of workplace injury is most probably underestimated.

Vickers *et al.* (2003) in their report for the Health and Safety Executive of the United Kingdom, pointed to "poor management of risk [rather] than the absolute seriousness of the hazards faced" (p. 1) as the major problem for small businesses in relation to health and safety. These researchers attributed limited resources, low frequency of regulatory inspections, limited access of workers to representation and a low impact of adverse publicity for OHS infringements as the features leading to poor OHS performance. Benavides (2000) investigated the associations of types of employment with health outcomes in the European Union, finding that precarious employment was consistently and positively associated with musculoskeletal symptoms and job dissatisfaction.

Although both men and women are employed in precarious employment arrangements, women are mostly employed in part-time positions. For example, the European Agency for Health at Work Report (2002) stated that in the year 2000, more than a quarter of total employees in the European Union worked less than 25 hours a week and that this was the case for more than 40% of all working women. This predominance of female workers in part-time work is also true for cleaning workers in the NSW government sector (Weigall *et al.*, 2004).

From the literature reviewed to date, it can be extrapolated that risk factors for work-related musculoskeletal disorders amongst cleaning workers can be grouped into three main categories, which are summarised in Table 2.1. These factors must be considered in any evaluation of work-related upper limb musculoskeletal disorders that may be incurred by cleaning workers in common tasks such as vacuuming. However, no research was located to assess the relative importance of these risk factors to the development of work-related upper limb musculoskeletal disorders by cleaning workers in the common task of vacuuming.

Table 2.1: Summary of risk factors for work-related upper limb musculoskeletal disorders.

Physical Risk Factors	Psychosocial Risk Factors	Individual Risk Factors
Repetition	Job demands	Age
Force	Job control	Gender
Posture	Social relations at work	Socioeconomic status
Vibration		Pre-existing musculoskeletal disorders

2.4 Cleaning Industry and Cleaning Sectors

The cleaning industry in NSW employs 35,000 people (Building Services Association, 2004). The type of work in the sector includes vacuuming, dusting and waste collection (Australian Bureau of Statistics, 2001). It is difficult to quantify correctly the number of workers who perform cleaning work as in the hospitality sector, for example, many workers may be classified under other occupational categories and therefore not included in the number of workers (for example, room and bar attendants). In terms of income, cleaning workers are among the lowest paid occupational groups in Australia (Australian Bureau of Statistics, 2002).

As a sector, the cleaning industry total income for the period 1998/9 was $2,137 million, with an operating profit of 7.3% (Australian Bureau of Statistics, 1999). Cleaning in commercial office space accounted for approximately 42% of this total income, whereas cleaning educational facilities accounted for 16% of income, and retail premises 15% of income. However, the trend in the cleaning industry is one of growth. For example, in Australia there was a 35% increase in employment in this sector between 1995 and 2000, making the cleaning industry the third biggest employment sector in the country (Australian Bureau of Statistics, 2003). The peak union body in the cleaning industry, the Liquor, Hospitality and Miscellaneous Workers Union, in an unpublished submission to the Independent Pricing and Regulatory Tribunal on school cleaning, reported an increasing number of small and franchised cleaning businesses and increasing trend towards subcontracting in the cleaning industry (1999).

According to government records, the cleaning contract cost for government properties was $762 million in 2000 (NSW Legislative Assembly Hansard, 12 April, 2000). This represented approximately 6,800 cleaners working at government sites under the employment of three large cleaning companies who were awarded contracts in 1999 (Cook, 2004).

Under the NSW Workers' Compensation System, each employer must take out insurance against worker injury. The premium for this insurance is set by WorkCover, based on industry experience, and the premiums are set as a percentage of wages costs. Therefore, the level of premium is a reflection of the industry injury risk. For the cleaning industry the insurance premium is set at 15%, the highest level of premium. This high rate is comparable with very heavy industry sectors, which traditionally have received high levels of attention with regard to their injury rates, while the cleaning industry has been largely ignored. The relative risk in terms of premium (percent wages bill) compared to other high risk industry sectors, is summarised in Table 2.2.

The cleaning industry includes a diverse range of sectors, including industrial cleaning, shopping centres, hospitals and other government facilities. The cleaning sectors that formed the focus of this thesis were determined by a larger study undertaken for WorkCover NSW (see Section 1.5.5) in which a government, industry and union steering committee jointly identified the cleaning sectors of highest concern. These sectors were government schools, commercial office space, and commercial recreational/residential facilities (for example, clubs, hotels/resorts, and motels) (WorkCover NSW Cleaning Industry Steering Committee, 2004). As the subjects within this thesis were taken from these three sectors (see Section 3.1), a brief description of each sector and specific characteristics are outlined in the following sections.

Table 2.2: Examples of NSW workers' compensation insurance premium 04/05 (WorkCover NSW, 2004).

Please see print copy for Table 2.2

Government Schools: This work environment is in government educational facilities, such as primary and high schools. The areas cleaned are classrooms, playgrounds, foyers, staircases, offices, halls, tearooms/kitchens and bathroom areas. There are rarely lifts available in these settings to carry equipment between levels. Users of these facilities are children and adults. Desks and toilets in primary schools are designed for children to use and, as such, the consequent working heights for the cleaner is low.

Typical tasks for the cleaning worker in these facilities include waste paper and rubbish removal; vacuum cleaning all entrance mats and carpeted areas; removing cobwebs from the interior of buildings; moving chairs and desks for cleaning underneath and replacing when floor cleaning is complete; and wiping down tables in all rooms. Specific cleaning duties are specified for toilet and shower areas, urinals, carpeted areas, other floor surfaces (including gymnasiums), specialised teaching spaces (for example, art rooms, woodwork rooms and kitchens) and furniture, fittings and fixtures (Telopea Park School Cleaning Contract TPS 0201, 2002-2003).

Commercial Office Space: This work environment is characterised by multi-storey buildings with lift access to each floor. Areas cleaned include foyers, bathrooms, kitchens, meeting rooms, open office areas with multiple computer desks, single offices, and elevators/lifts. Cleaning duties in this work environment are characterised by vacuuming, carpet steam cleaning, detailing (for example, cleaning surfaces including tables, tiles, walls, mirrors, glass, and interiors of lifts), office equipment cleaning (for example, chairs, phones, copiers, and computer monitors), toilet and bathroom cleaning, kitchen cleaning and dish washing, floor and hard surface polishing, waste paper, rubbish and recycling management, pest control, sanitary services and other general cleaning tasks (One Planet Cleaning, 2007).

Commercial Recreational/Residential Facilities: This work environment includes hotels, motels, or entertainment venues such as clubs or large theatres. The hotel/motel cleaners predominantly service bedroom and ensuite bathrooms, and hallways. Cleaners in open public areas are required to clean foyers, restaurants, bathrooms, staircases and venue seating. Cleaners in this sector may or may not be able to access the different levels of the facility via a lift.

Duties for cleaners in this environment include those described above for the commercial office cleaners as well as specific duties such as preparing rooms for guests, maintaining furniture and fittings and room dressings, and customer service (Certificate II in Asset Management).

No studies were identified which compared the upper limb musculoskeletal demands of cleaning work across different cleaning sectors.

2.5 Vacuum Cleaning Tasks and Musculoskeletal Risk

The primary purpose of the vacuum cleaning task is to remove dirt and fine debris from the floor surface in the work area. The business imperative is that the floor is cleaned as quickly and effectively as possible, and to this end, the vacuum cleaning machine must be robust, have good suction and have a dust bag which can be easily emptied and re-used (unlike a domestic vacuum cleaner which either has a paper dust bag, or fabric bag, which is replaced entirely when full; or a chamber which is emptied when full).

2.5.1 Types of Vacuum Cleaners

Vacuum cleaning machines commonly used for commercial cleaning in Australia are of three main types.

Upright Machines: These types of machines are pushed or pulled across the floor surface by the operator. They have a motor, bag, hose and beater included in a single unit (see Figure 2.2). The cleaner pushes or pulls the unit via a handle, which is hinged at the base. These machines weigh approximately 8 kg when empty, with a dust collection bag capacity of generally 5 litres. The vacuum cleaning head is 380-640 mm in width (http://www.tensens.com.au/index.html?lmd=39414.415856, accessed 23 November, 2006).

Please see print copy for Figure 2.2

Figure 2.2: Example of an upright vacuum cleaning machine (http://ec1.imagesamazon.com/images/P/B00005QX3Z.01._AA280_SCLZZZZZZZ_.jpg. Accessed 23 November, 2006).

Canister or Barrel Machines: These machine types are pulled along the floor surface by the operator. These machines consist of a vacuum head, rigid wand, long flexible hose and solid canister containing a motor and bag (see Figure 2.3). The cleaner drags the canister along the floor surface using the flexible hose. These machines weigh approximately 7 kg when empty. The dust collection bag capacity is 10-18 litres and the vacuum cleaning head is 270-280 mm wide (http://www.uneedavac.com.au/clarkclean__professional_cleaning_equipment/ProVac_Series_Upright_Vacuum_Cleaners.htm, accessed 23 November, 2006).

Figure 2.3: Example of a canister vacuum cleaning machine.

Back Pack Machines: These machines consist of a canister with motor and bag carried on the back, with a flexible hose, rigid wand and vacuuming head. The machine is held in place by a rigid frame, made of plastic or metal. This frame is attached to the worker with a harness system (see Figure 2.4). Newer model back pack machines weigh 4-5 kg with empty bags, while the older versions typically encountered in the school environment weighed 8 kg. Dust collection bag capacity is 4-5 litres and the vacuum cleaning head is 270-280 mm wide (http://www.tensens.com.au/index.html?lmd=39414.415856, accessed 23 November, 2006).

Figure 2.4: Examples of a back pack vacuum cleaning machine.

In this thesis, as per the larger study for WorkCover NSW, upright machines were rarely used in commercial cleaning; their main use being to vacuum the internal carpets in lifts in commercial office space (Weigall *et al.*, 2005). For this reason, these types of vacuum cleaners have not been assessed in this thesis. Another type of upright cleaner, the self-propelling 'one-pass' vacuum cleaners and special wet/dry vacuum cleaners, are specialist in nature and therefore are beyond the scope of this thesis. Furthermore, none of these types of vacuum cleaners were used in any of the workplaces assessed in the original study, and are therefore not included in this thesis.

2.5.2 Vacuum Cleaning and Injury Risk

There is a paucity of research investigating cleaning tasks, with only a few studies having investigated vacuum cleaning tasks. The research into cleaning has mainly focussed on mopping and scrubbing tasks (Hagner & Hagberg, 1989; Sogaard, Fallentin, Nielsen, 1996; Paver, 1997; Sogaard, Laursen, Jensen, & Sjogaard, 2001).

The main tasks performed by cleaning workers consist of detailing (dusting, wiping, polishing), collecting rubbish, cleaning toilets and kitchens, mopping, sweeping and vacuuming. Tools, equipment and materials used by cleaning workers include cleaning chemicals, cloths, mops, buckets, brushes, dustpans and brooms, trolleys, bins and vacuum cleaners (including back pack, canister and upright models; see Section 2.5.1).

Despite the high injury risk associated with cleaning (see Section 2.4), there are only a small number of studies which have addressed the demands of general cleaning tasks. Messing *et al.* (1998) studied cleaning tasks in a Quebec hospital where the tasks were categorised as ‘heavy’ and ‘light’, with gender being the basis upon which tasks were allocated. Men were allocated ‘heavy’ tasks and women ‘light’ tasks. On examining the tasks, the researchers found that the ‘heavy’ work tasks were characterised by more neutral postures and heavier loads, whereas the ‘light’ tasks were characterised by light loads, repetitive upper limb and hand movements and more flexed postures. Vacuuming was not discussed, probably because hospitals typically have little or limited carpeted areas.

Perhaps the most useful study in terms of vacuum cleaning is that undertaken by Johansson & Ljunggren (1989). In this study, nine cleaners rated their perceived level of exertion and had their heart rate measured while performing common cleaning tasks, including vacuuming. Interestingly, heart rate remained relatively constant across all activities but rates of perceived exertion (RPE) changed with the task. The RPE was high for all tasks, being rated as ‘fairly strong’ or ‘stronger’, with vacuuming at the higher end of the scale (mean rating of 5.5 compared to 4.0 for toilet cleaning and 5.7 for swabbing (wet mopping). This study also took into account each participant’s physical fitness, estimated via the use of a submaximal bicycle ergometer test. The results of the fitness analysis were then used to calculate oxygen uptake for each task. On average, the cleaning tasks were estimated to use 35% of maximum oxygen uptake, with swabbing/mopping being the highest demand at 42.5% and with vacuuming being estimated to utilise 34.5% of maximum oxygen uptake. The authors then compared this physiological work load with that of construction workers (39% maximum oxygen uptake), demonstrating that cleaning tasks have equivalent physiological demands to heavy work tasks (Johansson & Ljunggren 1989).

The only other relevant study located specifically addressing the musculoskeletal demands of vacuum cleaning tasks was that conducted by Aickin (1998) for WorkCover NSW. Part of this study involved the assessment of one cleaner performing vacuum cleaning tasks with a back pack vacuum cleaner, a canister vacuum cleaner and a barrel vacuum cleaner (for a description of the types of vacuum cleaners see Section 2.5.1). The physical demands of the tasks were measured using the Ovako Working Posture Analysing System (OWAS; Karhu *et al.,* 1977) and heart rate measures. Findings of the study demonstrated consistency in heart rate measures reported in the study by Johansson & Ljunggren (1989). Aickin (1998) noted, however, that the OWAS system was not sensitive enough to measure the repetitive arm movements that occurred below elbow height, which were clearly observed during vacuuming, particularly with the back pack vacuum cleaning machine. However, a comparison between the postural demands of the three vacuum cleaners on the user found that, when using the back pack machine compared to either the canister or barrel machine, there was increased trunk flexion, less walking and more arm activity. Acknowledging the small sample size (n = 1), this is the only study located which has examined the musculoskeletal demands of the back pack vacuum cleaning machine, thereby highlighting the need for further research in this area.

Woods & Buckle (2005) reviewed the design and use of cleaning equipment and made recommendations for buffing machines (floor polishers), mopping systems and vacuum cleaning machines. Their recommendations emerged following a comprehensive review of the musculoskeletal health of cleaners (Woods, Buckle *et al.* 1999). The vacuum cleaning machine recommendations were based on surveys, workplace assessments, 'expert' ergonomic assessments, user trials and use of focus groups. Issues that were identified included the length of the attachments for the vacuum cleaner, the grip (location, size, and texture), location of control switches, resistance of foot controls, adequacy of flex management systems (that is, power cord management), and the need for safety lights to identify machine activation. It must be noted, however, that back pack vacuum cleaner design was not addressed in this review. Furthermore, most of the studies that have been undertaken on vacuum cleaning tasks have concentrated on the physiological demands of vacuum cleaning rather than the musculoskeletal demands (Mengelkoch & Kirby, 2006; Johansson & Lujunggren, 1989; Norman *et al.* 2003). Consequently, this thesis will add valuable information on the assessment of musculoskeletal risk and vacuum cleaning tasks, and is unique in addressing the demands of back pack vacuum cleaning tasks.

2.6 Observational Ergonomic Risk Assessment Tools

Various methods have been developed to assess postures and determine postural loads in order to identify potential risk factors for musculoskeletal disorders in industry. The methods can be grouped into direct measurements, observational methods and self-report techniques (Kilbom 1994; Li 1999), and include a wide range of tool types from complex, such as highly technical and expensive laboratory equipment, to easy to use pen and paper checklists. The main observational ergonomic risk assessment tools documented in the literature include the:

- Revised NIOSH Equation (Waters *et al.*, 1993);
- Rapid Upper Limb Assessment (McAtamney & Corlett, 1993);
- The Strain Index (Moore & Garg, 1995);
- Ovako Working Posture Analysis System (Karhu *et al.*, 1977);
- Occupational Repetitive Actions (Occhipinti, 1998);
- Quick Exposure Check (Li & Buckle, 1999);
- Rapid Entire Body Assessment (Hignett & McAtamney, 2000);
- An Observation Method to Assess Physical Loads imposed on the Upper Extremities (Ketola *et al.*, 2001);
- A Posture and Load Sampling Approach to determining Low Back Pain Risk (Neumann et al., 2001); and
- Manual Tasks Risk Assessment Tool (Burgess-Limerick et al., 2004).

Most of these tools require the collection of detailed data and the use of specific equipment with lengthy analysis. As this thesis is a field based study, tools which were non invasive, and utilised simple pen and paper checklists were preferable.

Three observational tools designed specifically for studying musculoskeletal risk are the Manual Tasks Risk Assessment Tool Version 2.0 (Burgess-Limerick *et al.*, 2004); the Rapid Upper Limb Assessment Tool (McAtamney & Corlett, 1993); and the Quick Exposure Check Version 5.0 (Li & Buckle, 1998; Li, 1999). These three methods offer a compromise between the high cost of direct methods (where devices are attached to the body) and the low validity and subjectivity of self reported techniques (Kilbom, 1994). These non-invasive, simple measurement approaches can be used without interference while workers perform their regular duties, and so are highly suitable for field studies when examining work tasks such as cleaning. As such, these three observational tools are described in further detail in the following section.

2.6.1 Manual Task Risk Assessment Tool (ManTRA Version 2)

This risk assessment tool has been designed to measure the key risk factors highlighted for work-related musculoskeletal disorders, that is, repetition, force, posture, and vibration (Bernard, 1997). ManTRA provides a risk rating for exposure to musculoskeletal risk factors for different body regions associated with manual tasks in the workplace. It is a tool designed to be used in the field, without the need for specialised equipment, and was initially designed to be used by workplace health and safety inspectors in Queensland, Australia, when assessing the ergonomics of work tasks.

Tasks are assessed and qualitatively scored with respect to exposure, duration, cycle time, force, speed, awkwardness and vibration of five different body regions (lower limbs, back, neck, shoulder/arm and wrist/hand). The qualitative scores for cycle time and duration are combined to provide a repetition risk score. Similarly, force and speed are also combined to provide an exertion risk. Each body region is scored and a risk ranking is allocated by summing duration, repetition, exertion, awkwardness and vibration. This cumulative risk score provides a range between 5 and 25. The ManTRA scoring sheet can be found in Appendix 1. An unpublished research study has found high intra- and inter-rater reliability for the tool (Burgess-Limerick *et al.*, 2004, personal communications).

ManTRA was used to assess the musculoskeletal demands of cleaning work in the WorkCover study by Weigall *et al.* (2005). This larger study rated wet mopping, static mopping, vacuuming, buffing, detailing, cleaning toilets and emptying rubbish. The tasks rated as a risk were vacuuming for neck/shoulder and hand/arm/wrist, and buffing for the hand/arm/wrist. No other studies of cleaning work using this risk assessment tool have been located.

The only published full manuscript that was located which has utilised ManTRA to rate musculoskeletal risk, is that undertaken by Straker *et al.* (2004), in which a randomised controlled trial of a participative ergonomics approach in addressing workplace musculoskeletal disorders was implemented. The relative risk pre- and post-intervention in this study was rated using ManTRA, whereby, the ManTRA scores were aggregated across worksites to enable comparison on a broad scale. The results of the study demonstrated an improvement in musculoskeletal risk in the workplaces which received the participatory ergonomic intervention, compared to the control workplaces, indicating that consultation with the workforce is valuable in making changes and improvements in work practices.

2.6.2 Quick Exposure Check (QEC)

The QEC was developed at the Robens Centre for Health Ergonomics (Li & Buckle, 1998), in the United Kingdom; but was recently reviewed, improved and updated (David, 2005). The QEC is a tool developed and designed in consultation with health and safety professionals to be a ‘practical exposure assessment tool’ (Li & Buckle, 1998), which could be used to measure musculoskeletal risk exposure before and after an ergonomics intervention, requiring a small amount of training prior to use. The tool is unique in that it combines the ‘expert’ observer ratings and the ratings of the worker on task characteristics to give an overall score.

Assessment of exposure to posture and repetitive movement is provided for different body sites: the back, shoulder/upper arm, wrist/hand, and the neck. Task characteristics of weight, duration, hand force exertion and vibration are qualitatively scored by the worker. These observer and worker scores are then combined to provide an overall score for each body location and worker overall score. In the revised QEC, the worker assessment and task characteristics are expanded, and the scores are grouped into relative risk bands for each item.

The validity and reliability of the QEC tool were assessed and published in the original tool development. High levels of sensitivity and reliability were found for both intra-observer and inter-observer scoring (Li & Buckle, 1999), though scoring of the neck posture did show some difficulties with agreement (Kendall's coefficient of concordance = 0.25).

As noted above, the QEC was revised and improved in 2005. One of the main issues with the original assessment tool was the absence of risk rankings. The revised tool has provided these risk ratings, as well as some additional worker questions regarding vehicle driving at work, and a more specific question regarding vibration exposure at work. The revised tool was tested for reliability using 10 experienced professionals. Agreement was measured using Kendall's coefficient of concordance, with values ranging from 0.6 to 0.79. A QEC (Version 5.0) scoring sheet, as well as the revised QEC (Version 6), can be found in Appendix 2.

O'Keeffe (2004) compared QEC and ManTRA with self-reported body discomfort questionnaires in repetitive manufacturing tasks, finding that ManTRA and QEC were equally consistent on levels of body discomfort reporting.

2.6.3 Rapid Upper Limb Assessment (RULA)

The RULA tool is also an observational method/tool which assesses posture of the neck, trunk and upper limbs together with muscle function and the external loads experienced by the body (McAtamney & Corlett, 1993). RULA specifically identifies risks associated with the shoulder, hand and wrist postures. As opposed to ManTRA and the QEC, which both take into account task duration, RULA scoring is performed at a discrete point in time and time selection is based either on the posture held for the greatest amount of the work cycle or where the highest loads are deemed to occur. This tool uses body posture diagrams for the upper arm, lower arm, wrist, neck, trunk and legs to enable the postures of the worker to be coded according to the amount of flexion/extension, adduction/abduction away from the midline and twisting. Scores are also allocated for repetition or static loading and the force/load exerted. These body posture diagram codes and scoring tables are combined to calculate a risk score of between 1 and 7. A risk score of 5 to 6 indicates that investigation and changes to reduce risk are required in the near future, whereas a score of 7 indicates that investigation and changes are required immediately.

In their original article McAtamney & Corlett (1993) reported that RULA was found to be statistically valid when measuring neck and lower arm posture and risk of video display unit (VDU) operators in laboratory studies. RULA was also found to be reliable when used to assess the posture of video taped workplace examples of VDU operators; packing workers; sewing tasks; and brick sorting tasks; and rated by 120 physiotherapists, industrial engineers, as well as safety and production engineer trainees, with high consistency of scoring between subjects.

Published studies using RULA are limited to VDU, nursing care for residential patients, truck driving and assembly tasks. These studies found that RULA was a useful tool to measure risk to the upper limbs before and after an ergonomics intervention, as well as demonstrating significant association of trunk and neck scores and self-reported pain and discomfort (Cook and Kothiyal, 1998; Massaccesi et al, 2003). Although one doctoral thesis was identified which addressed the relative musculoskeletal risk of cleaners use of different toilet brush designs using the RULA tool (Kumar, 2006), no study was located which used RULA to examine other cleaning tasks such as vacuum cleaning.

The three musculoskeletal tools discussed in this section are useful for field based studies as they allow the worker to work normally without any interference from equipment. They have good reliability and validity and measure the key risk factors for musculoskeletal disorders. As a suite of tools, they involve the worker in the assessment (QEC), measure vibration (ManTRA) and specifically focus on the upper limbs (RULA). Although the 'parent study' of this thesis, commissioned by WorkCover NSW, utilised ManTRA and RULA in its assessment of cleaning tasks, no study has been identified which examined vacuum cleaning tasks using a variety of observational musculoskeletal risk assessment tools.

Cleaning work takes place within a specific work environment and, in Australia, this environment is overseen by state-based OHS legislation. This legislation will now be described.

2.7 Legislative Background

In NSW, workplaces are regulated with regard to OHS by the NSW Occupational Health and Safety Act (2000) and the NSW Occupational Health and Safety Regulation (2001). Specific guidance for managing work-related musculoskeletal disorders under the Act are derived from the National Standard for Manual Handling, 1990, the National Code of Practice for Manual Handling (1990), and the National Code of Practice for the Prevention of Occupational Overuse Syndrome (1994)*. Under the NSW Occupational Health and Safety Act (2000), employers are obliged to identify, assess and control hazards in their workplace, including hazards posed by manual tasks such as cleaning work.

For work-related musculoskeletal disorders, the existing Manual Handling Code of Practice instructs employers to take into account specific factors when identifying risks to musculoskeletal health, which are summarised in Table 2.3. The Code for the Prevention of Occupational Overuse Syndrome guides employers to consider, as part of risk identification, the factors listed in Table 2.4.

Table 2.3: Summary of risk factors considered in the Code of Practice for Manual Handling ([2005]:1990), Risk Identification.

Please see print copy for Table 2.3

* Both codes of practice have been reviewed and a new standard and code of practice was declared by the Australian Safety and Compensation Council in August 2007. The National Standard for Manual Tasks (2007) and the National Code of Practice for the Prevention of Musculoskeletal Disorders from Performing Manual Tasks at Work (2007) are yet to be adopted by the NSW Government, and consequently, manual tasks in NSW continue to be guided by the previous standard and codes of practice.

Table 2.4: Summary of risk factors considered in the Code for the Prevention of Occupational Overuse Syndrome, ([2013]:1994), Risk Identification.

Please see print copy for Table 2.4

The Code for the Prevention of Occupational Overuse Syndrome also requires employers to consider other factors when *assessing* the level of risk. These factors are outlined in Table 2.5.

Table 2.5: Summary of risk factors considered in the Code for the Prevention of Occupational Overuse Syndrome, ([2013]:1994), Risk Assessment.

Please see print copy for Table 2.5

The current Standard and Code of Practice for Manual Handling has undergone extensive review. This review has led to the development and declaration of the National Standard for Manual Tasks (2007) and the National Code of Practice for the Prevention of Musculoskeletal Disorders from Performing Manual Tasks at Work (2007) by the Australian Safety and Compensation Commission in August, 2007. The proposed Standard and Code of Practice are in response to individual states (Western Australia, Queensland, Victoria) implementing management strategies above and beyond those outlined in the current National Standard and Code of Practice for Manual Handling (National Occupational Health and Safety Commission, 2005). The revised standard and code of practice are important in relation to cleaning workers, as these benchmark materials are likely to be adopted by the NSW government within the OHS Act 2000 as per the current Standard and Code of Practice for Manual Handling. Functionally, the proposed standard and code of practice will place greater responsibility on designers, manufacturers and suppliers of equipment to consider the risk of musculoskeletal disorders to the end user; it places obligations on building owners and principal contractors to provide workplaces without manual handling injury risk. This particular obligation will allow contract and sub-contract workers, such as cleaners, to have their risk of musculoskeletal risk identified, assessed and controlled; this obligation does not currently exist. Further, this should mitigate the risk of musculoskeletal disorders for all workers in precarious employment situations.

2.8 Summary

The literature highlights the importance of three groups of risk factors in work-related upper limb musculoskeletal disorders: physical risk factors of force, duration, posture and vibration; psychosocial risk factors such as precarious working arrangements, relationships with supervisors and co-workers, and level of job control; and individual risk factors of age, gender, socioeconomic status and pre-existing musculoskeletal disorders. Although these three groups of risk factors are clearly identified in the literature, no research was located which systematically assessed the specific risk factors for cleaning workers in developing work-related upper limb musculoskeletal disorders when performing common cleaning tasks such as vacuuming. Therefore, this thesis aims to quantify the upper limb musculoskeletal risk in cleaning workers while they are performing vacuum cleaning tasks. Additionally, it will provide information on the relative risk to the worker of selecting back pack versus canister vacuum cleaning equipment to clean carpeted areas in three different working environments, government schools, hospitality and commercial office space.

Chapter 3
Methods

3.1 Subjects

As discussed in Section 1.5, the subjects for this thesis study were drawn from a larger cohort of 66 subjects (mean age 46.7 ± 11.7 years), who were recruited for a consultancy research project undertaken with WorkCover NSW on Repetitive Manual Tasks of Cleaners by Health & Safety Matters Pty Ltd (Weigall, *et al*., 2005)[*]. The focus of that study was to obtain an overall description of risk of upper limb musculoskeletal disorders for cleaning workers. The present thesis utilised video footage from the larger cohort, and interview data for the 24 subjects who were the focus of this study.

The 24 subjects in the present study were recruited from 24 different worksites, which spanned three employment sectors for cleaners: government schools (n = 10); hospitality (n = 9), and commercial office space (n = 5). A subject number of 24 was obtained, and 24 different worksites were selected, to allow adequate numbers for analysis across the three employment sectors following consultation with the University of Wollongong Statistical Consulting Service. These subjects represented the total possible number of subjects for whom video footage of complete vacuum cleaning cycles, using a back pack or canister machine, were available. No canister cleaners were utilised in the sample of commercial office space. Table 3.1 shows the distribution of subjects and vacuum cleaner types across the cleaning sectors.

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[*] Although part of a larger consultancy research project, it should be noted that the candidate collected data for this thesis as part of the consultancy team. Furthermore, the data presented in this thesis on vacuum cleaning is unique, and not part of the original consultancy.

The descriptive characteristics of the 24 subjects who participated in this study are outlined in Table 3.2. The mean age of the total cohort was 47.5 years (±12.1 years), which is representative of other studies of cleaning workers, such as the Robens Report (Woods *et al.*, 1999), in which the cleaners had a mean age of 49 years (±31 years). This high average age is also representative of the ageing workforce discussed in Section 2.3.3. The oldest subjects in the present study were within the government school sector, with the youngest subjects in the commercial office sector. Figure 3.1 illustrates the age spread across the three cleaning sectors. It is noted that the mean age of the cohort for the commercial office sector was lower than the other two sectors. Again, this is reflective of the larger study by Weigall *et al.* (2005), whereby the mean age of workers in the commercial cleaning sector was 37.7 years (±11.6 years).

The subjects in the present study were predominantly female as illustrated in Figure 3.1. Female subjects in the government school sector accounted for 90% of the sample; 89% of subjects in the hospitality sector and 100% in the commercial office space environment. This sample characteristic was also found in the United Kingdom study (Woods *et al.*, 1999), whereby 89% of the cleaners were female.

Table 3.1: Distribution of subjects and vacuum cleaner types across the cleaning sectors.

Vacuum Cleaner Type	Government Schools	Hospitality	Commercial Office Space
Back Pack	6	3	5
Canister	4	6	0
Total	10	9	5

Table 3.2: Mean and standard deviation in age (years) of the subjects (n = 24) across the three cleaning sectors.

Sector	n	Mean	Standard Deviation
Government School	10	52.1	10.6
Hospitality	9	50.0	8.5
Commercial Office	5	33.8	11.8
Total	24	47.5	12.1

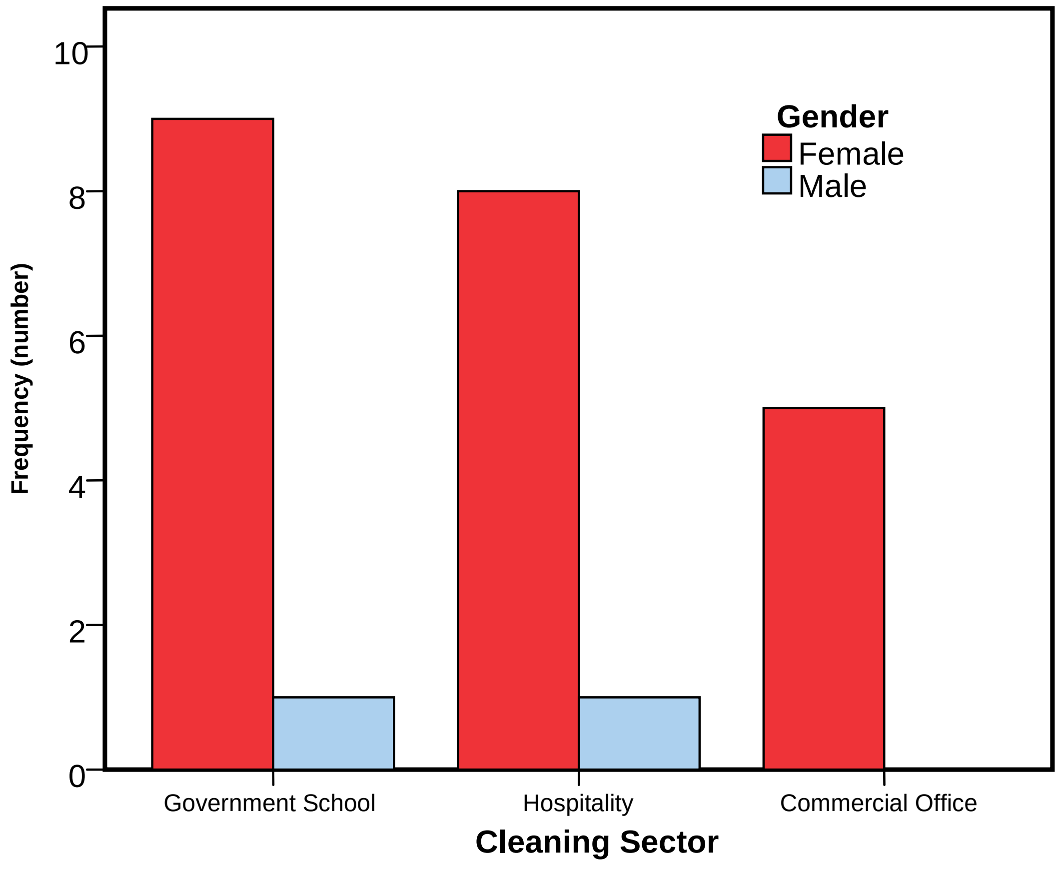

Figure 3.1: Distribution of gender across the three cleaning sectors.

This profile in the government school and hospitality sector of ageing and female workers echoes the risk factors for upper limb work-related musculoskeletal disorders as discussed in Sections 2.3.1 and 2.3.3. Therefore, it can be extrapolated that the sample in this study is representative of the larger cleaning workforce both in NSW and the United Kingdom. Workers are typically older female employees, and susceptible to musculoskeletal disorders.

The specific cleaning sites were identified by four major cleaning companies associated with the larger study (Weigall *et al.* 2005), at sites across Sydney and the Illawarra. The criteria for subject/site selection was that the worker could speak English and that two or more cleaning workers were employed at each site to allow maximum efficiencies in data collection and minimum disruption to the workplace. No criteria for length of worker experience or age of worker was specified. Consequently, the subjects were a group selected by the cleaning contractor companies and not workers chosen randomly. Although it is acknowledged that this method of subject selection may be biased and will not ensure that the sample is truly representative of cleaning workers, it is a limitation imposed externally upon the study.

Ethics approval was obtained from the University of Wollongong Human Research Ethics Committee to utilise the initial data (subject information and video footage of task performance) from the larger study following permission to do so being granted by WorkCover NSW. The initial consent forms completed by the participants were deemed adequate to cover the data analysis proposed for the purpose of this thesis.

3.2 Vacuuming Task

The vacuum cleaning task under assessment was restricted to vacuum cleaning conducted on level carpeted floor areas encountered in the normal duties for each worker. Vacuum cleaning stairs or tiered work areas were eliminated from the study to ensure that the comparison between vacuum cleaner types was valid. Two different types of vacuum cleaning machines were used by different subjects in this study: back pack type machines (n = 14) and canister type machines (n = 10) (see Section 2.4.1 for a full description of each machine type).

3.3 Data Collection

Data were collected at each work site during each subject's usual cleaning shift. Times of work site visits varied according to each site and subject's shift pattern. Many cleaners across the sectors worked split shifts, usually including two 3 hour shifts at each end of the day. However, the shift patterns varied as illustrated in Table 3.3, which outlines examples of shift patterns worked by subjects within the overall sample.

At the selected worksites each cleaner was informed of the purpose of the study and then provided with a consent form requesting their permission to interview them regarding their work tasks, and permission to video them for analysis of body postures while vacuum cleaning. Once consent was granted, demographic data were collected on each subject, including their age, gender, height, weight, years of experience in cleaning, hours of work/shift times, different tasks in their work, pace of work and other jobs they may have. Details of the tasks they typically performed over a shift, with duration for each task and details of the vacuum cleaner they use at work, including questions regarding machine vibration, were also documented. Each interview form was coded according to the site and worker.

Table 3.3: Typical shift times for subjects across the three cleaning sectors, government schools, hospitality and commercial office.

Government Schools	Hospitality	Commercial Office
5.30am – 8.30am 3.00pm – 6.00pm	7.00am – 3.00pm	5.00am – 8.00am 6.20pm – 9.20pm
5.30am – 2.30pm (Mon-Thurs) 5.30am – 4.30pm (Friday)	4.00am – 12 noon	5.00pm – 8.00pm
5.00am – 9.00am 3.00pm – 6.00pm	5.30am – 1.30pm	3.30pm – 2.30am
5.00am – 8.00am 3.00pm – 6.00pm	6.15am – 2.20pm	5.30pm – 8.30pm
5.30am – 8.00am 3.30pm – 6.00pm	9.30am – 2.00pm	5.30pm – 10.00pm
4.30am – 8.30am 2.00pm – 6.00pm	7.30pm – 3.30pm	4.00pm – 12 midnight

Each subject was then filmed, using a Samsung digital video camera (model VP-D130i), while they performed their normal vacuum cleaning duties and adhering to their normal methods of working. The video camera was hand-held by the researcher and focussed to obtain a good view of the subject's neck, shoulder, elbow, wrist, trunk and legs to allow accurate rating of the musculoskeletal risk using the selected ergonomic assessment tools (see Section 3.4). Duration of filming was for the total vacuum cleaning task, stopping only when the subject changed tasks (for example, when the subject completed a school room or area and moved to another task). The duration of the task varied with the work environment and ranged from 8 minutes to 30 minutes.

Corresponding coding to the interview forms were noted on the film case to match interview and video and the video images were stored in a locked cabinet for later analysis. To enable each assessment tool to be implemented, the 24 video tapes were replayed using the Samsung digital video camera and a 76 cm colour Phillips television monitor. The tapes were viewed, paused and replayed as necessary to score each task using the risk assessment tools. Each tape was assessed using all three assessment tools before moving onto the next subject's tape. The duration of the assessment of each tape with each tool was approximately 2 hours.

3.4 Risk Assessment Tools

The risk assessment tools selected for this study to identify risk factors for work-related upper limb musculoskeletal disorders were ManTRA version 2.0 (Burgess-Limerick *et al.*, 2004); QEC version 5.0 (Li & Buckle, 1998); and the RULA (McAtamney & Corlett, 1993). These risk assessment tools were selected as they are observational ergonomic risk assessment tools, suitable for field studies of cleaning work tasks such as vacuum cleaning. Researcher training in the use of these tools was gained via professional workshops (ManTRA and RULA) and self tuition from the literature (QEC). The training sessions for ManTRA and RULA involved theory and application practice, with the researcher benchmarked against other trainees, as well as trainer benchmarked assessments. The researcher was found to be consistent with each practice task assessment score. Use of the QEC was able to be compared to the recently modified QEC (David, 2005) and the author's scores on the sample test items on the QEC website were consistent with the 'expert' scores provided http://www.surreyergonomics.org.uk/index.php?option=com_content&task=view&id=7

&Itemid=7, accessed 2nd October 2005). Details of how each risk assessment tool was implemented are described below.

3.4.1 Manual Tasks Risk Assessment

As outlined in Section 2.6.1, using ManTRA the task of vacuuming was scored with respect to exposure, duration, cycle time, force, speed, awkwardness and vibration for five different body regions; the lower limbs, back, neck, shoulder/arm and wrist/hand. The scores for cycle time and duration were provided by the subject interview form (How long is your shift?) and the cycle time of the vacuuming task under review. The cycle time and duration time were combined to provide the repetition risk score. The force and speed scores were combined to provide an overall exertion risk. A cumulative risk score was also calculated using the scoring system shown in Appendix 1. Scores indicating musculoskeletal risk were: a score of 5 or more on exertion; a score of 8 for exertion and awkwardness; and a cumulative risk score of 15 or more.

3.4.2 Quick Exposure Check

A detailed description of the QEC has already been provided in Section 2.6.2. with the scoring system included in Appendix 2. In brief, details for the worker questions were obtained from the subject interview data (for example, How much time do you spend vacuuming per day? Do you have difficulty keeping up with the work?). The worker questions related to maximum weight handled and maximum force was extrapolated from the researcher's observations. As outlined in Section 2.6.2, the revised QEC now provides a risk rating as well as raw score. The risk ratings of the revised QEC were utilised in the data analysis for this thesis, to allow comparison with risk ratings across the three ergonomic observational risk assessment tools.

3.4.3 Rapid Upper Limb Assessement

A detailed description of the RULA tool is described in Section 2.6.3. In brief, RULA measures a point in time and that moment should be the most 'risky' posture or the posture adopted most frequently (McAtamney & Corlett, 1993). Consequently, each tape was observed three times, the most frequent posture identified (for example, trunk flexion to vacuum under desks), the time on the tape counter noted, the tape then viewed again at this point and rated using the score sheet following the procedures described in Section 2.6.3 and Appendix 3. The risk ratings in RULA are termed 'Action Levels' in the tool. Action Level 1 is low risk (score between 1- 2); Action Level 2 (score of 3 – 4), indicating that the task needs to be changed; Action Level 3 (score of 5 – 6), indicating the task needs to be changed soon, and Action Level 4 (score of 7), indicating the task needs to be changed immediately.

3.5 Data Analysis

3.5.1 Reliability Testing

To ensure that the researcher was reliable in assessing each task, reliability testing (intra-observer reliability) was established by selecting six subjects and rating the vacuum cleaning tasks using the three assessment tools (ManTRA, QEC, and RULA), and data from corresponding coded interview forms. This process was repeated over three consecutive days, to provide three ratings of each task with the three tools.

Pallant (2001) stated that test/re-test correlations can be measured using Cronbach's alpha. Cronbach alpha scores range between 0 and 1, with 1 being a perfect correlation. For high correlation, the value of Cronbach's alpha must be above 0.7 (Pallant, 2001). Mellis *et al.* (2001) also discussed and recommend Cronbach's alpha as a useful statistical test for internal validity and repeatability.

To test the reliability of the researcher in using the risk assessment tools in this study, a comparison of scores for each tool item and each tool was conducted using Cronbach's alpha as follows:

- Day 1 data were compared to Day 2 data;
- Day 1 were compared to Day 3 data; and
- Day 2 data were compared to Day 3 data.

Cronbach's alpha was calculated for each of these situations, with the results presented in Table 3.4. As seen in Table 3.4, all the Cronbach's alpha scores were greater than 0.7, indicating the data were deemed highly repeatable with a good level of intra-observer reliability in scoring the vacuuming tasks with the chosen risk assessment tools.

Table 3.4: Intra-observer reliability testing of the observational musculoskeletal risk assessment tools: ManTRA, QEC and RULA.

Data Compared	Cronbach's Alpha score
Day 1 and Day 2	0.948
Day 1 and Day 3	0.849
Day 2 and Day 3	0.871

3.5.2 Data Management

The video footage of each vacuum cleaning task was ranked using each of the tools, together with details of each task gathered from interviews (duration, repetition, work pace). All data were then entered on a Windows XP EXCEL spreadsheet. A study codebook was developed matching variables with SPSS variable names and coding instructions. Data were then transferred to an SPSS (Version 11.5; and Version 13) data sheet, for statistical analysis.

3.5.3 Statistical Analysis

To determine whether or not vacuuming as a task (using either type of vacuum cleaner, within any of the three sectors) posed a risk of upper limb musculoskeletal disorders, a one-sample *t*-test was conducted with each tool item to determine whether the mean score obtained for the 24 subjects was significantly ($p < 0.05$) greater than the score defined as the risk indicator for that item. To determine whether the risk of musculoskeletal disorders differed between the types of vacuum cleaner, a one-way between-groups analysis of variance design with one between factor (vacuum cleaner type) was conducted to explore the impact of vacuum cleaner type upon the risk scores of the assessment tools while vacuuming.

To determine whether the risk of musculoskeletal disorders differed between the cleaning sectors, the subjects were divided into three groups depending upon the sector they worked in (Group 1 government school; Group 2 hospitality; Group 3 commercial office). A one-way analysis of variance design with one between factor (cleaning sector) was then conducted to explore the impact of cleaning sector upon the risk scores obtained by each assessment tool while the subject was vacuuming. To determine which sectors were significantly different to each other, and which sector was experiencing the greatest risk, *post-hoc* analyses of the data were undertaken using a Dunnet's C Test. This test was chosen rather than a Tukey HSD test, as the Levene test for equality of variances showed that the variances of the groups were unequal (Pallant, 2001).

While there is a relatively small sample size in this study (n = 24), and guidance from several sources is to increase the alpha level to 0.1 or 0.15 (Pallant, 2001), a significance level of $p \leq 0.05$ was selected to limit the possibility of a Type I error to 5%. SPSS software (SPSS 11.5, 13.0 and 15.0 for Windows) was used for all statistical analyses.

Chapter 4
Results and Discussion

4.1 Introduction

The following chapter provides results and discussion addressing the three key questions underlying this thesis: establishing the link between the task of vacuuming and musculoskeletal risk; identifying any differences in risk between the three cleaning sectors; and determining whether there was a difference in risk between the two vacuum cleaners, the back pack and the canister. Results for each of the three observational risk assessment tools will initially be discussed separately to establish the link between vacuuming and upper limb musculoskeletal risk. The tool results will then be integrated to allow a more comprehensive exploration to address the remaining two key issues under investigation.

4.2 Vacuum Cleaning Tasks and Upper Limb Musculoskeletal Risk

4.2.1 Manual Tasks Risk Analysis

ManTRA provides a risk rating for overall cumulative risk, exertion risk, and exertion/awkwardness risk for each body region (see Section 2.6.1). To determine the risk posed by vacuuming tasks, a cumulative risk score of 15 or more was taken to indicate the task was a risk to a specific body region, as did an exertion risk score of 5 or more, or an exertion + awkwardness score of 8 or more. The results for the mean ManTRA risk scores obtained for each component of the risk assessment tool for all 24 subjects are shown in Table 4.1.

Table 4.1: Mean and standard deviation ManTRA scores obtained for each component of the risk assessment tool for all subjects (n = 24).

ManTRA Item	Mean	Standard Deviation	Risk Indicator Score	*p* - value
Lower limb cumulative risk	11.00	1.53	15	0.000
Lower limb exertion risk	1.33	0.56	5	0.000
Lower limb exertion/ awkwardness risk	2.67	0.76	8	0.000
Back cumulative risk	14.04	1.16	15	0.001
Back exertion risk	2.38	0.49	5	0.000
Back exertion/ awkwardness risk	5.13	0.61	8	0.000
Neck cumulative risk	14.00	1.50	15	0.003
Neck exertion risk	2.58	0.65	5	0.000
Neck exertion/ awkwardness risk	5.54	0.65	8	0.000
Shoulder/arm cumulative risk*	16.83	1.43	15	0.000
Shoulder/arm exertion risk	4.54	0.66	5	0.002
Shoulder/arm exertion/ awkwardness risk	8.38	0.82	8	0.036
Wrist/hand cumulative risk*	18.67	1.27	15	0.000
Wrist/hand exertion risk	4.83	0.38	5	0.043
Wrist/hand exertion/ awkwardness risk*	9.63	0.65	8	0.000

* Risk scores which were significantly higher than the risk indicator score are in bold.

As can be seen in Table 4.1 vacuuming tasks overall did not present a musculoskeletal risk to the back or lower limbs, with none of the mean values obtained for the 24 subjects exceeding the relevant risk indicator score. However, the mean scores for the shoulder/arm cumulative risk scores, the wrist/hand cumulative risk scores and wrist/hand exertion/awkwardness risk scores were all significantly higher than the risk indicator score and, therefore, the task was deemed a significant risk. Although the mean score for the neck cumulative risk (14) was not significantly greater than the risk indicator score of 15, the standard deviation values imply that some subjects registered risk for this test item. Similarly, the back cumulative risk score, the shoulder/arm exertion risk score, and the wrist/hand exertion risk scores indicated some subjects presented with risk during the activity of vacuum cleaning. These findings will be further explored in Section 4.5, where the results are broken down between the different types of vacuum cleaners, and the outliers are discussed in the form of case studies. As there are no other published studies utilising ManTRA to rate vacuum cleaning tasks, there is no available data with which to compare the findings from the present study.

4.2.2 Quick Exposure Check

As discussed in Section 2.6.2, the revised QEC (Version 6) provides a risk score guideline, whereby a score value of 10 for the shoulder/arm was classified as a low risk and a score of 21-30 as moderate risk. Both low and moderate scores were used as risk indicator scores to check for risk. Using the moderate indicator scores, all subjects (n = 24) showed risk for the back, shoulder/arm, wrist/hand and neck. QEC worker ratings were not included due to the differences between the QEC used in this study and the revised QEC, which provides risk ratings (see Section 2.6.2 and Appendix 2). The results for QEC moderate risk scores are shown in Table 4.2.

Table 4.2: Mean and standard deviation QEC moderate risk scores obtained for each component of the risk assessment tool for all subjects (n = 24).

QEC item	Mean	Standard Deviation	Moderate Risk Indicator Score	*p* - value
Back	26.50	2.65	21.0	0.000
Shoulder/Arm	23.83	3.58	21.0	0.001
Wrist/hand	26.50	2.65	21.0	0.000
Neck	13.00	1.77	8.0	0.000

The results for every item of the QEC obtained from this sample of cleaning workers indicated vacuuming was a risk for upper limb musculoskeletal disorders, as all test items rated as a moderate risk and were significantly higher than the moderate risk indicator score. The high mean score for the wrist/hand and neck are indicative of upper limb musculoskeletal risk. The scores of the shoulder/arm, while high, have greater variability, which may be due to variations in the height of the subjects in relation to the fixed length of the vacuum cleaner wand (see Section 2.5.1).

4.2.3 Rapid Upper Limb Assessment

Unlike the previous two tools, RULA provides an overall risk score (action level) for the task (see Section 2.6.3 and 3.4.3). The mean RULA scores obtained for this sample of cleaners whilst they were vacuuming (mean = 6.54; standard deviation = 0.509) was significantly higher than the risk indicator set at 5 (Action Level 3). This finding confirms that vacuuming is a risk for upper limb musculoskeletal disorders for this sample of cleaners, particularly as the mean score is 6.54, and the highest risk possible score 7.

4.2.4 Summary of Findings for All Tools

In summary, all the observational risk assessment tools used in the present study rated the task of vacuuming as a risk to the musculoskeletal health of cleaning workers. However, how the tools rated each of their items and the emphasis on body parts at risk varied among the tools. For example, the ManTRA test items rated vacuuming as a significant risk in terms of shoulder/arm cumulative risk, wrist/hand cumulative risk and wrist/hand exertion/awkwardness risk. All QEC items rated the task as a moderate risk, including the back, shoulder/arm, wrist/hand, and neck. RULA rated the task with a mean score of 6.54 (Action Level 3), indicating that the task needs to be changed soon. These differences reflect the different approaches of each tool, whereby ManTRA has greater number of test items and scores greater detail on the upper limb than does the QEC and RULA rates a specific aspect of the task in terms of the risks of the posture assumed at that time.

Despite this between-tool variation, the three observational ergonomic risk assessment tools used in the present study provide data confirming that the task of vacuum cleaning is a risk to musculoskeletal health, with the ManTRA and RULA, in particular, highlighting the upper limb risk. Having established that vacuuming is a risk, this chapter will now focus on the secondary key questions, as to whether there is a difference between the cleaning sectors in terms of risk.

4.3 Risk Rating of Vacuuming Tasks between the Three Cleaning Sectors

Results pertaining to the risk of vacuuming tasks will now be presented and discussed, firstly by examining the main effect of cleaning sector on results obtained for the individual tools, followed by the results for the post-hoc analysis addressing the issue of how the sectors rated in their risk for the task of vacuuming relative to each other.

4.3.1 Individual Risk Assessment Tools and the Three Cleaning Sectors

Analysis of the scores for the three risk assessment tools and the individual sector data revealed that there was a significant main effect of cleaning sector on several test items (see Table 4.3). These items included the ManTRA lower limb cumulative risk score; ManTRA lower limb exertion risk score; ManTRA lower limb exertion and awkwardness score; ManTRA neck cumulative risk score; and ManTRA shoulder/arm cumulative risk score; QEC back score; QEC shoulder/arm score; QEC wrist/hand score; and the QEC neck score. Interestingly, there was no main effect of cleaning sector on the RULA scores. Discrete comparison of the three cleaning sectors follows in Table 4.4.

Table 4.3: Significant main effects of cleaning sector on the tool risk scores.

Test	Item	$F_{2,23}$	*p* - value
ManTRA	Lower limb cumulative risk score	17.96	0.000
ManTRA	Lower limb exertion risk score	6.78	0.005
ManTRA	Lower limb exertion + awkwardness score	10.09	0.001
ManTRA	Neck cumulative risk score	6.52	0.006
ManTRA	Shoulder/arm cumulative risk score	10.47	0.001
QEC	Back score	9.56	0.001
QEC	Shoulder/arm score	7.29	0.004
QEC	Wrist/hand score	9.56	0.001
QEC	Neck score	9.56	0. 001

Despite the statistically significant main effect of cleaning sector on the test items shown in Table 4.3, the mean risk scores varied and the extent of actual risk differed across these items. That is, while the ManTRA and the QEC items in Table 4.3 showed significant differences between the sectors, not all scores indicated a risk. In fact, the test items which do indicate risk are the ManTRA neck cumulative risk score (almost risk level) and the ManTRA shoulder/arm cumulative risk score; and all the QEC test items. Table 4.4 demonstrates the test items which showed a significant risk score between the three cleaning sectors.

Table 4.4: Significant test items, means and risk scores between the three cleaning sectors.

Test Item	Sectors: Government Schools		Hospitality		Commercial Office		Risk Indicator Score
	Mean	SD	Mean	SD	Mean	SD	
ManTRA Lower limb cumulative risk score	10.50	0.97	12.44	1.13	9.40	0.55	15
ManTRA Lower limb exertion risk score	1.10	0.32	1.78	0.67	1.00	0.00	5
ManTRA Lower limb exertion + awkwardness score	2.20	0.42	3.33	0.71	2.40	0.55	8
ManTRA Neck cumulative risk score	14.00**	1.05	14.89**	1.62	12.4	0.55	15
ManTRA Shoulder/arm cumulative risk score	16.50*	0.97	18.00*	1.00	15.40*	1.34	15
QEC Back score	28.00*	0.00	26.67*	2.65	23.20*	2.68	21
QEC Shoulder/arm score	26.00*	2.11	23.56*	2.60	20.00**	4.47	21
QEC Wrist/hand score	28.00*	0.00	26.67*	2.65	23.20*	2.68	21
QEC Neck score	14.00*	0.00	13.11*	1.76	10.80*	1.79	8

* Risk scores which were significantly different across sectors.

** Borderline' risk rated test items.

4.3.2 Ranking of Sector Risk

To examine the relative risk between sectors for the task of vacuum cleaning, and to confirm where the differences lay, a *post-hoc* analysis using Dunnet's C test was conducted. The significant test items and the significant differences between sectors are presented in Table 4.5. As no significant differences between the cleaning sectors were identified for the RULA items, only results for the ManTRA and QEC items are discussed.

Table 4.5: Significant test item differences between the three cleaning sectors.

Tool Assessment Item	Sector	Mean	SD	Significantly Different to which Sector?	Greater Risk	Risk indicator reached?
ManTRA Lower limb cumulative risk score	2	12.44	1.13	1 3	Yes	No
ManTRA Lower limb exertion risk score	2	1.78	0.67	3	Yes	No
ManTRA Lower limb exertion + awkwardness risk score	2	3.33	0.71	1	Yes	No
ManTRA back cumulative risk score	2	14.67	1.12	3	Yes	No
ManTRA Neck cumulative risk score	**1** **2**	**14.00** **14.89**	**1.05** **1.62**	**3** **3**	**Yes** **Yes**	**Yes** **Yes**
ManTRA Shoulder/arm cumulative risk score	**2**	**18.00**	**1.00**	**1** **3**	**Yes** **Yes**	**Yes** **Yes**
QEC Back score	**1**	**28.0**	**0.000**	**2**	**Yes**	**Yes**
QEC Wrist/hand score	**1**	**28.0**	**0.000**	**3**	**Yes**	**Yes**
QEC Neck score	**1**	**14.0**	**0.000**	**3**	**Yes**	**Yes**

Significant risk in bold.

Sector 1 = government schools; Sector 2 = hospitality; Sector 3 = commercial office space.

ManTRA: It is postulated that the differences in risk calculated between the cleaning sectors are due to the specific task demands within each sector and the specific environments in each type of work area. The ManTRA neck mean cumulative risk score is highest in the hospitality sector (14.89) and was significantly different from the commercial office space sector. As discussed in Section 2.4, the characteristics of the hospitality sector include cleaning underneath beds and bedroom furniture, which results in extreme range of movement of the neck, particularly in lateral flexion. Similarly, government school cleaners are required to vacuum underneath low desks and chairs, which would account for the mean score on this item in the government schools sector of 14.

All three cleaning sectors have a mean score above 15 for the ManTRA shoulder/arm cumulative risk item, indicating a risk. The highest mean score (18) was calculated for the hospitality sector and was significantly different from the mean scores calculated for both the government schools (16.5) and commercial office space (15.4) sectors. Again, it is postulated that these differences are due to the specific task demands of cleaning under beds and very low furniture characteristic of the hospitality sector.

These environmental characteristics would also account for the significant difference in the hospitality sector lower limb cumulative risk mean score compared to the scores calculated for the government school sector and the commercial office space sector. However, there was also a difference in the equipment used between these two sectors; the hospitality sector cleaners using predominantly canister vacuum cleaners and the commercial office space cleaners using mostly back pack vacuum cleaning machines. Differences in risk when using back pack and canister vacuum cleaners are further discussed in Section 4.4.

The hospitality lower limb exertion risk mean score was also significantly different from the score calculated for cleaners working in commercial office space, while the hospitality lower limb exertion + awkwardness mean score was significantly different from the score calculated for the government school sector. Furthermore, the hospitality back cumulative risk mean score was significantly different from the score calculated for the commercial office space sector. The government schools neck cumulative risk mean score was significantly different from the score calculated for cleaners working in the commercial office space sector. The ManTRA tool provides detail about risk exposure to different body parts and in doing so, is more sensitive to the specific task demands in each cleaning sector.

QEC: All three cleaning sectors have significant risk according to the QEC test items. That is, the QEC back mean risk scores indicate a moderate risk, with cleaners in the government schools scoring higher than cleaners in the other two cleaning sectors. This finding is probably due to the constant need for cleaners in government school to move chairs in classrooms to vacuum underneath.

The QEC shoulder/arm mean scores indicated a moderate risk for cleaners in the government schools and hospitality sector. As discussed in the ManTRA results above, this was likely due to the demands associated with those two work environments whereby the cleaners are forward flexed to vacuum underneath furniture while the shoulder/arm is in extension.

The QEC wrist/hand mean scores indicated a risk across all the cleaning sectors. This was due to the wrist/hand posture displayed by the cleaners when using a vacuum cleaner, particularly at end range and reaching underneath furniture, such as beds and desks.

The QEC neck mean scores indicated a risk in all the cleaning sectors, although this was highest in the government schools, followed by hospitality and commercial office. This pattern of risk scores across the sectors mirrors the results of the ManTRA neck test item. These differences in risk scores are highlighted in Table 4.5.

4.3.3 Summary

From Table 4.5, it can be seen that cleaners working in government schools have a significantly greater risk of upper limb musculoskeletal disorders than those working in either hospitality or commercial office space. However, hospitality cleaners have greater risk ratings for ManTRA neck cumulative risk score than either government schools or commercial office space cleaners; and a significantly higher risk rating for ManTRA shoulder/arm risk score than commercial office space cleaning workers. Ranking the sectors in order of risk exposure to cleaners, the greatest risk is in the government schools sector, followed by the hospitality and then the commercial office space sector. However, it appears that the hospitality sector has the highest risk of neck disorder based on the findings of the ManTRA risk assessment tool. A simplified summary of these findings is in Table 4.6.

Table 4.6: Ranking of the cleaning sectors, according to the significant test items as per Tables 4.4 and 4.5. Three ticks indicates the cleaning sector with the highest risk scores, two ticks indicates the next highest score and one tick indicates the least highest score.

Tool Assessment Item/Body Region	Cleaning Sector: Government Schools	Hospitality	Commercial Office
ManTRA Shoulder/arm cumulative risk score	✓✓	✓✓✓	✓
QEC Back score	✓✓✓	✓✓	✓
QEC Shoulder/arm score	✓✓✓	✓✓	*
QEC Wrist/hand score	✓✓✓	✓✓	✓
QEC Neck score	✓✓✓	✓✓	✓

* Risk scores did not reach the risk threshold value

Contributing factors to these risk scores have been discussed in Section 4.3.1, and these differences will be explored in the next section of this thesis, examining the third key question under investigation as to whether there is a difference between the two different types of vacuum cleaners.

4.4 Risk Rating of Vacuuming Tasks: Back Pack and Canister Vacuum Cleaners

There was a main effect of vacuum cleaner type on the ManTRA lower limb cumulative risk score ($F_{(1, 23)} = 7.615$, $p = 0.011$) and the ManTRA neck cumulative risk score ($F_{(1, 23)} = 8.015$, $p = 0.016$). However, there was no main effect of vacuum cleaner type on any other assessment items for ManTRA, QEC or RULA.

While the categories of lower limb cumulative risk score and neck cumulative risk score showed a significant main effect of vacuum cleaner type, the mean scores did not indicate a risk, as shown in Table 4.7. However, the neck score of 14.90 for the canister type of vacuum cleaner was very close to the risk cut-off value of 15.

Table 4.7: Significant test items, means and risk scores between vacuum cleaner types.

Test Item	Back Pack (n = 14)		Canister (n = 10)		Risk Indicator Score
	Mean	SD	Mean	SD	
ManTRA Lower limb cumulative risk score	10.36	1.40	11.90	1.29	15
ManTRA Neck cumulative risk score	13.36	1.51	14.90	1.52	15

As can be seen in Table 4.7, although the ManTRA lower limb cumulative risk score for the canister cleaner was substantially higher than for the back pack cleaner, neither score was high enough to be considered a risk. However, the neck cumulative risk score for the canister vacuum cleaner was just under the risk indicator score of 15. Using a risk management approach this task should be considered to rate as a risk, especially when reviewing the spread of data. Consequently, while Table 4.7 provides information on the mean scores, it is useful to see the distribution of scores for each of these two test items between the types of vacuum cleaner. Figures 4.1 and 4.2 graphically represent the range of scores for the ManTRA lower limb cumulative risk and the ManTRA neck cumulative risk, respectively, for the back pack and the canister type vacuum cleaners. The differences between the two types of vacuum cleaners are clearly demonstrated in Figure 4.2 for the ManTRA neck cumulative risk score, where it is clear that the canister cleaner scores are higher.

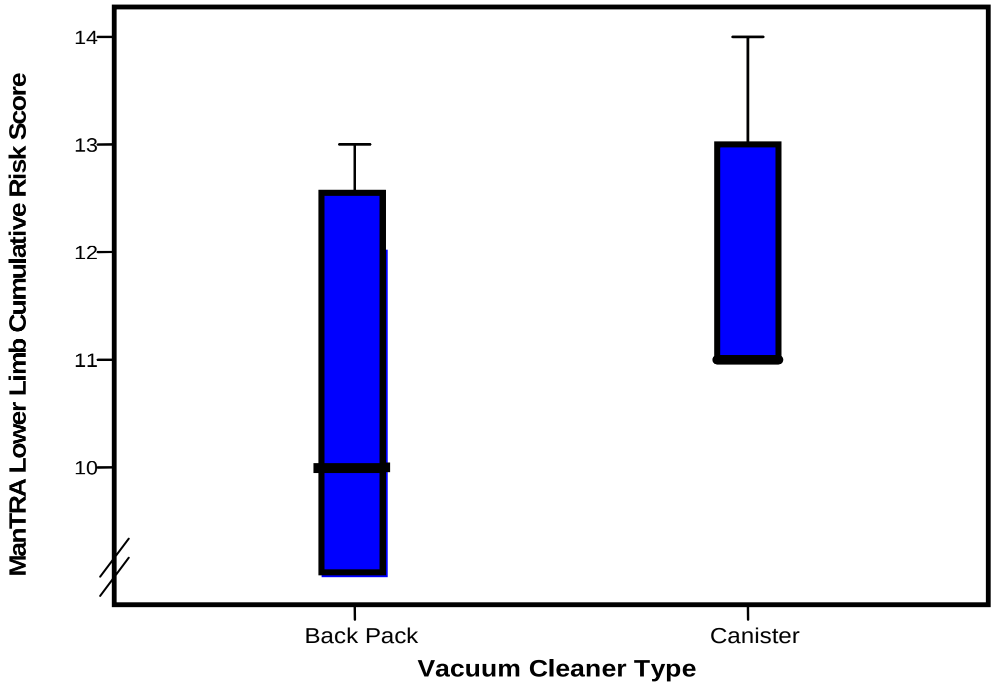

Figure 4.1: Box plot of scores for ManTRA lower limb cumulative risk between back pack and canister vacuum cleaners. Note that a score of 15 indicates risk is present.

The distribution of scores is represented by the box and whiskers. The box length contains 50% of cases; the line represents the median value, while the whiskers in this plot show the highest values. This representation is consistent for all following box plots.

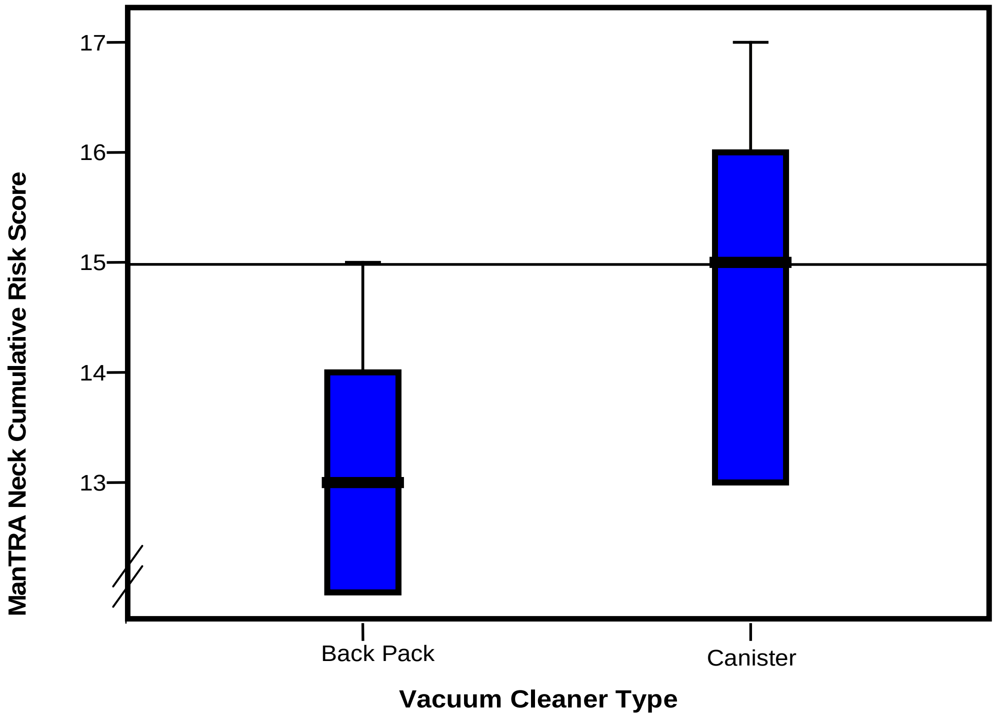

Figure 4.2: Box plot of scores for ManTRA neck cumulative risk between back pack and canister vacuum cleaners. The horizontal line at '15' indicates risk.

4.5 Exploring Vacuum Cleaner Type and Sector

To explore differences between the two types of vacuum cleaners with respect to each other and to each cleaning sector, it is imperative to review the outliers in the data sets for the ManTRA and QEC*. Although mean scores provide an aggregate measure of the risk to cleaning workers while vacuuming, these values may mask the risk to individuals. Examining the 'outliers' in a data set can provide useful information regarding specific activities or equipment type which may place some cleaners at more or less risk than the rest of the cohort. Therefore, outliers identified in the present data sets are discussed as short case studies.

* There is insufficient difference in the mean scores for RULA to explore outliers

4.5.1 Case Study 1: Subject 9

This cleaning worker was employed in the government schools sector and used a back pack vacuum cleaner. The subject scored higher than the mean on the ManTRA back cumulative risk score (see Figure 4.3) and on the ManTRA wrist/hand cumulative risk score (see Figure 4.4). To investigate this difference in scores, Subject 9's video tape and details were reviewed to provide greater detail regarding these higher scores. The factor which raised this subject's risk rating the most was the duration of the shift, 9 hours consecutively, compared to the shorter shift length of 3 hours, or split shifts typically worked by most of the other subjects within the government schools sector. The effect of shift length and duration of vacuum cleaning tasks (exposure) on the ManTRA risk rating will be discussed in greater detail in Section 4.6.

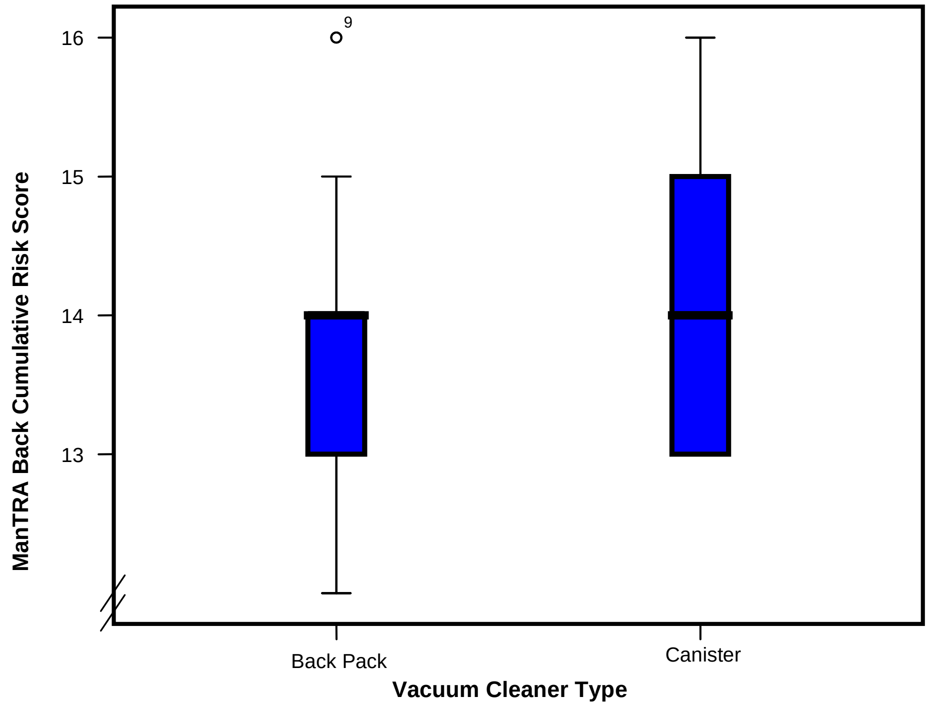

Figure 4.3: Box plot of all scores for ManTRA back cumulative risk across the three cleaning sectors. Subject 9's (Case Study 1) data is indicated to highlight the worker's higher risk score. A score of 15 indicates risk.

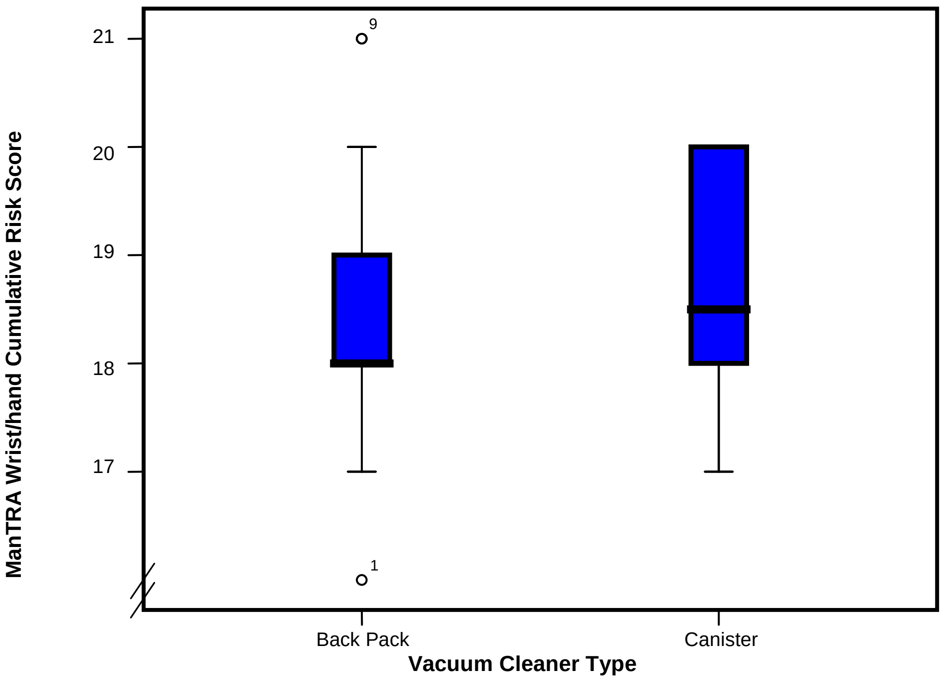

Figure 4.4: Box plot of all scores for ManTRA wrist/hand cumulative risk across the three cleaning sectors. Subject 9 (Case Study 1), and Subject 1 (Case Study 2) data are plotted individually to highlight the different risk scores for back pack and canister cleaners, respectively. (Both subjects were employed in the government schools sector). A score of 15 indicates risk.

4.5.2 Case Study 2: Subject 1

This subject, also a government schools cleaner using a back pack machine, worked only a 3 hour shift and consequently, the ManTRA wrist/hand cumulative risk score is lower than the mean, although still rating as a risk (see Figure 4.4) due to the postures adopted for the vacuuming task. This subject's lower risk experience is due to task duration. As discussed in Section 2.3.1, repetition is a major physical risk factor for the development of musculoskeletal disorders, and shift length will affect the exposure to this risk factor. That is, longer shifts lead to increased exposure to repetitive tasks and shorter shift lengths reduce exposure and allow more time for muscle recovery. Therefore, one recommendation for cleaning workers could be task rotation with a variety of postural demands, as well as reviewing the shift length and shift patterns of cleaning workers to optimise muscle recovery.

4.5.3 Case Study 3: Subject 3

This subject, who worked in the hospitality sector, consistently scored lower than the mean on the ManTRA wrist/hand exertion risk (see Figure 4.5), QEC back score (see Figure 4.6), QEC neck score (see Figure 4.7), QEC wrist/hand score (see Figure 4.8), QEC and shoulder/arm score (see Figure 4.9). Subject 3's video tape was reviewed to explore the different score this subject had on the ManTRA wrist/hand exertion risk score (see Figure 4.5) and the QEC risk scores (see Figures 4.6, 4.7, 4.8 and 4.9). This subject worked an 8 hour shift, in open public areas ('front of house'); and the assessment took place in an open foyer area with few obstacles, enabling the subject to work in a relatively upright posture.

Section 2.3.1 discusses the importance of posture as a risk factor for the development of musculoskeletal disorders (Bernard *et al.* 1997). The work environment outlined in this case study allowed the subject to assume more upright postures than those other hospitality cleaners who cleaned hotel rooms where their working posture was compromised by vacuuming underneath low beds and furniture. The effect of work task and work environment will be discussed in Section 4.6.

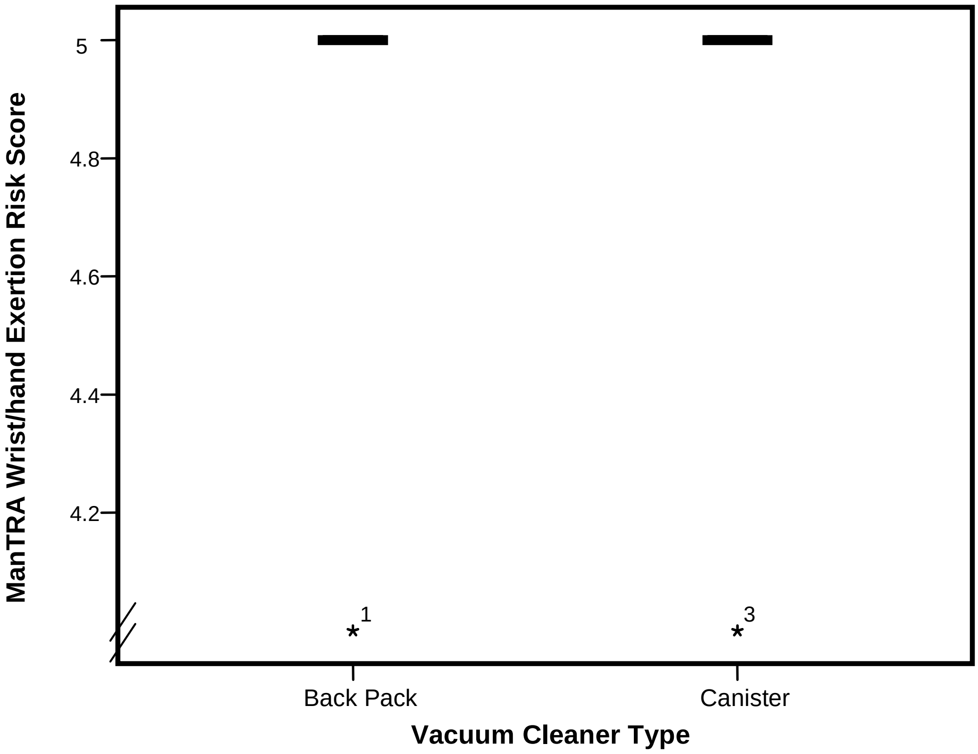

Figure 4.5: Box plot of ManTRA wrist/hand exertion risk scores. Note the lower scores (outliers) of Subject 1 (Case Study 2), a government schools cleaner; and Subject 3 (Case Study 3), a hospitality cleaner. A score of 5 indicates a risk.

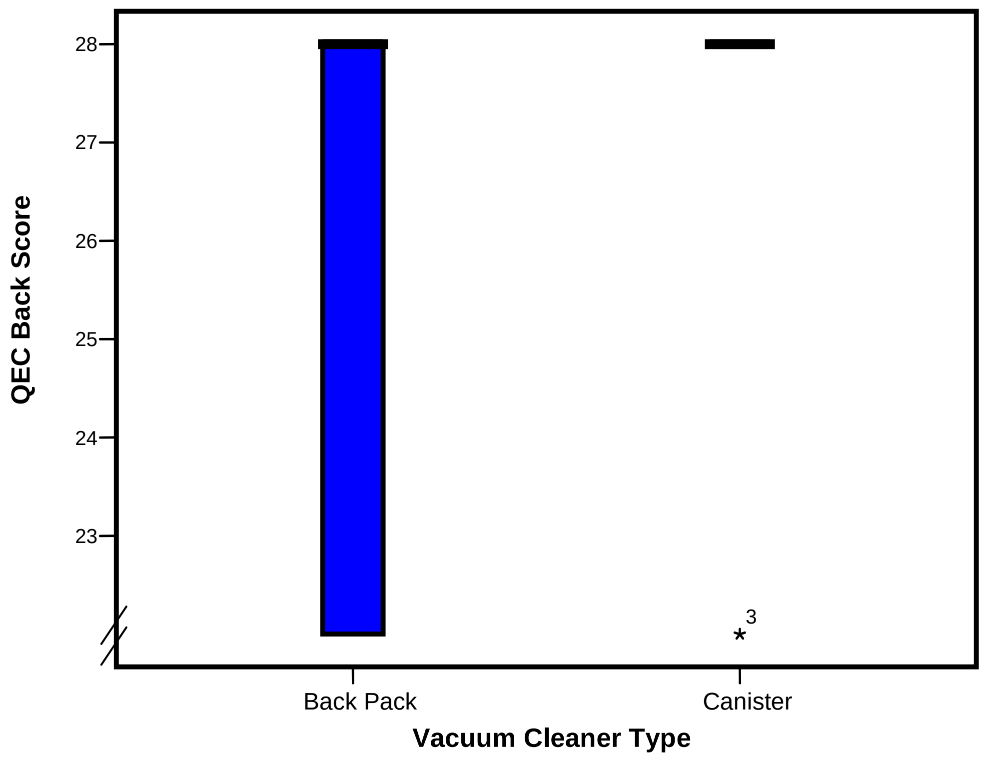

Figure 4.6: Box plot of QEC back scores. Note the lower score for Subject 3 (Case Study 3), a hospitality cleaner. A score of 21-30 is a moderate risk.

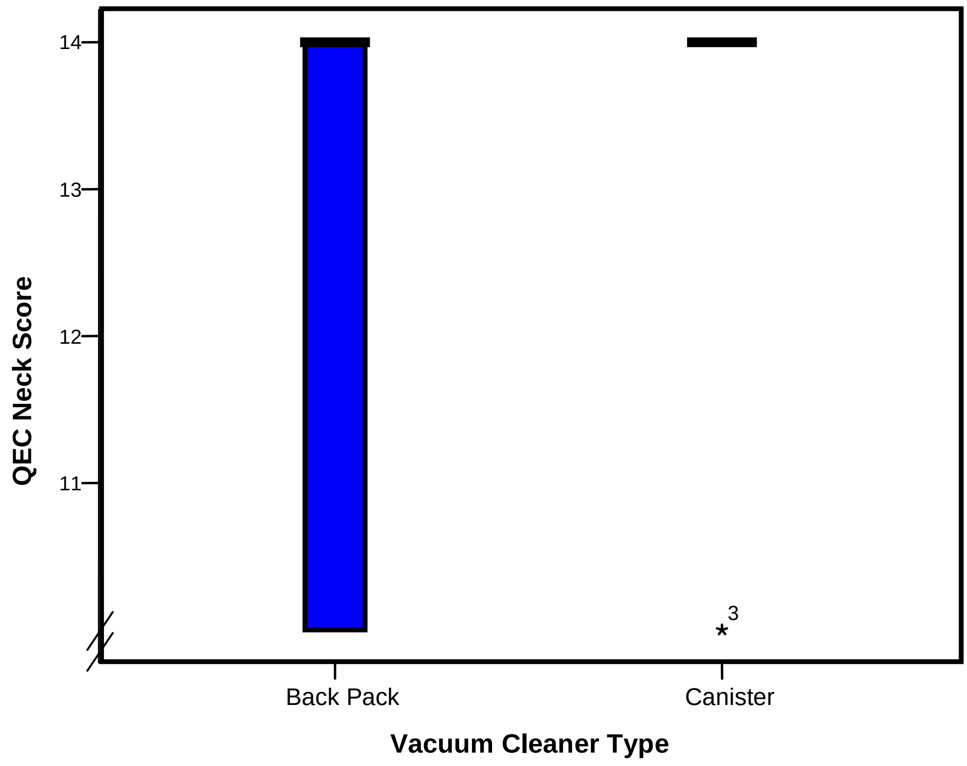

Figure 4.7: Box plot of QEC neck scores. Note Subject 3 (Case Study 3), a hospitality cleaner. A score of 8 -10 is moderate risk, 12 – 14 high risk.

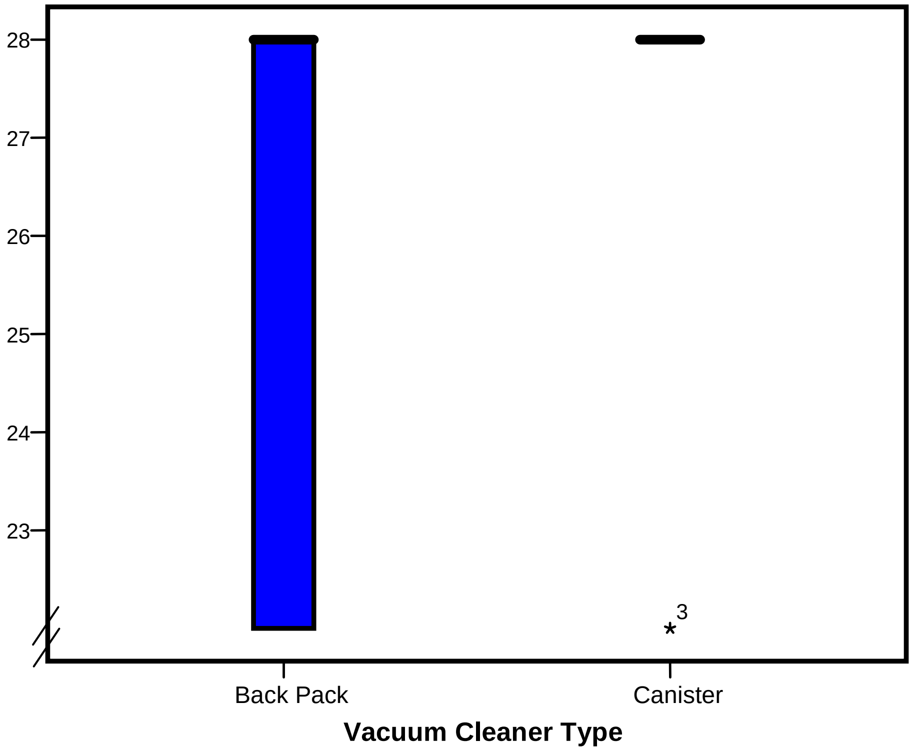

Figure 4.8: Box plot of QEC wrist/hand scores between vacuum cleaners. Note lower score of Subject 3 (Case Study 3). A score of 21 – 30 indicates a moderate risk.

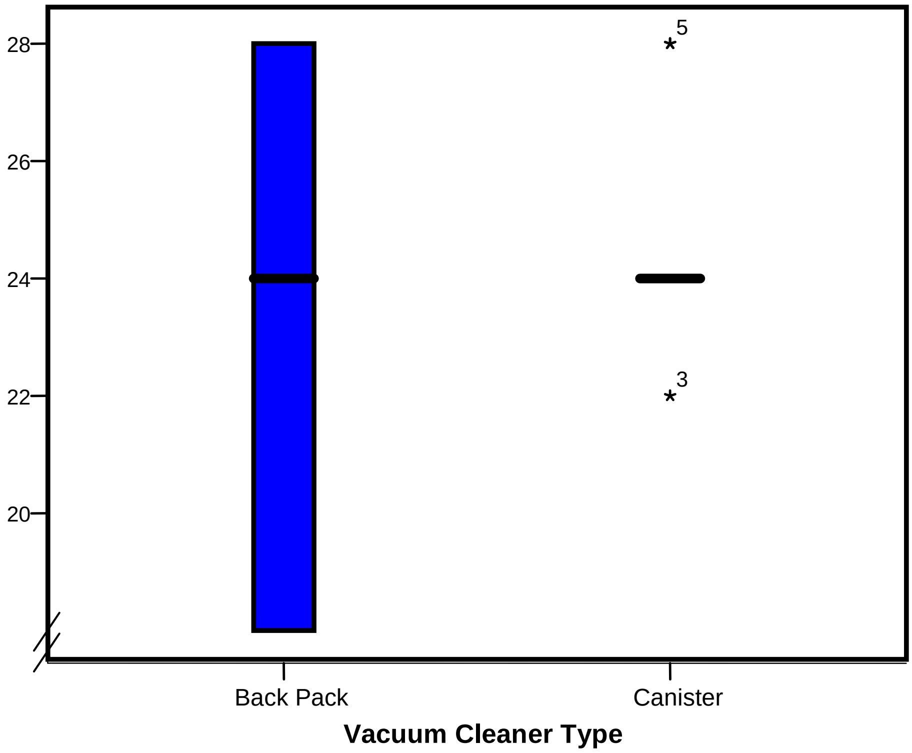

Figure 4.9: Box plot of QEC shoulder/arm scores between the vacuum cleaners. Note Subject 3 (Case Study 3) a hospitality cleaner, scoring below the mean, and Subject 5 (Case Study 4), a government schools cleaner, scoring above the mean. A score of 21 – 30 indicates a moderate risk.

4.5.4 Case Study 4: Subject 5

This subject worked a split shift (3 hours 20 minutes in the morning and 3 hours in the evening) in the government schools sector; the task viewed and assessed was vacuuming under school desks using a canister vacuum cleaner. The video tape and details for Subject 5 were reviewed to explore the different score on the QEC shoulder/arm risk score (see Figure 4.8). It was noted that Subject 5 tilted the chairs with the left hand while vacuuming with the right, causing an elevated and abducted left shoulder. Although this technique resulted in a faster work pace, it created awkward postures in the left shoulder and right wrist, in turn, contributing to higher risk scores. An alternate method to reduce this risk could be that a classroom with chairs and tables be vacuumed by firstly lifting chairs and placing them on the tables, and then vacuuming. It is postulated that a faster work style would be advantageous for the worker to achieve their allocated cleaning in time due to the precarious nature of cleaning work, and work organisation factors discussed in Section 2.3.3. That is, contracts for cleaning work are becoming more and more competitive with less time allocated to complete the task. This influence of work style/posture and the work organisation factors are discussed in Section 4.6 below.

4.6 Summary of Findings for all Tools and Types of Vacuum Cleaners

As discussed in Sections 4.4 and 4.5, there were significant differences between vacuum cleaner types for the items of the ManTRA lower limb cumulative risk score and the ManTRA neck cumulative risk score only. However, the mean scores for each vacuum cleaner type did not rank as a risk. To explore the individual differences further, outliers were identified and discussed. Five themes emerged by examining these case studies, and these themes can be linked to the physical and individual risk factors outlined in Sections 2.3.1 and 2.3.2.

Firstly, shift length impacts on the risk experience, with the longer the shift, the more time spent on vacuuming with greater exposure to the identified risk factors for upper limb musculoskeletal disorders. That is, the longer the shift, the more repetitive the musculoskeletal movements. As cleaning work overall involves repetitive upper limb work, reducing shift length is one strategy to decrease the exposure to the overall risk.

Secondly, the work environment impacts on task demands and can increase or decrease risk experience. Case Study 3 demonstrated that an open foyer area allows the worker to maintain an upright posture and minimises risk, no matter which type of vacuum cleaner the worker is using. In this study, the government school cleaners were rated as experiencing the greatest risk followed by cleaners in hospitality and finally cleaners working in commercial office space. This ranking reflects the complexity and characteristics of each work environment, which can influence risk from developing musculoskeletal disorders.

Schools present with the particular demands of low furniture for younger students; the impact of young children on a classroom with paint, glue, and craft activity debris; as well as the amount of demountable buildings at some sites (as evidenced by the work sites visited in this study) requiring cleaners to clean very dirty and/or muddy floors. Demountable buildings are used in government schools to manage the fluctuating numbers of school students each year, and are commonly placed in playground areas, which are often grassed and not concreted. The hospitality sector has similar difficulties with the need to vacuum under low furniture, such as beds and bedroom furniture. However, the environment in the hospitality sector is more contained and predictable in nature than the school environment. The commercial office space is a more open environment than either of the other two sectors. With adult users, access underneath desks is easier and less cluttered; furniture does not need to be lifted, and chairs, for example, can be rolled out of the way for vacuum cleaning underneath desks. Ideally, school furniture and the school environment could be more 'controlled' (i.e. more predictable) to resemble the commercial office space environment.

Thirdly, related to work environment and broader work organisational factors as discussed in Section 2.3.2, is the work style/technique the subject adopts. This work style is affected by the need to achieve the task in a short time frame. Case study 4 highlights this issue, whereby faster work techniques were utilised to the detriment of musculoskeletal risk. Cleaning work should be adequately scoped out for the cleaners so that sufficient time is allowed to complete their allocated tasks.

Fourthly, the actual environmental and overall work demands have led each work sector to select equipment suited to that job. The government school cleaners have large areas to vacuum and can usually move easily from one classroom to another. In this environment, the use of a back pack vacuum cleaner is practical, as the cleaning workers are able to put it on when they commence vacuuming the floor of a particular building and complete the task quickly. The hospitality sector can utilize back pack or canister vacuum cleaners for open foyer 'front of house' areas, but for vacuuming bedrooms, these workers reported that they have self-selected canister cleaners as it would be impractical to take the back pack vacuum cleaner on and off for each room, while completing the other tasks in that room; for example bed making and cleaning of bathrooms. It is important, therefore, that equipment is matched to task demands to enhance the productivity and comfort of the worker.

Finally, equipment design impacts on the postures adopted by the workers. The key design issue which impacted on the subjects in this study was the length of the vacuum cleaner wand, regardless of back pack or canister type (see Section 2.3.1 and Section 2.5.1). For each of the sectors within this study, all wand lengths were fixed with no adjustability possible. For shorter subjects this led to compromised upper limb postures, and for taller subjects compromised back postures, and therefore greater exposure to postural risk factors. This important design issue was discussed in Section 2.5.2 where Woods & Buckle (2005) recommended the adjustability of the length of the attachments for vacuum cleaners. Furthermore, English (1995) highlighted that cleaning workers were over-represented in wrist/forearm disorders, whereby the height of the worker was associated with an increased risk of injury. These key issues will be addressed in the next chapter with suggestions for further studies.

4.7 Summary of Results and Discussion

The results of this study indicate that vacuuming is a risk to the musculoskeletal health of cleaners. The three observational ergonomic risk assessment tools, the ManTRA, the QEC and RULA, all registered the task as a risk, with some variation between the tools reflecting the specificity and/or sensitivity of each tool.

Differences were found between the three cleaning sectors in terms of overall risk from vacuum cleaning tasks. The sector with greatest risk was found to be the government school cleaners followed by the hospitality and then commercial office space cleaning sectors. The implications for these findings are potentially serious when considering the impact of age on the experience of upper limb musculoskeletal disorders, as the government school cleaners are the oldest of the cohort (mean age 52.1 years), compared to the hospitality cleaners (mean age of 50.0 years) and the commercial office cleaners (mean age of 33.8 years).

A significant difference between the vacuum cleaner types was also found on two ManTRA test items, the lower limb cumulative risk score and the neck cumulative risk score; both items scoring canister vacuum cleaners as higher risk. The scores for the lower limb, however, did not indicate a risk, while the score of 14.90 for the canister vacuum cleaner was considered a risk for the purpose of this study, using a risk management approach. This higher risk rating for canister vacuum cleaners on the neck score is thought to be due to the use of these vacuum cleaner types in the hospitality sector to clean underneath beds and low furniture, and consequently the difference is due to the environment and not the equipment used. However, further studies are required to substantiate this notion.

Chapter 5
Summary and Conclusions

5.1 Summary

This thesis has reviewed evidence for the risk factors associated with work-related musculoskeletal disorders, in particular, upper limb musculoskeletal disorders. A field based research study was then conducted to examine the risk of the task of vacuum cleaning for these upper limb musculoskeletal disorders in three cleaning sectors (government schools, hospitality and commercial office space). Video images of 24 cleaners performing vacuuming tasks was analysed using the three observational ergonomic risk assessment tools, ManTRA, QEC and RULA.

The findings from this study supported the first research hypothesis that vacuuming is associated with risk to the upper limb musculoskeletal health for cleaning workers. The second hypothesis, that there would not be a difference between cleaning sectors was not supported. In fact, risk experience was found to be dependent upon cleaning sector (government schools, hospitality or commercial office space). Furthermore, the hypothesis that there would be no difference between vacuum cleaner types (back pack and canister) on risk ratings, was not conclusively supported. That is, although the ManTRA tool revealed significant between-vacuum cleaner differences for the two test items of lower limb cumulative risk score and neck cumulative risk score, the lower limb cumulative risk score did not rate as a risk for either type of vacuum cleaner, while the canister vacuum cleaner rated as a risk for the neck cumulative risk score. It is postulated that this difference was not related to vacuum cleaner type but rather the work environment, whereby canister vacuum cleaners are used exclusively to clean bedrooms in the hospitality sector and the cleaning workers are required to vacuum underneath beds and low bedroom furniture, which compromises their posture, particularly the neck. To confirm this conclusion, further studies need to be conducted in a laboratory setting to compare the effect of using the two types of vacuum cleaners on vacuuming technique.

The above results highlight the shortcomings of using one method (in this case, postural observation) to identify ergonomic issues in the work environment. That is, although observational ergonomic assessment tools are appropriate for investigating ergonomics hazards, they are not in themselves definitive measures of all ergonomics risk. Rather, they form a component of the overall ergonomics approach and provide a basis upon which to identify key risk factors of a task. This thesis has used observational tools and identified specific risks in specific work sectors for the task of vacuuming. A detailed analysis of the task demands and work environments are required to explain, substantiate and provide direction for corrective actions, as outlined in Sections 4.5 and 4.6 of this thesis. Thus, the underpinning knowledge and skills of an ergonomist are required to examine all the interactions between the worker, the machine and the environment in which the task and job take place. Thus, vacuum cleaning as a task needs to be considered as part of an overall work system, which includes the worker, the equipment and the environment in which the worker performs their tasks. A summary of the thesis findings will now be provided, followed by directions for future research.

5.1.1 Physical Risk Factors

As outlined in Section 2.3.1, the risk factors for work-related musculoskeletal disorder are repetition, posture, duration and vibration (Bernard *et al.* 1997). The observational ergonomic risk assessment tools selected for this study were able to address each of these factors, as discussed in Section 3.4. The risk factor of vibration was only addressed using the ManTRA and QEC tools, and not measured specifically. The findings from the tools in this study highlight the risk factors of repetition, posture and duration for cleaning workers. The significant differences in risk experience for the task of vacuum cleaning between the sectors is accounted for by the specific task demands of each work sector and the characteristics of the work environment as discussed in Sections 4.5 and 4.6 of this thesis.

5.1.2 Individual Risk Factors

The individual risk factors for work-related musculoskeletal disorder of age, gender and precarious employment are discussed in Section 2.3.3. The subject characteristics of this study match the individual risk factors; that is, 93% of the subjects were female and the mean age was 47 years, with the oldest worker (63 years) in the government schools sector, and the youngest (22 years) in the commercial office sector. Thus, the older workers are in the government schools sector, which has the highest risk rating of any sector. It has been shown that this group of subjects had also worked as cleaners for the longest period (Weigall *et al.*, 2005). Consequently, this group of workers can be viewed as particularly vulnerable to the risk of upper limb musculoskeletal disorder. The issue of precarious employment was outside the scope of this thesis study.

5.1.3 Work Environment

For the purpose of this thesis, the vacuuming tasks under investigation were those conducted on level carpeted areas, as described in Section 3.2. However, review of the results of the observational ergonomic risk assessment tools outlined in Sections

4.5 and 4.6 demonstrates the characteristics and complexities of the work environment and their effect on resultant risk scores. An overview of the work environment, the equipment and the worker are essential to understand the origin of the risk and point to control measures to be taken.

5.1.4 Equipment

Equipment was addressed in this study by dividing the vacuum cleaners into the two key types, back pack and canister. There are many other aspects of equipment, including design and maintenance, which impact on the way the worker uses the equipment and the resultant postures they need to adopt. The non-adjustable wand lengths of both types of vacuum cleaners have been described in Section 4.5 and 4.6 as an issue with regard to posture of the shoulder and neck, most noticeably for shorter workers. Dimensions of the equipment handles, details of floor tools, widths of vacuum cleaner heads and ease of operation are outside the scope of this thesis, but clearly are an issue to be addressed.

The Robens Report on the musculoskeletal health of cleaning workers in the United Kingdom (Woods *et al.*, 1999), undertook a broad study including questionnaires, workplace assessments, laboratory studies and focus groups. The laboratory studies reviewed specific aspects of equipment design and use of upright and canister (termed 'tub' in this study) vacuum cleaners. Their study provided a number of recommendations for vacuum cleaner design (upright and canister), which include reducing the weight of machines, ensuring that handle or wand length is appropriate for attachments to minimise poor postures, as well as advice regarding control switches and cord/flex management. These recommendations for adjustable wand length are supported by the findings of this thesis.

English *et al.* (1995) conducted an epidemiological study of work-related musculoskeletal disorders in orthopaedic clinics in the United Kingdom (see Section 2.3.1). This study found cleaning workers were over-represented in wrist/forearm disorders and that the height of the worker was associated with injury, whereby the shorter the worker, the greater risk of injury. This finding was supported by the results of the present study, highlighting the ergonomics design issues with work equipment in terms of non-adjustability of wand length on the vacuum cleaners, as well as the need to address the appropriateness of wand diameter for the user population.

5.2 Conclusions

In conclusion, this thesis has found that vacuum cleaning is a risk to cleaning workers for upper limb musculoskeletal injury, regardless of whether they are using a back pack or canister machine. While the findings for the relative risk for work-related upper limb musculoskeletal disorders between vacuum cleaner types indicated that canister vacuum cleaners are 'riskier' than back pack vacuum cleaners, it is thought this difference was due to the task demands and work environment characteristics rather than the equipment itself.

This thesis has found, however, that government school cleaners experience greater risk of work-related upper limb musculoskeletal disorder than workers in either the hospitality or commercial office space sectors. This finding is particularly relevant and important, as these workers also present with the most individual risk factors for musculoskeletal disorder; that is, they are mainly female and are ageing.

5.3 Recommendations for Future Research

To further explore the issues surrounding the task of vacuuming, laboratory studies, such as those conducted in the Robens Report (Woods *et al.*, 1999), would be a useful adjunct to the field-based study reported in this thesis. Such laboratory studies could systematically examine vacuum cleaning equipment in detail, in particular the impact of adjustable and non-adjustable wand length on the technique of cleaners. Additional design features could also be investigated such as floor attachments (for example, ease of use, width, suction power, and durability), types of harnesses and fit of the harnesses for the back pack vacuum cleaners, ease of operation, power cord management, maintenance issues and user feedback. Additionally, direct measurements of back pack and canister vacuum cleaner users could be undertaken to provide measurements of the kinematics representing technique, and how technique is associated with joint loading. This form of study would provide valuable data on back pack vacuum cleaner design, as no studies have been identified which have addressed these issues. Such studies could provide evidence to inform design changes to reduce the risk of work-related musculoskeletal disorder from the task of vacuuming as demonstrated in this thesis study.

Observational ergonomic risk assessment tools are useful measures of musculoskeletal risk. However, a full understanding of the work process and interactions between the worker, equipment and environment while performing the task is essential to fully identify the ergonomic risk factors for potential work-related musculoskeletal disorders. Underlying ergonomic principles of designing equipment for adjustability are essential to optimise worker comfort and productivity, and reduce the risk of injury.

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Appendix 1

Manual Tasks Risk Assessment Tool

Please see print copy for Appendix one

Appendix 2

Quick Exposure Check Tool

Please see print copy for Appendix two

Appendix 3

Rapid Upper Limb Assessment Tool

Please see print copy for Appendix three