AN ERGONOMIC PERSPECTIVE ON THE WORKLOAD OF HOME CARE AIDES

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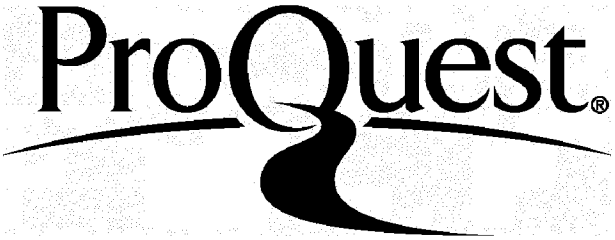

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ABSTRACT

Home care aides are exposed to heavy client handling, other physically demanding activities, and hazardous home conditions. These factors might contribute to the musculoskeletal strains or injuries that they are experiencing. However, there had been little previous research on the associations between the characteristics of low back pain and these work factors. It is also unclear whether using low-tech transfer devices could reduce home care aides' workload during client transferring.

In this thesis, a cross-sectional survey was designed to collect information about the occupational characteristics, work organization, and physical workload of home care aides. The survey was distributed to both agency-hired aides and client-hired aides. Physical activities, clients' health conditions, and home conditions were examined as a function of the type of employment and client mobility. The survey was also used to investigate the association between work factors and low back pain. A laboratory experiment was used to evaluate the biomechanical exposure during client transfers between bed and wheelchair using four different low-tech transfer devices and manual transfers, and compared the boards' usability with each other.

The survey results showed that client-hired aides are more likely to care for clients with limited mobility. Higher frequencies of client handling activities and other direct care activities were associated with clients with limited mobility. Low back pain was commonly present among home care aides and was characterized as a frequent occurrence, moderately severe and related to their home care work. Client handling activity, hazardous home environments, obese clients or client with limited mobility were separately indicative of higher physical demands and increased risk for low back pain. A

hypothetical multivariate low back pain model was proposed to examine whether client handling activities, other direct care activities, housework and cleaning activities, length of work in home care, using transfer devices, hazardous home conditions, clients with obesity or with limited mobility were associated with low back pain. The final model suggested that the combined effects of client handling activities, hazardous home conditions as well as length of work in home care were positively associated with the elevated risk of low back pain.

The laboratory study suggested that the exerted hand forces and the average trunk flexion velocities using a transfer device were significantly lower than in a manual transfer. Transfer devices with a sliding mechanism provided easier transfers than boards without a sliding mechanism. It is strongly recommended to form a high to low transfer in order to take advantage of gravity when performing client transferring.

Home care agencies are suggested to establish an ergonomic assessment program in order to assess clients' conditions and physical limitations, and to provide and make transfer devices accessible to the aides in order to avoid unnecessary manual client handling.

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I. Introduction

1. Objectives and specific aims

Home care aides often perform manual client transfers, which involve unassisted heavy lifting and are extremely risky for a single aide. These transfers and other physically demanding tasks are risk factors for musculoskeletal disorders among home care aides. However, very few studies have investigated whether there are any associations between home care aides' work environment or work factors and low back pain.

The overall objectives of this thesis are to characterize the work organization of home care aides, to investigate the association between low back pain and occupational exposures, and to evaluate the usability of client transfer devices among home care aides.

1.1. Aim One

The aims of the first section are to characterize the work organization of home care aides and compare physical workload. The sub-aims are:

1) Identify the demographic characteristics of the home care aides;
2) Identify the home care aides' work organization including their tenure in home care, hours worked per week, the number of visits in the past week, and use of client handling devices in the past year; and
3) Identify the differences in physical activity, hazardous home conditions, and clients' health conditions during client visits as a function of the type of

4) employment, and as a function of employment (agency-hired aides vs. client-hired aides) and client mobility (limited vs. non-limited)

1.2. Aim Two

The aims of the second section are to describe low back pain and its characteristics among home care aides, and the associations between low back pain and work factors. The sub-aims are:

1) Describe low back pain prevalence, low back pain characteristics and consequences (i.e. taking pain medication, work interference) of low back pain among agency-hired aides and client-hired aides;
2) Describe the association between low back pain and tenure in home care, hours worked per week, past work-related injury, physical activity, hazardous home conditions, using client handling devices and the clients' health conditions during visits; and
3) Investigate whether there are any multiplicative effects (i.e., effect modification) among various occupational exposures on low back pain.

1.3. Aim Three

The aims of the last section are to investigate whether using low-tech transfer board could help to reduce aides' physical workload during a simulated client transfer between a wheelchair and bed, and to evaluate the usability of different transfer boards. The sub-aims are:

1) Investigate whether using a transfer board could reduce the force on each hand, shoulder and low back EMG, as well as trunk kinetics during client transfer compared with using other transfer techniques; and
2) Investigate whether transfer boards offer advantages in the usability – such as ease of use, physical effort, aide safety, and comfort etc. – compared with each other.

2. Background and significance

2.1. Home care aides

2.1.1. Aging population drives the needs of home care aides

In the United State, the population of those 65 and older reached 40.3 million in 2010 (BLS, 2014). More than one-third of this aging population had at least one type of disability such as difficulties with walking, climbing stairs or doing errands alone (BLS, 2014). Factors such as the aging population nation-wide and globally, the rising cost of formal medical facilities, living longer with more chronic diseases, and wanting to be at home during sickness, all drive the health care practice from professional facilities to the home (Davis et al., 2015; NRC, 2011). There are over 2 million personal care aides and home health aides in the U.S and this number is project to increase by more than a quarter from 2014 to 2024 (BLS, 2015a).

2.1.2. Lack of recognition in society

Although home care aides help those clients who are disabled or had limitation in mobility, their work contribution were often unrecognized by the greater society (Markkanen et al., 2014). Majority of the aides felt their work was very important (97%), although the aides perceived that their supervisors (77%), home care agencies (66%) and the society (56%) does not valued their work as much as themselves (Bercovitz et al., 2011). A common perception assumed that home care aides' work deemed as 'Companionship services' and is less demanding than other forms of employment, and there are few occupational safety and health (OSH) hazards (Quinn et al., 2015).

2.1.3. Home care aide employment approaches in Massachusetts

In Massachusetts, most home care aides are employed in one of two ways: 1) They work for a home care agency that hires aides and assigns the aides to clients, referred to as an agency-hired aide (AHA) in this study; or 2) the client or client's surrogate hires and supervises the aide directly, which is referred as a client-hired aide (CHA) in this study (Quinn et al., 2015). The pay for both agency-hired and client-hired aides primarily comes through the government agency Medicare (56%), as well as private insurance (12%), out-of-pocket payment (6%) and other sources (CDC, 2007). In the state of Massachusetts, all aides hired directly by clients using public funds were represented by a labor union, whereas most agency-hired aides were not in a union (Quinn et al., 2015).

2.1.4. Job content

Home health aides and personal care aides are typically employed to help people with basic self-care tasks, referred to as activities of daily living (ADL), and/or everyday tasks that support an independent lifestyle and are called instrumental activities of daily living (IADL). Activities of daily living (ADL) include bathing or showering, dressing, eating, getting in or out of bed or chairs, using the toilet, and getting around in the home (CDC, 2009). IADLs include everyday household chores, doing necessary business, shopping, or getting around for other purposes (CDC, 2009).

2.2. Home care aides' occupational exposures

2.2.1. Ergonomic exposure due to client handling activities

Home care aides' daily tasks expose them to high levels of physical workload imposed by client handling and other patient care tasks (Galinsky et al., 2001). Unlike lifting heavy static objects, client (in this thesis, the terms 'patients' and 'clients' are used to refer to the person receiving care) handling tasks may involve carrying a client whose weight is shifting or unevenly distributed, and whose body usually does not allow an optimum coupling condition. Many clients at home are elderly and frail, and can bear little or none of their own weight. Sometimes the clients can be uncooperative or even combative, driving the aides off balance by making sudden movements (Galinsky et al., 2001). Galinsky pointed out that the level of physical strain experienced by health care worker on the job is largely determined by the client's condition and physical limitations (Galinsky et al., 2001). Physical demands during client transferring may be aggravated when the client is obese or uncooperative (Beer et al., 2014), and thus lead to more musculoskeletal strains.

Waters suggested a weight limit of 35 pounds for a limited range of client handling tasks in which the client is cooperative and unlikely to move suddenly during the task. When the weight to be lifted exceeds this limit, assistive devices should be used (Waters, 2007). However, normally, the unassisted manual lifting or transferring weights are rarely less than 35 pounds. The compression force applied on aides' spine during moving a client weighing over 90 pounds exceeds safety limits specified by the National Institute for Occupational Safety and Health (NIOSH) (Galinsky et al., 2001).

From the description above, the client handling tasks may entail heavy lifting or sudden movement such as catching fallen clients. Many of these tasks involve forceful exertions and awkward postures that may lead to shoulder or low back musculoskeletal disorders (MSDs). Marras suggested that single person manual client transferring and repositioning tasks were extremely hazardous and were associated with substantial risk for the development of low-back injury regardless of what actual transfer tasks were being performed, even with two aides worked together (Marras et al., 1999).

2.2.2. Ergonomic exposure due to other physical activity

Not only are client handling tasks physically demanding, but aides may perform other tasks such as moving heavy equipment, and feeding, bathing or dressing clients, that also involve forceful exertions, twisting, bending, stretching, reaching or constrained postures (Galinsky et al., 2001). Wipfli and Baron (Baron et al., 2004; Wipfli et al., 2012) suggested a list of physically demanding tasks causing pain or concern for injury among the home care aides. These tasks included: unassisted client lifting and transferring, bathing, dressing, push/pull/lifting wheelchair, supporting client while walking or catching while falling, cleaning bathroom, cleaning floors, cleaning kitchen, and moving household objects. In a focus group study, Baron (Baron & Habes, 2004) found that home health care workers rated housekeeping tasks as being as physically demanding as client lifts and transfers.

2.2.3. Home environment as risk factors

A home is not usually designed to accommodate for the delivery of health care nor is the physical environment easily adaptable for mechanical lifting devices. A client's home may be crowded, dimly lit, or cluttered and the furniture arrangement might lead to

awkward postures and thus make aides' tasks difficult (Galinsky et al., 2001; Markkanen et al., 2014; McBride et al., 2011). In addition, the home environment generally is not under the control of either the agency or the aides (CDC, 2010). Aides sometimes were asked to perform tasks that beyond their job responsibility (Baron & Habes, 2004).

In contrast to institutional settings where colleague support and client handling devices are readily available, aides usually work in isolation and can not get help from other colleagues (Kim et al., 2010; McBride et al., 2011). Client transfer devices widely used in hospitals or nursing homes may be ill-suited for the home environment due to home attributes or users' insufficient expertise (NRC, 2011). However, these factors remain understudied in regards to their impact on the physical workload and the risk on MSDs.

2.3. Home care aides' musculoskeletal disorders and injury

2.3.1. Musculoskeletal disorders' prevalence in home care aides

According to a CDC report, sprains and strains were the most common reason for lost work time injuries among homecare aides in 2007 (CDC, 2010). In 2014, the incidence rate for home health aides and personal care aides with MSD cases was 55.4 and 60.6 per 10,000 full time employees respectively, which was higher than the national average incidence rate of 33.8 per 10,000 full time employees (BLS, 2015b).

The scientific literature confirms that low back pain and MSDs are significant problems among home care aides. The low back pain prevalence among home care aides ranges widely from 31% to 70% (Faucett et al., 2013; Horneij et al., 2004; Johansson, 1995; Knibbe et al., 1996). The associations between MSDs and physical workload are

more frequently studied among hospital nurses or nursing home aides than in the home care workforce (Davis & Kotowski, 2015). Few studies have investigated the risks of low back pain from general physical demands or bending or squatting events (Faucett et al., 2013; Kim et al., 2010), however, the association between low back pain and specific physically demanding tasks or activities were ambiguous. Understanding the risk of certain physical demanding tasks might be helpful to inform the plan for future ergonomic intervention.

2.3.2. Assessment method of musculoskeletal disorders

Many studies have utilized subjective surveys to assess musculoskeletal pain (back, shoulder, neck, upper/lower extremity) among nurses in hospitals and nursing homes (Kurowski et al., 2014), but very few studies have assessed the prevalence and characteristics of low back or other musculoskeletal pains in home care aides (Davis & Kotowski, 2015). Most home care aides studies have utilized 12-month recall questions from the Nordic Musculoskeletal Questionnaire (NMQ) (Kuorinka et al., 1987) to assess low back pain (Eriksen et al., 2006; Horneij et al., 2004; Johansson, 1995; Knibbe & Friele, 1996; Moens et al., 1993). Kim suggested defining a musculoskeletal case to indicate a more severe low back strain (Kim et al., 2010) (defined as having pain, numbness, tingling, aching, stiffness or burning in the past year that lasted 1 week or more, or occurred at least monthly; with at least moderate pain on average, based on a 5-point pain scale).

2.4. Measurement of occupational ergonomic exposures

2.4.1. Pros and cons of self-reported, observational and direct measurement

In general, physical workload can be measured by self-report from the workers, directly from the instruments or visual observation. When selecting human performance measurement method, the researcher should follow the guidelines that include: directly relevant to the outcome, directly observable in task performance, not requiring additional interpretation, precisely definable, objective, quantitative, easily collected, at appropriate levels, reliable and meaningful to the researchers and decision makers (Muckler, 1992).

In order to identify the optimum work analysis method, a comparison between self-reported, observational and direct measurement methods was made in Table 1, where the advantages and disadvantages of few measurement methods were described. Direct measurement such as surface electromyography (EMG) and lumber motion monitor (LMM) are appropriate for tasks that can be simulated or performed under a highly-controlled laboratory environment or in actual workplaces, whereas observational measurement methods such as OWAS or Posture, Activity, Tools and Handling (PATH) are appropriate for medium or moderately repetitive tasks in the field (Buchholz et al., 1996; Karhu et al., 1981), and are often preferred for very large studies because they can be less expensive per subject analyzed. In contrast, self-reported measurement, such as questionnaire, is even less expensive, and furthermore can be applicable to highly variable tasks or those are difficult to observe in the field or to simulate in a laboratory. Nevertheless, questionnaire data may introduce misclassification due to subjectivity in recall or misunderstanding due to lower literacy or knowledge levels. Furthermore, difference in instrumentation may reduce data comparability among investigations.

Unlike a mass production plant or automated manufacturing environment where the tasks features a standardized working procedure, many occupations, such as

construction workers or health care providers, composed a variety of physical tasks that are not standardized in sequence, length, or frequency. Although observational methods such as OWAS, PATH have been used previously to measure ergonomic exposures in various non-repetitive works, using these methods for highly dynamic jobs would be labor-intensive and require numerous and/or long observational periods (Karhu et al., 1981; Marras et al., 1999). EMG or LMM measurements usually require long set-up and calibration times and may not be feasible for this situation. The cost and time required to conduct an on-site observational study with individual measurement may hinder workers' routine activities. Therefore, conventional observation instruments and protocols may not fit job analyses for tasks that are highly unpredictable.

Comparing with technological and labor intensive observational exposure measurement and direct measurement methods, using less expensive self-administered survey would cost less time, labor and is more feasible for jobs pertaining geographically dispersed, highly dynamic, and hard-to-reach population.

2.4.2. Assessment of occupational exposure in home care aides

In the literature, the measurements of home care aides' occupational exposures have been either qualitative or quantitative. Baron et al conducted interviews and asked the home care aides to describe qualitatively the tasks that caused pain or discomfort (Baron & Habes, 2004). Johansson used self-reported body postures such as trunk twisting or flexion angles to indicate quantitative physical exposures (Johansson, 1995). Faucett's study (Faucett et al., 2013) asked the aides to report physical work environment or biomechanical aspects of their work (such as using hoists, or slides to maneuver their work), and the number of time they transfer a recipient or perform bending or squatting

on their last work day. However, this method required the subject to mentally estimate and convert concrete physical tasks into biomechanics terms. In a study that aimed to estimate the risk of physical demand tasks on low back pain, Kim et al measured the home care aides' physical demands by telephoning the aides and collecting information about the frequency of their most physically demanding tasks identified in Baron's study, using a single question *'How often is your work very physically demanding?', using a four-point scale (never to always).* Aides were also asked about the frequency of 12 physically demanding direct care and domestic chores tasks, using a 5-point range of frequencies (more than once per day to less than once per week) (Kim et al., 2010).

2.4.3. Client handling device usage

2.4.3.1. Client handling assistive device and efficacy

A broad list of transfer assist devices for client handling and safe use is available in literature, these devices include: draw and slider sheets, transfer belts, slide/transfer boards, turning discs, patient transfer sling, walking/gait belts, triangle/trapeze bar, and rotation disks. Other devices for non-weight bearing home care clients include: hospital beds, floor hoists, sit-to-stand hoists, wall mounted hoists, track mounted hoists (Parsons et al., 2006a, 2006b; WorkSafeBC, 2006).

Few investigations have assessed the usage of different assistive client transfer devices, and demonstrated the benefits of using assistive transfer device to reduce physical exposure during client transferring or repositioning tasks in laboratory settings (Heacock et al., 2004; Hess et al., 2007; Zhuang et al., 1999b). However, very few studies have assessed the efficacy of assistive device in home care.

2.4.3.2. Effectiveness of client handling assistive device

Many literatures examined the effectiveness of using assistive device or mechanical lifts to reduce ergonomic exposures in hospitals or other institutions (Hignett, 2003; Kurowski et al., 2014; Nelson et al., 2006). Marras suggested that the only means to reduce low back pain in health care workers would be to incorporate mechanical lifting devices and eliminate manual patient/client lifting. Several interventions to minimize the impact of the biomechanical loading was necessary during client handling were investigated. These include interventions that: 1) reduced bending (such as adjustable beds); 2) eliminated lifting (patient hoists); 3) reduced carrying (such as sliding devices); and 4) multi-faceted interventions (combined physical alternations along with organizational and psychosocial changes). Among these interventions, the one that eliminated the need to exert force (carrying and lifting) reduced the risk by a greater extent than those interventions that only addressed postural changes (Marras, 2008).

One of the challenges is to allow those assistive devices commonly used in hospital to be adaptive at home. For example, the wall mounted hoists would become a permanent feature in a home and therefore might require structural changes or reinforcements. Considering cluttered room conditions and the cost as well as the size of the large lifting devices, low cost and low-technological client transfer devices need to be considered seriously as possible ergonomic intervention solutions for home care aides. However, the efficacy and the usability of low-tech transfer devices for home care aides have not been well studied.

Client transfer boards (sometimes called slide boards) are assistive devices that allow a client with mobility challenges to be transferred between a bed and chair, or other similar resting places. A lab-based study that compared three different boards has shown

the benefit of using transfer boards in reducing physical workloads while performing client transfers among home care aides (Hess et al., 2007). Recently, new technology has been embedded into transfer boards, some of which use sliding mechanisms to replace traditional surface transfers in order to minimize the friction between the client and transfer board and thereby reduce forces required for the transfer.

However, a focus group study showed that a majority of aides were unaware of even the basic devices such as gait belts and transfer boards, nor were they familiar with how a client could obtain the devices (Baron & Habes, 2004). A recent study showed that nearly 40% of aides reported having no access to equipment to move clients (Quinn et al., 2015). There is both an access problem and a knowledge gap about client handling device use among home care aides. The effectiveness of using assistive devices in reducing physical exposure or musculoskeletal disorders in home care is still unknown at large.

2.4.4. Biomechanics exposure measurement during client handling

Hess et al. evaluated the biomechanics demands of using slide board transfer techniques and two other manual transfer methods to move clients from bed to wheelchair among home care aides. The study used a Borg scale, lumbar motion monitor, and a dynamometer to capture the perceived exertion level, low back kinematics and hand forces, respectively. More comprehensive measurement strategies were used in the Zhuang and Marras studies for biomechanical evaluations of transferring a client using different transfer methods. These transfer methods included basket-sling transfers, overhead lift devices, stand-up lifts, slide boards, two-person manual transfers and single person manual transfers (Marras et al., 1999; Zhuang et al., 1999a). Zhuang's study used

a 3-D motion capture system, force platforms, and a 3-D biomechanical model to estimate the hand force magnitude and direction of the subjects, and to estimate the low back compressive force and the percent of population with sufficient strength capability to perform the tasks, respectively (Zhuang et al., 1999b). Marras' study measured not only the trunk motions such as trunk twisting and lateral bending motions, but also the spinal compression, anterior–posterior and lateral shear forces (Marras et al., 1999).

2.4.5. Generic usability

The International Standardization Organization defines usability as 'the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (Thomas Tullis, 2008). The usability that Thomas and colleagues focused on is goal-oriented: the performance of the tools and the user's satisfaction with the tools. In his theory, the usability performance include: time to perform the tasks, effort needed to accomplish the task, errors committed, how quickly the user becomes proficient with using the tool (learnability), and user satisfaction with ease of use, perceived reliability, and perceived comfort, compared to the expectation before actual use (Thomas Tullis, 2008).

While these definitions provide useful guidance, they are too general to be interpreted directly for usability evaluation of patient handling devices. In addition, many usability evaluations of medical device are focusing on clients' safety, but very few have looked at the devices' impact on care givers' health and safety. One study(Moody et al., 1996) found that the factors that made nurses reluctant to use mechanical aids included: lack of proper training, devices being unavailable or inaccessible, and spatial constraints. These issues may also impact the users' motivation, performance efficiency, and safety

during patient transfer tasks. Thus, a usability test for patient handling devices at home should consider not only the specific task's performance demands on home care workers, but also the safety and health implications of using these patient handling devices.

2.4.6. Transfer device usability

Several investigators have developed usability evaluation tools for mechanical lifts or draw sheets in the hospital environment (McGuire et al., 1996; Moody et al., 1996). In a nursing home study by Zhuang et al. (Zhuang et al., 1999b), they suggested six criteria to evaluate resident transfer methods: perceived physical exertion (psychophysical stress), resident comfort, resident security, ease of use, aides' preference toward method and task performance time. Heacock (Heacock et al., 2004) evaluated the ease of use and safety of a mechanical client lifting devices among home support workers in a simulated home environment. Heacock found that there was improvement in perceived exertion, ease of use and safety by using the mechanical lift device compared to manual transfer method. Usability features such as perceived exertion, comfort and safety, home storage, device maintenance, device size, portability of the device, etc. are critical factors that may have an impact on task performance and home care aides' satisfaction towards the device. However, very few studies have developed a systematic approach to evaluate low-tech client handling devices usability among home care aides.

2.4.7. Summary of exposure measurement

Considering the massive home care aide population in this study, the thesis used questionnaire instruments collect occupational exposure and health outcomes information of home care aides. In order to examine the physically demanding client handling tasks,

the thesis used load-cell, surface EMG and lumbar motion monitor to measure ergonomic exposure of simulated client transferring tasks for a small group of home care aides.

3. Thesis organization

The thesis is based on two separate investigations, a cross-sectional survey of home care aides and a laboratory biomechanical experiment. In the first study (Chapter 2 and 3) the self-administered questionnaires were distributed to aides through on-site in-service training in home care agencies, and by mailing the surveys to aides through their union. The surveys were collected, coded, scanned, and analyzed for the specific aims described in chapter 2 and 3. In the laboratory experiment (Chapter 4), the study utilized load cells, surface EMG and lumbar motion monitor to evaluate the biomechanical exposures during client transfers using different transfer techniques. A survey was used to compare the usability between different transfer devices.

In Chapter 2, descriptive statistics were used to compare demographic information such as age, gender, length of work in home care, and the workload conditions for agency-hired aides and client-hired aides. The descriptive frequency of client handling device use among aides, the frequency of physical activities, clients' health conditions, as well as clients' home conditions during client visits were compared as a function of type of employment and client mobility (limited vs. non-limited) using chi-square statistics.

In Chapter 3, Chi-square tests were used to compare low back pain prevalence and its characteristics for agency-hired aides and client-hired aides. Univariate modeling was used to examine the association between low back pain and different occupational risk factors including the number of physical activities per visit, the presence of hazardous home conditions, the use of client handling devices, the number of hours worked per week, the number of visits made in the past week, as well as the aide's length of work in

home care. Multivariate modeling was used to elucidate the combined effect of potential risk factors on low back pain.

In Chapter 4, five different techniques for client transfer (between bed and wheelchair) were evaluated based on a complete randomized blocked design. The dependent variables included 90 percentile hand forces, surface electromyography on shoulder and low back, and average trunk flexion and velocity during transfer. Usability measures included comparing aides' perception of effort and ease of use for client transfers as well as the boards' portability.

In Chapter 5, an overall conclusion and implication of the thesis are provided. The conclusion presents major findings about home care aides' type of employment, low back pain and its characteristics, as well as work-related risk factors. It also summarizes transfer board usability evaluation and the recommendations for safe transfer device use, training and informs the future client transfer device intervention.

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Table 1: Comparison between self-reported, observational and direct measurement methods

	Examples	Advantages	Disadvantages
Self-reported method	1. Survey 2. Borg scale 3. Likert scale	1. Easy to use 2. Appropriate for large population 3. Various tasks measurement 4. No need to train the researcher	1. Subjective measurement 2. Recall bias 3. Rough estimation 4. Incomparableness among investigations
Observational measurement method	1. OWAS 2. PATH 3. Armstrong video analysis system	1. Various or highly-repetitive tasks 2. More objective than self-reported method 3. Focus on posture frequency and time study	1. Need to train the researcher 2. Inter-rater reliability 3. Not applicable for large population
Direct measurement method	1. Surface EMG 2. Lumbar Motion Monitor 3. Electrogoniometer 4. Dynamometer	1. Objective measurement 2. Accurate and reliable measurement 3. Applicable to highly repetitive tasks	1. Cost of measurement equipment 2. Set-up of the measurement equipment 3. Not applicable to large population 4. High demands in training the researcher 5. Exposure measurement only for specific body posture

II. Home care aides' physical activities and potential for musculoskeletal strain: results from the Safe Home Care Survey

1. Introduction

1.1. Home care population in the U.S

The aging U.S. population is driving the demand for a robust healthcare workforce to serve older adults (Quinn et al., 2015). In the U.S., the percentage of the population aged 65 and over was 13.0 percent of the total population in 2010 and is projected to reach 20.9 percent by 2050 (BLS, 2014). In recent decades, long-term care for this group has been shifting from institutional care to home and community based care (BLS, 2014). This is reflected in the strong growth of two occupational categories that provide hands-on home care: home health aides and personal care aides. Currently, there are about 1 million home health aides and 1.7 million personal care aides in the United States (BLS, 2015a). The Bureau of Labor Statistics (BLS) projects job growth in these occupations of 38% and 26% respectively over the period 2014-2024 (BLS, 2015a).

1.2. Home care aides' job duties

Home care recipients are referred to as "patients," "clients" or "consumers" depending on the medical or social system through which care is provided. In this study, we use the term "client" to refer to all types of home care recipients.

Home health aides and personal care aides are typically employed to help these recipients with basic self-care tasks referred to as activities of daily living (ADL) and/or everyday tasks that support an independent lifestyle and are called instrumental activities of daily living (IADL). ADLs include bathing or showering, dressing, eating, getting in or out of bed or chairs, using the toilet, and getting around in the home (CDC, 2009). IADLs include everyday household chores, doing necessary business, shopping, or getting around for other purposes (CDC, 2009). Taken together, these tasks constitute a substantial physical workload and many require repetitive motions and awkward postures which can lead musculoskeletal strain and injuries. There is limited quantitative research on the musculoskeletal strain hazards of home care aides.

The objectives of this study were: 1) to characterize home care aides' work organization, physical workloads, and work environment during client visits; 2) to compare the physical workload by type of employment: agency-hired aides versus client-hired aides; and 3) to compare the physical workload for clients with and without limited mobility.

2. Background

In Massachusetts, home care aides mainly are hired in two different ways: 1) a private business called an agency hires the aide, assigns her/him to the client, and supervises her work, here called "agency-hired aides;" or 2) the client or client's family hires and supervises the aide directly, here called "client-hired aides." The pay for both agency-hired and client hired aides primarily comes through the government agency Medicare (56%), as well as private insurance (12%), out-of-pocket payment (6%) and other sources (CDC, 2007). In Massachusetts, all aides hired directly by clients using public funds were represented by a labor union, whereas most agency-hired aides were not in a union (Quinn et al., 2015).

2.1. Home care aides' physical tasks and home environment measurement

2.1.1. Physical tasks measurement

Home care aides' work is difficult to study because the aides work alone and are geographically dispersed. Quantitative measurements of physical workload frequency or client lifting intensity are very difficult to collect due to the need to protect clients' privacy. Instead of direct observation, therefore, quantitative physical workload has more often been characterized by asking the aides to report the frequency of trunk flexion or twisted postures (Jansen et al., 2004; Torgen et al., 1995). However, the interpretation of certain tasks into body postures requires thoughtful consideration by the worker (Kim et al., 2010). Other studies done by Baron (Baron et al., 2004) and Wipfli (Wipfli et al., 2012) conducted focus group research to characterize home care tasks and arrangement. These results suggested similar lists of tasks that the aides described as causing the most

pain or concern. These tasks included: unassisted client lifting and transferring, bathing, dressing, push/pull/lift wheelchair, supporting client while walking or catching while falling, cleaning bathroom, cleaning floors, cleaning kitchen, and moving household objects. However, very little if any research has characterized quantitative exposures in home care tasks.

2.1.2. Hazardous home condition measurement

The home is a unique work environment that may be crowded, dimly lit, or cluttered and the furniture arrangement might make aides' task difficult and lead to awkward postures (Galinsky et al., 2001; Markkanen et al., 2014; McBride et al., 2011). This challenge might be aggravated when the client is obese or lack of mobility (Beer et al., 2014). Based on the literature review, there is little study about the accessibility and the usage of assistive devices to handle the clients among home care aides. Only one study has described the influence of hazards in client's home on self-reported MSDs (Zeytinoğlu et al., 2000).

2.2. Musculoskeletal disorders among home care aides

According to a CDC report, sprain and strains were the most common reason for lost work time injuries to homecare workers in 2007 (CDC, 2010). Compensation costs, lost wages, and lost productivity related to work-related MSDs are between $45 and $54 billion annually (NRCIM, 2001). In 2014, the incidence rate for home health aides and personal care aides of MSD cases was 55.4 and 60.6 per 10,000 full time employees respectively, which was higher than the national average incidence rate of 33.8 per 10,000 full time employees (BLS, 2015b).

2.3. Lack of literature on work load among home care aides

MSDs and physical workload are more frequently studied among hospital nurses or nursing home aides than in the long term care or home care work forces (Davis et al., 2015; Kurowski et al., 2014). Some studies (Arlinghaus et al., 2013; Houston et al., 2013) have reported general factors for work-related injuries such as race, job dissatisfaction, or lack of equipment. There is a general understanding of the risk factors for MSDs in home care (CDC, 2010), but few studies if any have examined ergonomic workloads or environmental factors that constitute risk factors for the development of low back pain or other MSDs among home care aides.

2.4. Objectives of the study

We sought to characterize quantitatively the nature of home care work and identify occupational characteristics for future MSDs prevention. The objectives of this study were to: 1) Characterize home care aides' job arrangement, physical workloads, and the work environment during client visits. 2) Compare the physical workload by the type of employment (agency hired aides versus client hired aides) as well as by existent of client's mobility.

3. Methods

3.1. Study design

3.1.1. Survey administration

The study was part of the Safe Home Care Project at the University of Massachusetts Lowell. The overall aims of the Safe Home Care Project included quantifying occupational safety and health hazards among home care aides and translating the findings into effective preventive interventions (Quinn et al., 2015). The study utilized a self-administered cross-sectional questionnaire that was distributed to home care aides employed through different medical and social service systems in Massachusetts. U.S.A. One group of surveys was distributed to the aides through on-site in-service training in the home care agencies; these workers are referred as agency-hired aides (AHAs). The rest were distributed by mailing the surveys to the aides through their union, these aides are referred as client-hired aides (CHAs). During the survey administration through the on-site events, the managers of the home care agencies were not present while the aide took the survey. Details of survey design are described elsewhere (Quinn et al., 2015).

The recruitment criteria included: 1) at least 18 years old; 2) performed direct client home care in the past month before participating the survey data collection. Home care aides were asked to provide informed consent and an incentive of twenty dollars was given to the aides for completing the survey. All methods and materials were approved by the UML Institutional Review Board (IRB).

3.1.2. Survey component development

The survey consisted of two sections:

Section One. Information about the aide and general work organization, and

Section Two. Characteristics of recent visits to individual clients

Section One was designed to collect demographic and health characteristics of the aide, her/his overall work organization, information about the length of work in home care, the number of clients visited in the past week and the number of hours worked every week. Aides were asked to indicate all of the types of client handling devices that they had used in the past 12 months. These devices include: a) devices that move client from side to side, such as slide boards and draw sheets; b) balance-keeping devices such as a gait belt; c) mechanical lifts, and d) other devices. In the Section One, the unit of analysis was each individual home care aide.

Section Two of the questionnaire asked detailed information about the aide's most recent visit to each client visited in the past month (up to five clients with identical questions about each of those visits). The unit of analysis in this section was each individual client visit. For each client visit, questions covered client's health conditions, physical mobility, physical activities performed by the aide during the visit, and hazardous home environment conditions.

Development of question related to clients' health condition and hazardous home environment was informed by studies about home care aides' occupational hazards (Galinsky et al., 2001; Kim et al., 2010) and the information about typical client visits elicited in earlier Safe Home Care focus groups with home care aides (Markkanen et al., 2014). In order to help aides to remember their physical activity and the clients' health

condition during the visit, we asked them to write down the initials of their clients on the survey for their reference.

Hazardous home condition questions asked whether a home condition contained small space, clutter, slippery floor, or the aide had needed device for that visit. In the question about clients' health condition, the aides were asked about whether a client visit contains any major health conditions. These conditions included whether client had limited mobility, diabetes, respiratory condition (for example COPD, asthma), dementia, mental illness/psychological issues, home dialysis, IV therapy, infectious disease, incontinence, obesity or overweight, smoking and being on oxygen.

Physical activity related questions were largely adopted from the results of focus groups in other studies where specific physical tasks were identified to cause aides the most pain (Baron & Habes, 2004; Galinsky et al., 2001; Kim et al., 2010; Torgen et al., 1995; Wipfli et al., 2012). Three broad categories of physical activities were assessed: client handling/transferring (move the client in bed, help into/out of bed, chair, wheelchair, or other sitting position, or help into/out of the bath or shower); other direct care (help with bathing, help with dressing, putting on stockings); and cleaning/housework (clean bathroom or kitchen, vacuum the floors, mop the floors, move equipment or furniture, do the laundry, change bed linens, assist with cleaning the pet waste or litterbox, take out the trash). For any of the client handling or transfer activities, aides were asked whether they used a handling or transfer device.

3.2. Statistical analyses

We calculated descriptive statistics for aides' occupational characteristics, client characteristics as well as activities performed during client visits. Associations were examined at the aide level about the demographic and work history factors as a function of type of employment (agency-hired or client-hired). At the client level, we calculated the frequency of performing the three types of physical activities by the type of employment and by client mobility. Missing values (or Nonresponse) that were less than 5% were reported in the "Note" at the bottom of each table and were excluded from the analyses, missing values (or Nonresponse) that were greater than 5% was listed in a separate column in the tables. Comparisons between the two contrast groups were done by using Chi-Square tests with the significant at the $p<0.05$ level. Of note, the comparison as a function of client mobility was computed between client with limited mobility and without. All analyses used SAS statistical software (SAS 9.2, SAS institute Inc. Cary, North Carolina, USA).

4. Results

4.1. Demographic information

A total of 2826 surveys were distributed to agency-hired aides and client-hired aides during 2012 to 2013. The survey yielded quantitative information from 1249 home care aides including detailed descriptions of 3484 client visits in the month prior to the survey (Table 2). Responses were split approximately equally between 634 agency-hired aides and 615 client-hired aides. The majority of aides were women (87%), the mean age was 47 years old, and more than 40% of the aides were 50 years or older. More agency-hired aides (26%) had worked 10 years or longer with the same employer than the client-hired aides (10%). On average, the agency-hired aides made twice as many visits as the client-hired aides, although the total number of hours worked per week was similar (Table 2).

4.2. Usage of assistive devices

Approximately one-third (35%) of all aides reported using at least one assistive device to mobilize or lift a client in the 12 months prior to the survey (Table 3). These devices include: slide boards, draw sheets, or other devices for moving clients from side to side; gait belts or other devices for keeping a client balanced while walking; or mechanical lifts (such as a Hoyer lift); and other devices identified by the aides (e.g. grab bars, walker, shower chairs, hospital beds). More agency-hired aides reported having used a slide board or gait belt than did client-hired aides ($p<0.05$), although fewer of them noted using a wheelchair than client-hired aides ($p<0.05$).

4.3. Activities performed, clients' health and home environmental conditions in recent visits by home care aides

About half of the visited clients had limited mobility, as judged by the aides (Table 4). Client-hired aides' clients were especially more likely to have limited mobility. Other reported health conditions included diabetes (30.3% of visits), incontinence (28.6%), dementia (20.5%), and overweight/obese client (19%). Dementia was more commonly observed in the clients of agency-hired aides. One-tenth of the clients were on oxygen. About one-sixth of the clients' homes had cluttered home conditions. One-tenth of the visited homes were judged to have too little space to work.

Client handling activities—transferring, moving, repositioning in bed, and catching a falling client--was much likely among client-hired aides than among agency-hired aides. Overall, about two-thirds of client visits contain at least one type of client handling activity and transfer device was used among 41.4% of those visits with client handling activity. Common client handling activities were move client into/out of the bath or shower (51% of all visits); move client into/out of a chair, wheelchair, toilet, or other sitting position (42%); move client into/out of bed (31%); and move client in bed (22%). Catching the client while falling – task that was usually involves lifting a client from the floor manually – happened one sixth of all client visits. Client-hired aides were much more likely than agency-hired aides to perform any of the client handling activities asked in the questionnaire. Over half of the visits involved other direct care activities included assisting with bathing or dressing and these activities happened more frequently in client-hired aides' visits than in agency-hired aides' visits.

Approximately two-thirds of client visits entailed routine cleaning tasks: bathroom or kitchen cleaning (82.7% of visits), taking out trash (70.7%), changing bed linens (68.1%), vacuuming floors (63.3%), or doing laundry (60.5%). Most cleaning and house-keeping tasks were more frequent among client-hired aides' clients.

4.4. Physical activities, client health conditions, and home conditions in recent client visits, by client mobility as assessed by home care aides

For each client they reported on, aides were asked if the client had limited mobility, i.e. client needs assistance with moving (Table 5). Aides reported "yes" to limited mobility in 43% of recent client visits, "no" in 39% of recent visits, and "not sure" about mobility or left the field blank in 18% of visits. The frequency in most of the client handling activities (move client in/out of chair, move client in/out of bath, helped the client into/out of the bed, used transfer device, moved the client in bed), and in other direct care activities (dressing, bathing, putting on tight support stocking for clients) were about 20-30% higher among the clients with limited mobility than those without ($p<0.0001$). There was also a higher prevalence (>35%, $p<0.0001$) in moving equipment or furniture among those clients with limited mobility than without. Certain health conditions included incontinence (23% higher), diabetes (6), dementia (9), obese or overweight (10), and was on oxygen (5) ($p<0.0002$) were more likely in clients with limited mobility than those without. Notably, the accessibility to the needed devices was more likely among the client with limited mobility than without. At the client visit level (Table 5), 68.9% of the time the aides had the needed ergonomic device for the client

who needs to move, whereas 42.1% of the time the ergonomic device was actually used when the client needing mobility assistance during client visits.

4.5. Use of client handling devices

Similar percentages for agency-hired aides and client-hired aides (60.4%, 54.0% respectively) reported not using a handling device (Figure 1). Client-hired aides were more likely to reported "always" using an client handling device (30.7% - always, 8.9% - sometimes) compared with Agency-hired aides who were more likely to use the devices "sometimes" (13.6% - always, 32.4% - sometimes).

5. Discussion

5.1. Comparison of routine physical work load between agency-hired aides and client-hired aides

This study collected data from two distinct groups of home care aides in Massachusetts, agency-hired and client-hired aides. Earlier Safe Home Care focus group findings suggested that home care agency managers can influence their aides' occupational safety and health via client evaluations and care plans, orientation and in-service training, and establishing and enforcing agency policies on client handling and other risk factors (Markkanen et al., 2014). These factors—lack of employer advocates, and less mobile consumer—highlight inherently less support, higher physical demands and higher risks for client-hired aides. Differences in results between the two groups can elucidate potential opportunities and interventions.

Client-hired aides tend to have fewer clients on average and longer visit durations than the agency-hired aides. Generally, the frequency of physical activity (client handling activity, other direct care activity, and cleaning and housework activity) was higher among client-hired aides than agency-hired aides. Agency-hired aides were also more likely to use slide boards and gait belts than client-hired aides. It can be inferred that client-hired aides were in a disadvantageous situation, entailing higher physical workload and had with less support in client handling devices than the agency-hired aides.

There was a marked contrast between the agency-hired aides and the client-hired aides in their core job demands. Among the most frequently performed activities (over 50% of visits) in client-hired aides, tasks like client handling (83.5%), bathing (66.2%) and dressing (74.9%) usually involve body contact, needing conversation, and getting

cooperation from the client. In contrast, the most frequently performed tasks (over 50% of visits) by agency-hired aides were cleaning or maintenance: clean bath/kitchen (82.6%), take out trash (67.4), change bed linens (64.6), vacuum floor (64.3%), and do the laundry (55.8%). These require little interaction with clients but impose a need to cope with potentially cluttered homes. It is apparent that agency-hired aides' tasks were mostly related to coping with the home environment, whereas the client hired aides' tasks focused on the clients' mobility needs in addition to the cleaning and maintenance tasks.

The contrast in physical activities between the agency-hired aides and client-hired aides implies the necessity of a thorough needs assessment before assigning an aide to a client, in order to assure a predictable physical workload. Future interventions that aim to reduce physically demanding tasks for agency-hired aides might focus on the evaluation of the home environment challenges, and the intervention for client-hired aides should consider adapting the client handling devices to home usage.

5.2. Comparison of routine physical work load by client mobility

In this study, a significant higher frequency of client handling, other direct care and housework (move equipment or mopping floor) was recorded among visits to clients with less mobility. This indicated a higher physical demand for those aides. Notably, a higher percentage of house work activity in this group, such as moving equipment or furniture during the visits, or mopping the floor could be indicators of encountering more hazardous home condition such as clutter, small space, and might aggravated the physical demands of client handling tasks that causing awkward postures (NRC, 2011). In addition, the frequency of client with incontinence and obesity were much higher (>10%) among

clients with less mobility, which could also aggravate the complexity and the physical demand of client handling tasks.

Some literature suggests that physically demanding client handling tasks are risk factors for MSDs. Kim (Kim et al., 2010) found that the physical demands among homecare workers were significantly associated with an excessive risk on the back MSDs incident. Baron and Habe's study (Baron & Habes, 2004) suggested that direct care activity (i.e. bathing) and cleaning or other housework cause equivalent strain to client handling. It can be inferred that moving clients with limited mobility is likely to be a risk factor for back MSDs for home care aides, although further quantitative investigation is needed. The contrast in home care aides' physical workload and client characteristics may also be ascribed to the different employment approaches.

5.3. Accessibility and usage of client handling device

In this study, we consider that clients' limited mobility is an indicator for the necessity to use assistive devices. The aides had the needed assistive devices for about 2/3 of the time when caring for clients who need help to move. However, only 42% of the time the ergonomic device was actually used when needed. This prevalence (42%) in home care aides was lower than nurses in nursing homes (68%) or in hospitals (59%) (Koppelaar et al., 2011). The result implies that institutional support such as having access to proper device or safe client handling policy enforcement might be helpful in the promotion of client handling device accessibility and usage. This is internally consistent with our finding that having access to the needed client transfer device was positively

associated with device usage. Furthermore, agencies usually have an advantage in promoting the device usage over the individual aides hired by the clients.

Considering the isolated working condition and small space in the home environment, some usability factors are critical while choosing and evaluating the assistive devices for client handling tasks. Given that large sized or heavy assistive devices are not suitable to carry to multiple clients in different locations, the criteria for selecting transfer devices should include low cost, easy to carry, clean and easy maintenance. The Chapter 4 of this thesis investigated the usability of low-tech client transfer devices used by home care aides.

5.4. Strengths and Limitations

The strengths of this study included the large sample size (1249 home care aides contributing information on 3484 client visits). The unique survey design allowed us to look into a comprehensive list of physical activities during up to five recent client visits. In addition, this study succeeded in comparing the physical workload, home condition and client health condition by two types of employment, and by client mobility at the visit level.

A potential limitation of this study is limited generalizability, since our study was conducted only in the state of Massachusetts. Selection bias was also plausible; home care agencies that agreed to participate were aware of the commitment of administration support and the raised awareness of workplace hazards among their employees who participated in the survey. As a result, we infer that these agencies were more progressive

than average about occupational safety and health, and thus, physical workloads may be understated relative to all home care agencies.

Recall bias is possible because the aides were required to remember their past experiences up to a year and their reflection might not be accurate. Aides' responses to the questionnaire may not reflect actual conditions in the work place if they had difficulty understanding the questions due to limited literacy.

Our questionnaire permitted calculation of the occurrence of a long list of physical activities; however we did not collect information on the intensity or frequency of each activity. Thus, we could not fully describe the variability of physical workload across the clients' visits. It is recommended that future studies collect the information about intensity and frequency of tasks, especially with tasks involving heavy physical activity, such as client handling, assisting with bathing, or house cleaning, at the visit level.

5.5. Recommendations

This study quantified the occurrence of a wide range of physical activities, potentially, hazardous home environmental conditions, clients with health conditions that required intensive physical handling by the aides, and lack of client handling devices. Given the evidence that moving less mobile clients could increase the risks of low back MSDs, preventive interventions need to focus on how to reduce the physical exposure in client handling activity, especially for clients who need assistance in mobility. Possible solutions include assessing the need of the client proactively, increasing the independence of the clients and/or providing proper client handling devices in clients' home and training for aides on how to use assistive devices safely. In general, government

organizations and insurance companies should encourage safe and effective use of assistive devices in home care. Home care agencies should utilize the advantage of institutional resources, such as management support and educational capacity, to enforce device usage regulation-such as a safe client handling plan, to protect home care aides from MSDs injury.

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Table 2: Safe home care survey population: Selected demographic and occupational characteristics, Massachusetts 2013

	All aides, N = 1249			Agency-hired aides, N=634			Client-hired aides, =615		
	n*	Per cent**		n*	Per cent**		n*	Per cent**	
Age									
<40	374	30		155	24		219	36	
40 - 50	295	24		166	26		129	21	
50-60	350	28		180	28		170	28	
>60	203	16		118	19		85	14	
Gender									
Female	1086	87		602	95		484	79	
Male	159	13		31	5		128	21	
Tenure with current employer									
<2 years	369	29		172	27		197	32	
2-9 years	608	49		275	43		333	54	
≥ 10 years	226	18		164	26		62	10	
Measures of work load (mean, SD, IQR)									
Visits in the past week	9.6	9.7	3 - 13	13.4	10.5	6 - 20	5.7	7.0	1 – 7
Hours worked per week in home care	25.5	15.3	15 - 30	25.8	14.0	15 - 30	25.3	16.7	15 - 30

* Data may not sum to total observations due to missing values

** Percentages may not sum 100% due to missing values

Table 3: Client handling devices used in the past 12 months by home care aides (N=1249) in the Safe Home Care Survey, Massachusetts 2013

	All aides N = 1249		Agency-hired aides N=634		Client-hired aides N=615		
	n*	Percent**	n*	Percent**	n*	Percent**	p Value***
Client handling devices used in the past 12 months†							
Slide board	253	20.3	153	24.1	100	16.3	0.0005
Gait belt	269	21.5	194	30.6	75	12.2	<.0001
Mechanical lift	236	18.9	129	20.4	107	17.4	0.1832
Any device	442	35.4	255	40.2	187	30.4	0.0003
Other devices							
Wheelchair	68	5.4	16	2.5	52	8.5	<.0001
Walker or cane	51	4.1	21	3.3	30	4.9	0.1621
More than one††	11	0.9	4	0.6	7	1.1	0.3374

* Data may not sum to total observations due to missing values

** Percentages may not sum 100% due to missing values

*** From $\chi 2$ testing H_0: No difference between agency versus client-hired aides

† Devices used were not mutually exclusive

†† Device Include at least one of these: shower chair, stair lift, electric bed, stand pivot, and porch lift.

Table 4: Activities performed, clients' health and home environmental conditions in recent visits (N=3484) by home care aides in the Safe Home Care Survey, Massachusetts, 2013

	All aides		Agency-hired aides		Client-hired aides		
	n*	Percent**	n*	Percent**	n	Percent**	p Value***
Client handling activity							
Any client handling activity	21	64.4	1438	57.4	761	83.5	<.0001
Moved client into/out of bath	17	50.7	1116	45.4	586	65.1	<.0001
Moved client into/out of chair	14	42.0	817	33.6	585	65.0	<.0001
Helped the client into/out of the bed	10	30.7	485	19.9	538	60.5	<.0001
Used transfer device	88	26.8	557	23.0	326	37.3	<.0001
Moved the client in bed	73	22.3	317	13.0	421	47.8	<.0001
Caught client while falling	57	17.5	261	11.0	311	35.3	<.0001
Other direct care activity							
Assisted with dressing	20	61.0	1381	56.0	672	74.9	<.0001
Assisted with bath	18	54.5	1235	50.2	592	66.2	<.0001
Assisted with putting on tight support stocking	10	31.3	604	25.1	424	48.6	<.0001
Cleaning and house work activity							
Cleaned bath/kitchen	27	82.7	2057	82.6	740	82.7	0.98
Took out trash	23	70.7	1661	67.4	719	79.6	<.0001
Changed bed linens	22	68.1	1580	64.6	694	77.7	<.0001
Vacuumed the floors	21	63.3	1569	64.3	537	60.7	0.06
Did the laundry	20	60.5	1365	55.8	656	73.3	<.0001
Mopped the floors	97	30.0	522	21.9	456	51.9	<.0001
Moved equipment or furniture	73	22.2	317	13.0	421	47.8	<.0001
Clients' health condition							
Client had limited mobility	14	52.2	892	43.7	601	73.3	<.0001
Client had diabetes	95	30.3	687	29.3	269	33.1	0.04
Client was incontinent	89	28.6	649	27.9	244	30.9	0.11
Client had dementia	63	20.5	500	21.7	136	17.2	0.01
Client was obese or overweight	58	19.0	407	17.7	181	22.6	0.003
Client was on oxygen	31	11.1	218	10.3	96	13.2	0.03
Clients' home environment							
Had assistive device needed	18	57.8	1283	55.9	535	63.0	0.0004
Cluttered conditions	59	17.6	467	18.8	126	14.3	0.002
Too little space	33	10.1	248	10.1	88	10.1	0.99
Slippery floors	19	5.9	150	6.1	47	5.4	0.44

* Data may not sum to total observations due to missing values

** Percentages may not sum 100% due to missing values

*** From $\chi 2$ testing H_0: No differences between clients with versus without limited mobility.

Table 5: Physical activities, client health conditions, and home environmental conditions in recent visits (n=3484) by home care aides in the Safe Home Care Survey, Massachusetts 2013. Data stratified by client mobility.

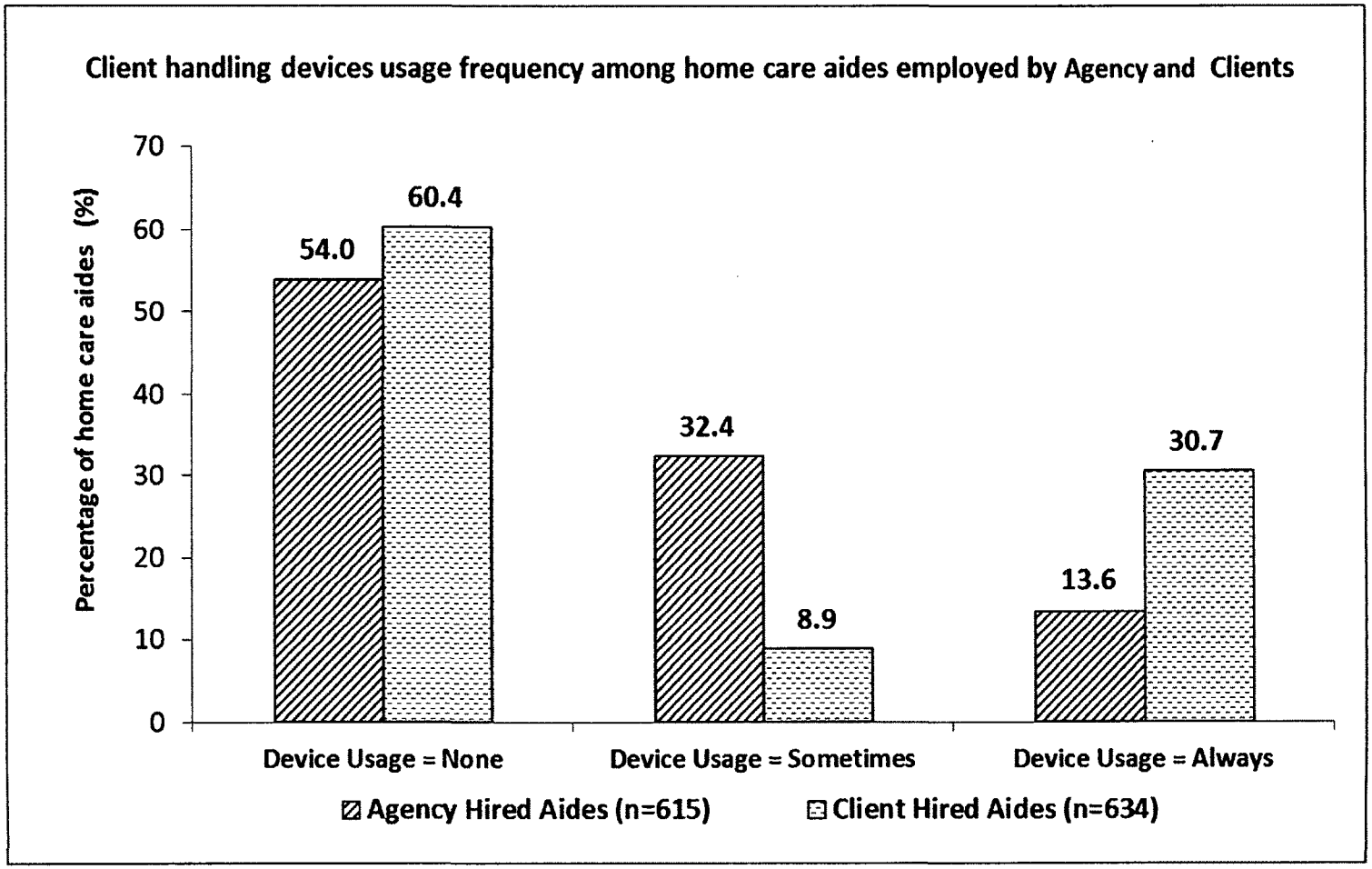
	Had limited mobility (N=1493)		No limited mobility (N=1370)		Missing (N=621)		
	n*	Percent**	n*	Percent**	n*	Percent	p Value***
Client handling activity							
Moved client into/out of chair	1000	68.7	209	15.7	193	35.4	<.0001
Moved client into/out of bath	919	63.3	519	38.6	264	46.9	<.0001
Helped the client into/out of the bed	771	53.1	130	9.7	122	22.5	<.0001
Used transfer device	601	42.1	152	11.4	130	24.4	<.0001
Moved the client in bed	588	40.9	70	5.2	80	14.9	<.0001
Caught client while falling	340	24.2	135	10.2	97	18.3	<.0001
Other direct care activity							
Assisted with dressing	1154	79.0	580	43.4	319	56.3	<.0001
Assisted with bath	951	65.5	587	43.7	289	51.4	<.0001
Assisted with putting on tight support	586	41.1	281	21.3	161	30.0	<.0001
Cleaning and house work activity							
Cleaned bath/kitchen	1195	82.2	1123	83.5	479	81.9	0.36
Changed bed linens	1017	70.7	874	65.5	383	67.7	0.003
Took out trash	1012	70.0	966	72.0	402	69.4	0.26
Did the laundry	859	59.7	808	60.7	354	62.0	0.60
Vacuumed the floors	802	56.1	927	69.3	377	67.6	<.0001
Moved equipment or furniture	588	40.9	70	5.2	80	14.9	<.0001
Mopped the floors	493	34.9	330	25.0	155	29.3	<.0001
Client health condition							
Client was incontinent	576	43.5	184	13.8	133	28.9	<.0001
Client had diabetes	431	32.6	349	26.1	176	35.6	0.0002
Client had dementia	321	24.6	201	15.2	114	24.4	<.0001
Client was obese or overweight	320	24.5	181	13.6	87	19.0	<.0001
Client was on oxygen	163	13.8	101	8.2	50	11.7	<.0001
Clients' home environment							
Had assistive device needed	976	68.9	551	45.2	291	57.3	<.0001
Cluttered conditions	269	18.5	207	15.3	117	21.0	0.02
Too little space	190	13.2	90	6.7	56	10.3	<.0001
Slippery floors	95	6.6	63	4.7	39	7.2	0.03

* Data may not sum to total observations due to missing values

** Percentages may not sum 100% due to missing values

*** From $\chi 2$ testing H_0: No differences between clients with versus without limited mobility.

Figure 1: Frequency of client handling device usage in the past 12 months between agency hired versus client hired aides



III.Low back pain risks and occupational factors among home care aides

1. Introduction

1.1. Home care aides in the U.S

Home healthcare workers help ill, elderly, or disabled persons who live in their own homes instead of in a healthcare facility (NIOSH, 2010). Their primary work tasks are to help with basic self-care tasks referred to as activities of daily living (ADL) and everyday tasks that support an independent lifestyle called instrumental activities of daily living (IADL). ADLs include bathing or showering, dressing, eating, getting in or out of bed or chairs, using the toilet, and getting around in the home (CDC, 2009). IADLs include everyday household chores, doing necessary business, shopping, or getting around for other purposes (CDC, 2009).

1.2. Home care aide's physical workload

Home care aides' daily tasks expose them to high levels of physical workload imposed by patient care and cleaning tasks (Galinsky et al., 2001). Forceful exertion and awkward postures in lifting, moving, bathing have been shown to be associated with high rates of back injury and other musculoskeletal disorders (MSDs) in home care aides (Galinsky et al., 2001; Meyer et al., 1999; Waters et al., 2006). Kim et al. found an excessive risk of back MSD significantly associated with high physical demands of work among home care aides (Kim et al., 2010). In two focus group studies, housekeeping

tasks such as doing laundry, house cleaning, and rearranging furniture were also considered physically demanding and caused pain or concern for injury among home care workers (Baron et al., 2004; Wipfli et al., 2012).

1.3. Occupational hazards and injuries of home care aides

The occupational hazards among home care aides include musculoskeletal strain, exposure to potentially infectious agents, exposure to cleaning chemicals used for infection prevention, and potential exposure to violence (NIOSH, 2010; Quinn et al., 2015). In 2014, the incidence rate for home health aides and personal care aides of MSDs cases with days away from work were 55.4 and 60.6 per 10,000 full time employees respectively, which was significantly higher than the national average injury rate of 33.8 per 10,000 full time employees (BLS, 2015).

1.4. Home as a work environment

Home care aides often visit multiple clients with various health diagnoses or conditions. The home is not usually designed to accommodate care providers, nor is it under the control of home care aides. Each home that the home care aide visits is a different physical setting and some may hinder their ability to provide care (McBride et al., 2011). Home conditions may be crowded, dimly lit, or cluttered and the furniture arrangement might make aides' task difficult (Galinsky et al., 2001; Markkanen et al., 2014; McBride et al., 2011). As a result, tasks such as lifting, pushing or pulling may be performed with an awkward body posture or involve extra strain and exertion, which could cause injury (NRC, 2011). Most of the time, the aides have to work in an isolated

work environment without assistance (Kim et al., 2010; McBride et al., 2011; Meyer & Muntaner, 1999; Wipfli et al., 2012).

A recent study showed that nearly 40% of aides reported having no access to equipment to move clients (Quinn et al., 2015). A focus group study showed that a majority of aides were unaware of the availability of even basic devices such as gait belts and transfer boards, nor were they familiar with how a client could obtain the devices (Baron & Habes, 2004). Other ergonomic devices such as hospital beds, mechanical lifts, and gait belts that are commonly used in hospitals or nursing homes may not be conveniently accessible or feasible at home (NRC, 2011).

1.5. Low back pain and risk factor model

Informed by the Integrated Model from Faucett (Faucett et al., 2013), we theorized that low back pain risk would be associated with increased exposure to several occupational risk factors: client handling activity, other direct care activity, cleaning and house work activity during client visits, clients with obesity, visiting homes with hazardous conditions (i.e. clutter, slippery floor, small), longer working hours, number of visits per week, and one's work history in home care. We hypothesized that the interaction (effect modification) between client handling activity, hazardous home condition and moving client with obesity would cause or aggravate the physical workload of client transfer task. We also propose that using a client handling device could potentially reduce the physical workload during the transfer. The theoretical low back pain model is visualized in Figure 2.

1.6. Scientific evidence of low back MSDs among home care aides

The association between MSDs injury and physical workload has been more frequently studied among hospital nurses or nursing home aides than in home care work force (Davis et al., 2015; Kurowski et al., 2014). Scientific literature confirmed that low back pain and MSDs are significant problems among home care aides. The prevalence of low back pain among home care aides in the literature ranges from 31% to 70%, probably because of different case definitions recall periods, and other measurement issues (Faucett et al., 2013; Horneij et al., 2004; Johansson, 1995; Knibbe et al., 1996). However, there is a lack of quantitative evidence about the association between low back pain prevalence and work-related risk factors in this occupation.

1.7. Agency-hired aide and client-hired aide

In the U.S, most home care aides are employed in one of two ways: 1) They work for a home care agency that hires aides and assigns the aides to clients, this refer to as an agency-hired aide (AHA) in this study; 2) the client or client's family member or surrogate hires and supervises the aide directly, which is referred to as a client-hired aide (CHA) in this study (Quinn et al., 2015).

1.8. Objectives of this study

Considering the high frequency of MSDs among home care aides, this study will mainly focused on physical and environmental exposures and their association with musculoskeletal strain. Up to now, few empirical studies, if any, have quantitatively characterized the prevalence of low back pain and hazardous occupational characteristics

among home care aides. The objectives of this study were to: 1) describe the characteristics of low back pain among home care aides; and 2) estimate the association between low back pain and job characteristics.

2. Methods

2.1. Study design and administration

The study utilized a self-administered cross-sectional survey that was part of the larger Safe Home Care Project at the University of Massachusetts Lowell. One group of surveys was distributed to AHA's through on-site in-service training in the home care agencies; the others were distributed by mailing the survey to CHAs through unions from 2012 to 2013. The details of survey administration were described elsewhere (Quinn et al., 2015)(See Chapter 2 in this dissertation). All methods and materials were approved by the UML Institutional Review Board (IRB Protocol # 14-126).

2.2. Survey development

The survey was developed around occupational characteristics measurement and low back pain outcomes. The occupational characteristics in this study include: tenure of work in home care, average number of hours worked per week, number of visit in the last week, physical activity performed during client visits, client handling device usage during client visits, as well as client health conditions and hazardous home conditions in visits. The low back pain outcome include: the presence of low back pain in the past 12 months, low back pain's duration, frequency, severity, whether the aides sought medication, the impact on their lives, and the work-relatedness of the pain. The development of the survey is described below.

2.2.1. Low back pain outcome measurement

The questions related to low back pain history and characteristics were contained in the first part of the survey (aide's level question), and were adopted from the Nordic Musculoskeletal Questionnaire (NMQ) (Kuorinka et al., 1987). The index question for low back pain was: *Have you at any time during the last 12 months had discomfort (ache, pain, etc.) in your low back?* The aides were directed to the following questions if their response to the question was "Yes."

The pain frequency question was: *How often have you had this discomfort in the past 12 months?* Pain frequency information was obtained in four categories: "every day," "about once every week," "about once every month," or "less than once every month."

The pain duration question was: *How long does the discomfort last each time?* Pain duration information was obtained in five categories: "less than 1 hour," "more than one hour but less than 1 day," "more than 1 day but less than 1 week," "more than 1 week but less than 1 month," and "more than 1 month."

The pain severity question was: *Please rate the level of the low back discomfort that you may have had during the past week.* Pain severity information was described in one of the five levels, "none," "mild," "moderate," "severe," and "worst pain ever in my life."

Home care aides were asked whether they took pain relievers (like aspirin, Advil, Tylenol) for the pain, and whether in the past 12 months they have been prevented from doing normal work due to the symptom. These replies were described as: "not at all," "slightly limited," "moderately limited," "very limited," or "unable to work or do other regular activities."

Worker's perception of the work-relatedness of pain was obtained from two separate questions: 1) whether they were already in home care when the pain first started answered as "Yes" or "No;" and 2) whether they think the low back discomfort was related to their home care work, with answer categories of "Yes," "Partly related," or "Not related."

2.2.2. Occupational characteristics factors

Injury due to slips, trips and falls, or client handling

The aides were asked if they ever had any injuries or pains that led to medical care or lost work time due to slips, trips or falls outside/inside the home, or due to performing handling/transferring clients. A home care aide who answered "Yes" to any of these was considered as "Ever injured".

Work history and job organization

The aides were asked how long they have been working with their current home care employer(s). Length of work in home care was described in four levels: less than 2 years, equal to or greater than 2 years but equal to or less than 4 years, equal to or greater than 5 years but equal to or less than 9 years, and equal to or greater than 10 years. For the modeling analyses, work history was treated as a continuous variable (linear increase from category One to category Four). Hours worked in the past week were originally collected under four ranges: less than 10 hours, 10-20 hours, 21-40 hours and more than 40 hours. For analysis, the number of hours that home care aide worked per week were transformed into five levels and were treated as a continuous variable: 0 hours (include

missing value), 5 hours, 15 hours, 30 hours and 50 hours. The average number of hours worked per week ranges from 0 to more than 50 hours.

This second part of the survey was organized around the information about the clients visited (up to 5) in the past month, with identical questions about each of those visits (Quinn et al., 2015).

2.2.3. Physical workload

Questions about the physical activities performed by home care aides were largely adopted from focus group results in other studies where specific physical tasks were identified to cause aides' pain (Baron & Habes, 2004; Galinsky et al., 2001; Kim et al., 2010; Torgen et al., 1995; Wipfli et al., 2012). These physical activities were classified into three sub-categories based on the work content: client handling/transferring (move the client in bed, help into/out of bed, chair, wheelchair, or other sitting position, or help into/out of the bath or shower, catch the client while falling); other direct care (help with bathing, help with dressing, putting on stockings); and cleaning or other housework (clean bathroom or kitchen, vacuum the floors, mop the floors, move equipment or furniture, do the laundry, change bed linens, assist with cleaning the pet waste or litterbox, take out the trash).

2.2.4. Client's health condition

The aides were asked about any major health conditions of the clients they visited. These conditions included whether the client had limited mobility, diabetes, a respiratory condition (for example COPD, asthma), dementia, mental illness/psychological issues,

home dialysis, IV therapy, infectious disease, incontinence, obesity or overweight, smoking or being on oxygen.

2.2.5. Hazardous home condition

Independent hazardous home condition variables include had "a cluttered home," "slippery floor," and "too little space to work." Aides were also asked whether or not they have the needed equipment to handle or move the client during the visit.

2.2.6. Device usage during client handling/transferring

A composite variable was built to describe whether the aide used a client handling device to move the client who had limited mobility during the visit. The variable was defined by fulfilling all of three conditions: the client has limited mobility, any client handling activity was performed, and the aide used a device.

2.3. Computation of occupational characteristic indices

For each home care aide, the total numbers of physical activities performed per visit were summed in each physical category for up to 5 valid visits: client handling/transferring (up to 5 activities per visit), other direct care (up to 3 activities per visit), and cleaning or housework (up to 8 activities per visit). The average number of physical activities for each category was computed (total number of physical activities performed by the aide divided by the number of client visits). The unit of all 3 physical workload indices is activities.

In this study, the following occupational characteristics were treated as continuous variables:

- Average number of total physical activities per visit (0-16 activities),
- Average number of client handling activities per visit (0-5 activities),
- Average number of other direct care activities per visit (0-3 activities),
- Average number of cleaning or housework activities per visit (0-8 activities),

The percentage of visits where the client had limited mobility or was obese was computed as the total number of clients with that condition divided by the number of visits.

For each aide, the percentage of visits where the aide used a client handling device was the total number of visits with the device used, conditional on the client's limited mobility, divided by the total number of visits containing client handling activity.

The percentage of visits that had one or any of hazardous home conditions (clutter room, slippery floor, too small space to work) was computed as the total number of clients with one or any of these condition divided by the total number of visits.

These last three indices were recoded into categorical variables of three levels: 1) 0%; 2) greater than 0% and less than 100%; or 3) equal to 100% ("None", "Some" and "Always"). These last three indices were also dichotomized as "None" (0%) vs. "Any".
In this study, the following variables were treated as dichotomized variables:

- Any client with any hazardous home condition
- Any client with cluttered home condition
- Any client visit with slippery floor condition
- Any client with too little space condition

- Any visit where client handling device was used
- Any client who was obese
- Any client with limited mobility
- Past Injury (due to client handling, fall related injuries)

2.4. Data analyses

Descriptive statistics for aides' low back pain history, characteristics, and low back injury was computed. The proportions of aides hired via agencies or directly by clients were compared using Chi-Square tests ($p<0.05$). Arithmetic means of the physical activity were compared between aides with and without low back pain using a t-test ($p<0.05$). Univariate Cox proportional hazard regression models were applied to examine the association between low back pain and occupational characteristic factors, physical exposure indices, home condition indices and client's health condition indices. The statistical significance level was set at $p<0.05$.

Based on the low back pain model described in Figure 2, the study applied multivariate Cox proportional hazard regression models to explore the combined effect of exposure indicators for low back pain. The inclusion criteria for multivariate models were that the exposure indicator was on the hypothesized causal pathway to low back pain (Figure 2) and it had a statistically significant ($p<0.05$) association in univariate modeling. Although the clients' limited mobility is a predictor of client handling and is on the causal pathway to the low back pain, it was not included in the multivariate modeling. The study only examined clients' limited mobility in the univariate model. All analyses used SAS statistical software (SAS 9.2, SAS institute Inc. Cary, North Carolina, USA).

3. Results

3.1. Low Back Pain characteristics and low back injury

One third of the home care aides reported low back pain in the past 12 months and there was no difference between the client-hired aides and agency-hired aides (Table 6). Among the aides who had low back pain, about 60% experienced pain at least once a week, or rated the pain as at least moderately severe. Client-hired aides reported a higher percentage of severe pain than agency-hired aides (70.6% vs. 46.2%). The majority of aides stated that the pain first started when they were working in home care (74.7%), thought that it was work-related (78.1%), and used pain relievers (69.3%) for their low back pain.

3.2. Association between occupational characteristics and low back pain

The average number of physical activity tasks per client visit was 6% higher in aides with low back pain compared to those without (Table 7). The average number of client handling activities per client visit and the average number of hours worked per week were significantly higher in aides with low back pain (15.6% and 8.9% higher respectively). The average number of other direct care activities and cleaning or housework activities per visit were not associated with having low back pain (Table 7). There was no significant risk due to increased percent of visits with device usage, or the number of visits made in the past week.

In the univariate models (Table 8), the longer an aide's tenure in home care work, the higher the risk of low back pain ($p=0.04$). The increased risk of low back pain was proportional to the categorical length in work history (not shown in table). Aides who

ever had a back injury in the past due to client handling or work-related slips, trips, or falls were more than twice likely to have low back pain than the aides not injured ($p<0.001$). Other work factors that were significantly associated with increased risk of low back pain include the average number of client handling activities per client visit, any client visit that contained hazardous home condition, and any client with limited mobility or with obesity.

3.3. Multivariate modeling of low back pain

In the multivariate Cox proportional hazardous regression models of low back pain (Table 9), the average number of client handling activities per client visit was retained as an important association. Moving any clients with a hazardous home condition also contributed to the model (Model No.5, $p<0.0001$). There was no significant interaction between these two variables in predicting the increased risk of low back pain. Client mobility was not included in the multivariate model, since it was predictor of client handling and was on the causal pathway between client handling activity and low back pain, and was shown to be a strong indicator for client handling activity (confounding).

When the length of tenure in home care work—an indicator of cumulative exposure of physical workload—was added into the model containing average client handling activities and hazardous home condition, each of the three variables was separately associated with elevated risk of low back pain (Model No.7, $p<0.0001$).

We also examined the risks of any client with obesity, and the number of hours worked per week, but neither significantly contributed to the multivariate model. All three risk (hazard ratio) magnitudes of average number of client handling activity,

hazardous home condition and the length of home care work were similar to their values in the univariate models.

4. Discussion

This study showed that home care aides experienced a high prevalence of low back pain. Of the aides who reported low back pain, over half experienced it at least once a week or at a level of pain described as at least moderate. Over half of them used pain medication. Most of the pain was perceived as work-related or started while working in home care. Client handling, work history, and hazardous home conditions were all associated with an increased risk of low back pain. Obese clients and clients with limited mobility were also associated with an elevated risk. To our knowledge, this is by far one of the largest cross-sectional studies to describe low back pain characteristics and examine their associations with physical workload and clients' home environment factors among home care aides.

4.1. Low back pain prevalence

The low back pain prevalence among home care aides in this study (34.9%) is similar to the findings in a recent study about customer-directed home care (31%) (Faucett et al., 2013) but is generally lower than in other home care studies (Eriksen et al., 2006; Horneij et al., 2004; Johansson, 1995; Knibbe & Friele, 1996; Moens et al., 1993) which used a similar question to measure 12-month low back pain prevalence (Kuorinka et al., 1987). The wide ranges of prevalence values reported (31%-70%) may be due to the differences in workload, demographic background, heterogeneity of the different study population, or other characteristics (Knibbe & Friele, 1996). The annual low back pain prevalence in this study is lower than the annual prevalence (55%) in general nursing aides (Davis & Kotowski, 2015).

4.2. Low back pain severity and consequences

The higher percentage of moderate or severe pain among client-hired aides (70.6%) compared with agency-hired aides (46.2%) appears consistent with client-hired aides having more clients with limited mobility (73% versus 43%), and therefore more frequent client handling activity (Table 7). The finding adds to the existing evidence that client handling activities are physically challenging and could cause or aggravate MSD symptoms (Galinsky et al., 2001; Kim et al., 2010).

The proportions of aides who had at least moderate pain (58.9%) and used pain medication (69.3%) in this study were higher than in Chen's study of nursing aides (38% had intense pain, 44% seek medical care) (Chen et al., 2007). We have reported that 16% of the home care aides experienced moderate interference with their normal work from the pain. The high proportion of home care aides using medication when they had severe pain suggested that aides tend to self-medicate to continue working through this pain (Markkanen et al., 2014).

4.3. Physical workload and other work-related risks

The average number of physical activities performed during client visits was significantly higher in those who had low back pain. Of the three types of physical activities, client handling was shown to be the most influential factor for higher risk of low back pain. Performing one additional client handling activity during the client visit was associated with an 8% elevated risk of low back pain, regardless of what type of client handling activity it was. This was consistent with Marras' study, which suggested

that single person manual client transferring and repositioning tasks were extremely hazardous and were associated with substantial risk for the development of low-back injury, regardless of what actual transfer tasks were being performed (Marras et al., 1999).

Although Baron et al (Baron & Habes, 2004) mentioned that housekeeping tasks were as physically demanding as client handling, that was not confirmed here. The average number of other direct care activities was also not a statistically significant risk factor for low back pain. This might be attributable to variability in the biomechanical loading of individual physical activities: for example, putting on tight stocking, bathing or dressing, may involve important but different level of physical exposures. However, we could not collect quantitative data that would allow us to differentiate these tasks appropriately. Future research should quantify these non-handling activities for a more comprehensive analysis.

We did not treat the aides' past injury as a predictor for low back pain, although it was associated with elevated risk. It is plausible that aides who had injuries in the past are more likely to have a reduced pain threshold (i.e. more sensitive to pain) and therefore were more likely to report pain. It is also possible that past injury reflects the impact of past (and continuing) exposure, so its inclusion in the model could result in over-adjustment.

4.4. Device usage

Contrary to what one might expect, the use of a client handling device had a weak positive association with low back pain in this study. In a study about the use of lifting devices among aides in nursing homes and hospitals, Koppelaar reported a similar result,

that aides with back complaints were more likely to use lifting devices (Koppelaar et al., 2011). It is plausible that there might be a reverse causation mechanism, meaning that those aides with low back pain were more likely to use the assistive devices to reduce the workload and to alleviate the pain. Obviously, in a cross-sectional study the temporal direction of the effect is ambiguous. The interpretation of this finding is also difficult because of the survey item wording. The description in our survey "use client transfer and handling device" could elucidate an increased workload, because "using the device" does not necessarily mean the reduction of the physical exposure, reversely, it might indicate performing physically demanding client handling tasks.

The limitation of the study design or method could produce diluted or even contradictory findings about this association. It is plausible that device had no protective effect on low back pain risk because of the unique home care work. Due to insufficient training on device usage, aides may not have the knowledge to perform client handling safely. It is also possible that a small space or cluttered home environment could make the client transfer using a device more physically challenging. Therefore, using client handling might bring about more physical exposures and thus contributed to the elevated low back pain risks.

4.5. Work history

In the univariate model, the length of home care work (in years) was associated with the increased risk of low back pain, and the average number of hours worked per week retained a weak risk with marginal statistical significance. The length of home care work might be an indicator of accumulated occupational exposure in the past, and

therefore, long home care work tenure is likely to be a factor that causes or aggravates low back pain. Facucett's study found an increased risk on chronic low back pain with prolonged tenure in the job as well (Faucett et al., 2013). The average number of hours worked per week is a metric of weekly exposure time and is also associated with having low back pain in this study.

In this sector generally, cost controls have resulted in shorter home visit times, and the aides have to accomplish many tasks within the allotted time or choose to stay to complete the work on their own time (Markkanen et al., 2014; Wipfli et al., 2012). This could potentially increase aides' work intensity.

4.6. Client/home characteristics

Galinsky pointed out that the level of physical strain experienced by health care worker on the job is largely determined by the client's condition and physical limitations (Galinsky et al., 2001). This is likely also true for home care aides. In our study, having clients with limited mobility or with obesity was associated with an elevated risk of low back pain (49% and 27% higher risks than client without the conditions). In chapter Two of this thesis, we reported that in nearly half of the visits (43%) clients had limited mobility, and those visits were associated with higher frequencies of client handling activities, other direct care activities, or moving equipment or furniture. This probably leads to a higher level of physical strain. Furthermore, the size and the weight of clients could also influence the ease of moves and transfers (Beer et al., 2014).

Walking or climbing stairs (25.8% of aged 65 and above) and doing errands alone (18.5%) are the most common disabilities among the U.S population aged 65 and over

(BLS, 2014). It is suggested that interventions to increase the clients' physical capacity and providing assistive devices for client with limited mobility could potentially reduce the aides' physical workload.

In addition, many clients had hazardous home environments, including clutter, small rooms, and slippery floors. These factors were associated with 43% elevated risk of low back pain. Similarly, Zeyinoglu et.al (Zeytinoğlu et al., 2000) reported that the hazards in clients' home, including exposure to infectious diseases, clutter, extreme temperature and dim lit conditions, were associated with MSDs for visiting home care workers. The elevated risks for low back pain due to these hazardous home environment factors could be aggravated by other factors such as working alone or coping with a client who is not cooperative (Beer et al., 2014).

4.7. Summary of evidence about hypothesized model (Figure 3)

These results partially confirmed our theory that client handling activities and hazardous home conditions were associated with increased risk of low back pain, although clients with obesity did not retain an association in the multivariate model, which was probably due to the collinearity with client mobility. The length of work in home care, in the univariate model, was also associated with low back pain.

In the multivariate model, performing one extra client handling activity during a client visit was associated with a 9% elevated risk, whereas visiting a client's home with hazardous conditions increased the risk of low back pain by 48%. The consistent and independent risk magnitudes of the two factors show that client handling tasks and hazardous environments are important and pervasive hazards in home care. Considering

that about 40% of the aides have no access to equipment (Quinn et al., 2015), and that aides have little or no control over the environment, it can be inferred that these risk factors pose a strong threat for development of low back pain among home care aides. In order to minimize the risks, interventions that address client transfers are fundamental to protecting aides.

4.8. Limitations and strengths of study

Exposure misclassification: One of the limitations was possible recall bias. Aides conducted many visits and may have difficulties in accurately remembering and reporting the information about their clients. Recall bias may affect exposure estimates such as hours worked per week, activities performed, or other occupational characteristics. Furthermore, the activities' physical demand was averaged regardless of each individual task's intensity, which may shift the hazards towards or away from the null. For example, one type of activity may contain a smaller magnitude of biomechanics exposure per one unit of increment than another type of activity in calculating the low back pain risk. Therefore, the risk associated with one unit increment of the "lighter" task could be overestimated in the model.

Selection Bias: It is possible that there might be a "healthy worker effect" if those who had worked longer were more likely to quit the job due to low back pain, thus taking the less healthy aides out of the worker population. If that is true, then we could have underestimated the risk in the study. Another possible limitation was the low response rates (30%) from the client-hired aides. If the low back pain risk was higher among those missing responses, while the exposure level was the same, then the risk of low back pain

in our model would be underestimated. Cross-sectional study design is another limitation since it did not capture the temporality between exposures and low back pain outcomes. Another potential confounder of the study is that almost all male aides are in client-hired aide group. This might contribute to the underestimated low back pain risk in this group, since male aides may have fewer exposures to housework or other physical demands in their own homes.

A prominent strength is that the study was conducted among agency-hired aides and client-hired aides that captured over 1200 home care aides in Massachusetts with nearly 3500 client visits. The high response rate (84%) from the agency-hired aides was an important strength. The difference between the two sub-groups probably was partly attributable to the survey administration methods (Quinn et al., 2015). In addition, this study captured a wide range of quantitative occupational characteristics about the home care aides' jobs including physical activity performed in recent client visits, clients' health conditions and hazardous home conditions. This is more comprehensive than any other individual study (Faucett et al., 2013; Kim et al., 2010; Waters et al., 2006; Wipfli et al., 2012). The study also had advantages in its questionnaire structure. Aides could report activities and conditions separately by client, as they experienced the workload, rather than attempting mentally to average or sum a potentially diverse set of physical activities over multiple clients.

4.9. Conclusion

This study adds to the existing evidence that client handling activities and hazardous home environments are persistent risk factors for the elevated risk of low back

pain among home care aides. Prolonged length of work in home care, visits to clients with limited mobility and clients with obesity were also related to low back pain. Furthermore, the low back pain prevalence, severity level and its consequences call for further intervention to reduce the physical workload, particularly manual client handling. These findings can inform interventions studies about initial client evaluation, identification of hazardous home environments and identifying physically demanding tasks in home care. It is suggested that hazardous home conditions, client mobility and health conditions be assessed before implementing a care plan so that it protects workers as well as clients. As the aging population with disability and the home care work force kept increasing nation-wide and globally, more attention is expected to protect home care aides from injury.

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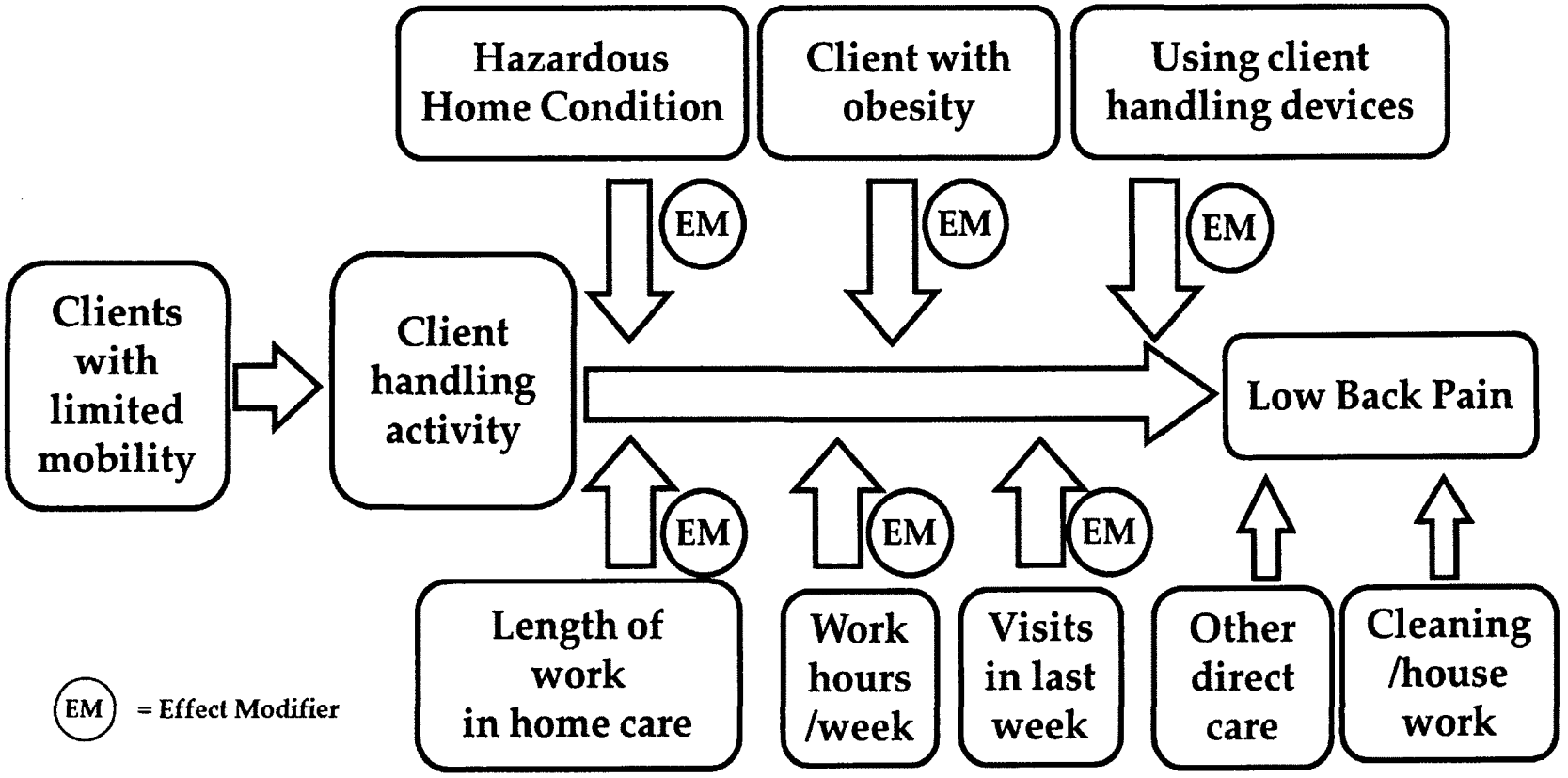

Figure2: Low back pain risk model in home care aides

Table 6: Low back pain history, characteristics, and low back injuries among agency-hired (N=634) and client-hired aides (N=615) from the Safe Home Care Survey, Massachusetts 2013

	All aides			Agency-hired aides			Client-hired aides			
Low back pain outcomes	N†	n	Per cent	N	n	Per cent	N	n	Per cent	p-value*
Low back pain history and characteristics										
Low Back Pain in the past 12 months	1202	420	34.9	613	201	32.8	589	219	37.2	0.1104
LBP frequency at least once/week	410	249	60.7	195	110	56.4	215	139	64.7	0.0879
LBP lasted for more than 1 week	409	61	14.9	196	28	13.3	213	35	16.4	0.3691
LBP severity at least moderate	411	242	58.9	197	91	46.2	214	151	70.6	**<.0001**
Require medication	411	285	69.3	199	131	65.8	212	154	72.6	0.1344
At least moderately impacts the ability to work	410	65	15.9	196	24	12.2	214	41	19.2	**0.0555**
Pain first started at work	407	304	74.7	195	145	74.4	212	159	75.0	0.8819
Pain considered work related	410	320	78.1	197	147	74.6	213	173	81.2	0.1066
Low back injury due to performing clients handling										
Injury due to client handling in past 12 months	1220	24	2.0	619	9	1.5	601	15	2.5	0.1902
Injury due to client handling before past 12 months	1220	37	3.0	619	24	3.9	601	13	2.2	0.0809

Note: * from $\chi 2$ statistics, Test of H_0: no difference of low back pain characteristics, injury reported by agency-hired versus client-hired aides. Sig.($p<0.05$)

† Denominator "N" for each row varies due to missing values.

Table 7: The low back pain in past year and the physical activity, device usage, and job loading among home care aides, Safe Home Care Survey, Massachusetts 2013

	Low back pain=yes			Low back pain=no			Mean	
Average physical activities, job loading and device usage (range of No.)	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**Difference %**	**p-value***
Total physical activities per visit (0-16)	420	8.17	3.40	778	7.72	3.75	5.8	**0.042**
Client handling activities per visit (0-5)	420	2.08	1.53	775	1.80	1.56	15.6	**0.003**
Other direct care activities per visit (0-3)	419	1.55	0.95	774	1.53	1.02	1.1	0.776
Cleaning or housework activities per visit (0-8)	419	4.56	2.10	776	4.42	2.22	3.1	0.292
Hours worked per week - All aides (0-50+)	420	25.7	16.0	782	23.6	15.9	8.9	**0.024**
Visits in past week - All aides (0-97)	386	9.97	10.06	684	9.47	9.55	5.3	0.415
Client visits (%) where device was used (0-100)	416	34.3	42.4	766	29.7	40.4	15.5	**0.065**

Note * from t-test statistics, Test of H_0: no difference in responses in group with versus without low back pain. Sig.($p<0.05$)

Table 8: Risk of low back pain with exposure to different risk factors: univariate Cox proportional hazardous regression models. Safe Home Care Survey, Massachusetts 2013

Risk factors for low back pain	Hazard Ratio	CI	p-value*
Occupational characteristics factors/indices			
Length of home care work (0-2, 2-4, 5-9, >=10) (years)	**1.10**	(1.00 - 1.20)	**0.04**
No. hours worked per week (One hour)	1.01	(1.00 - 1.01)	0.07
Number of visits made in the past week (One visit)	1.00	(0.99 - 1.01)	0.51
Ever injured due to slip in/out home or client handling (Y/N)	**2.55**	(1.98 - 3.27)	**<.001**
Average physical activity indices			
Total physical activities per visit (One activity)	1.02	(1.00 - 1.05)	0.10
Client handling activities per visit (One activity)	**1.08**	(1.01 - 1.14)	**0.02**
Other direct care activities per visit (One activity)	1.01	(0.92 - 1.11)	0.82
Clean or housework activities per visit (One activity)	1.02	(0.98 - 1.07)	0.40
Home condition indices			
Any visit with hazardous home condition (Y/N)	**1.43**	(1.18 - 1.73)	**<.001**
Any visit where client handling device was used (Y/N)	1.16	(0.95 - 1.40)	0.14
Clients' health condition indices			
Any client with limited mobility issue (Y/N)	**1.49**	(1.15 - 1.93)	**<.001**
Any client with obesity (Y/N)	**1.27**	(1.04 - 1.55)	**0.02**

*Cox Proportional Hazardous Regression Model. Sig.($p<0.05$)

Table 9: Increased risk of low back pain with exposure to potential risk factors: Multivariate Cox Proportional Hazardous Regression Models. Safe Home Care Survey, Massachusetts, 2013.

Model Number	Average number of client handling activities / visit †	Any clients with hazardous home condition †	Length of work in home care† (0-2, 2-4, 5-9, >10) (years)	Any Clients with obesity †	Chi-square	p-value
1	(1.076, 0.0178)					
2		(1.427, 0.0003)				
3			(1.099, 0.0361)			
4				(1.268, 0.0207)		
5	(1.085, 0.01)	(1.46, 0.0002)			18.79	<0.0001
6	(1.075, 0.024)			(1.277, 0.0172)	10.1	0.0064
7	(1.090, 0.0074)	(1.483, <.0001)	(1.079, 0.0935)		23.33	<0.0001
8	(1.085, 0.0123)	(1.351, 0.0047)		(1.169, 0.1431)	17.6	0.0005
9	(1.091, 0.0085)	(1.392, 0.0021)	(1.070, 0.1454)	(1.126, 0.2744)	21.19	<0.0001

† Results are presented as: (Low back pain hazard ratio, p-value). Sig.($p<0.05$)

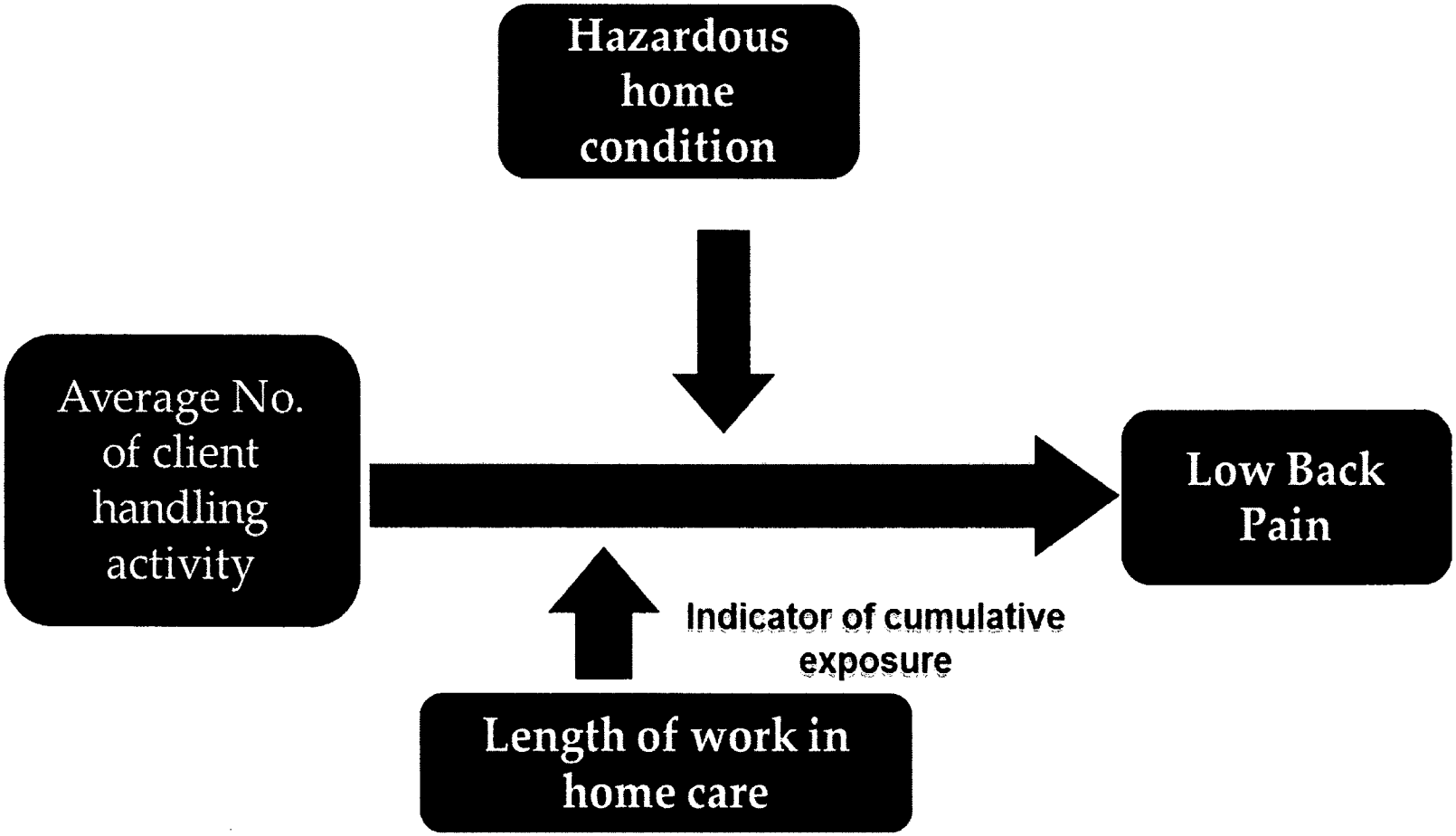

Figure3: Multivariate modeling of low back pain

IV. Ergonomic evaluation of low-tech transfer devices by home care aides

1. Introduction

Home care aide jobs are among the fastest growing occupations in the U.S. and constitute an essential workforce for our aging population (BLS, 2013). A significant part of home care aide job activities include client lifting, transferring, and other client mobility tasks (Markkanen et al., 2014,Home Care Aide Council, 2008). It is well-established that manual client lifting and transferring tasks are risk factors for low back injuries among nurses and aides in hospitals and nursing homes (d'Errico et al., 2007,Boyer et al., 2009). There is increasing evidence that these tasks also result in back pain and injuries among home care aides (Galinsky et al., 2001,Kim et al., 2010,Howard and Adams, 2010,Wipfli et al., 2012), although this group is greatly under-studied compared to hospital nurses (Davis and Kotowski, 2015). In an analysis of workers' compensation data for the State of Washington, Howard and Adams (Howard and Adams, 2010) report that between 1998 and 2007, the average claims rate for home health care workers was 1,375 claims/10,000 full-time equivalents (FTEs) compared to 862 claims/10,000 FTEs for all other industries. The proportion of home health care workers' injuries resulting from interactions with another person (89.6%) was comparable to those for nursing homes and hospitals.

Unlike in hospitals and nursing homes, home care aides often work alone with no or minimal assistance for client handling and mobility tasks and home conditions may be cluttered or otherwise constrain mobility tasks (Markkanen et al., 2014). Focus groups of home care aides and interviews with home care managers reported that there are very few client-lifting and mobility technologies that are technically and economically feasible in home care. They report that currently the most common client transfer and handling devices are slide boards and often these are not used because it is unclear which ones are the best for home care applications (Markkanen et al., 2014). In a survey of home care aides in Massachusetts, nearly 40% reported having no access to equipment to move clients (Quinn et al., 2015).

Client transfer boards (sometimes called slide boards) are assistive devices that allow a client with mobility challenges to be transferred between a bed and chair, or other similar resting places. A lab-based study that compared three different boards has shown the benefit of using transfer boards in reducing physical workloads while performing client transfers (Hess et al., 2007). Recently, new technology has been embedded into transfer boards, some of which use sliding mechanisms to replace traditional surface transfers in order to minimize the friction between the client and transfer board. The aims of this study were to: 1) assess the hand forces required to perform a home care client transfer using four different transfer boards and compare them to manual transfer; and 2) evaluate the usability of the transfer boards for practical application in home care.

2. Methods

This study used a randomized block design where the type of transfer methods served as an independent variable, the hand forces on the left and right hands and subjective responses to usability survey questions were dependent variables, and the individual subjects were treated as random effects.

2.1 Simulated home care environment (wheelchair and bed)

The client transfer simulation included a transfer from wheelchair (low) to bed (high) and a transfer from bed (high) to wheelchair (low). The study used a wheelchair that had removable armrests and footrests and the seat height was 48.2 cm from the floor that was paved with vinyl composition tile (VCT). The bed was composed of a metal frame with wheels, a box spring, and a twin sized mattress. The bed surface height was 56 cm from the lab floor. In order to facilitate the grasping during the transfer, two metal handles were attached to both sides of a 152 cm cotton medical gait belt. Both the bed surface and the wheelchair surface were covered with a 2 square foot-nylon sheet, with an aim of reducing the friction during the re-positioning task.

2.2 Transfer Boards Selection

We identified several transfer devices by conducting a comprehensive search on the internet using key words such as "patient transfer board" and "slide board." A large number of commercially available transfer boards were identified and categorized based on their design characteristics. For each category, we chose a board that appeared representative of other types of transfer boards with similar design characteristics. One

category selected was a conventional wood board, because these devices represent the types of low-tech slide boards commonly used by home care aides (Markkanen et al., 2014). We also choose transfer boards that were designed with a sliding mechanism (e.g. sliding pad, rolling parts), because it was hypothesized that they would reduce transfer forces.

Two transfer boards had different friction-reduction features were selected. The Roll Easy transfer board had wood balls installed between parallel grooves. The Beasy board provided a unique sliding feature and a rotatable pad to reduce the friction between the client and the sliding surface. In addition, we developed our own device for pilot-testing by applying a piece of Tyvek material (Dupont, 2014) on the wood board, so that the fabric could slide over the board along with the client during transfer. As a result, we adopted four transfer devices and used a manual transfer to simulate the client transfer tasks. The pictures and the weight of these transfer boards are displayed in Table 10.

2.3 Home care aide recruitment and task simulation

The recruitment criteria were that the home care aides: 1) had worked at least 3 months in any home care agency; 2) had experience with client handling activities; and 3) had no symptoms or diagnosis of low back injury or pain in the past 12 months. A total of 16 female subjects were recruited from local home health agencies. Home care aides' average (SD) age was 40.8 (10.4) years, and their work experience on average was 10.2 (7.0) years.

Before the task simulation, the homecare aides received a one-hour lesson and were given standardized instruction about how to perform the five transfer techniques.

All five trials examined the same two transfer tasks, which consisted of three parts: position the client from the back of the wheelchair (or bed) to the front edge of the wheelchair seat (or bed), transfer the client to the destination, reposition the client on the bed (or wheelchair) so that the client is safe and secure at the end of the transfer. The wheelchair to bed transfer was from a lower position to a higher position. The transfer's direction started from the aide's left side and was the same for all transfer methods during wheelchair to bed transfer. In contrast, the bed to wheelchair transfer was directed from the right to the left, beginning at the higher position of the bed and ending on the lower position. The transfer task period was defined as the interval between the apparent beginning of the hand force increases and the apparent end of the hand force decreases during the transfer.

Each subject completed the wheelchair to bed (W-B) (left-right, low-high transfer) and the bed to wheelchair (B-W) (right-left, high-low transfer) transfer using all five techniques (manual, Beasy board, Roll Easy board, wood board, and wood board with Tyvek material). The techniques were assigned in a random sequence to each aide.
Based on the research protocol, the aides were asked to follow three transfer principles: 1) Grasp the handles on the gait belt to position client as close as possible; 2) During the transfer, keep the back straight as much as possible, and flex the knees if necessary; 3) During the transfer board-based transfers, apply force in a horizontal direction instead of lifting (while using transfer boards). The client was instructed to use only minimum self-support for balance-keeping and safety purposes and was asked not to use her upper extremities to perform the transfer. One research team member who weighed 59.4 kg (131 lb) served as a mock client for all experimental trials.

Between the wheelchair to bed and bed to wheelchair transfers, each subject was given a two-minute break. The usability survey was administered by a research team member separately for each two-way transfer after it was completed. Prior to participation, all subjects read and signed an informed consent form. All study protocols and materials were approved by the University of Massachusetts Lowell Internal Review Board.

2.4 Hand force measurement

The hand forces were measured by two load cell sensors (SSM-50, Interface, Inc) that were attached in-between the cotton medical gait belt and the metal handles. During the task, the real time tensile force between the metal handles and the cotton gait belt was obtained. The analog data were transferred to an A/D board and were saved on a computer. The sampling rate for hand force data was 60 Hz. Two tripod-supported video cameras were used to record all the tasks being performed. One of the cameras were projected from the left side of the home care aides at the beginning of a transfer and the other camera was located on the right side of the aide at the end of a transfer.

2.5 Usability Survey

The usability survey was developed based on the Quebec User Evaluation of Satisfaction with Assistive Technology (Gelderblom et al., 2002) and other studies that evaluate the usage of mechanical transfers (Heacock et al., 2004). The survey was composed of open- and closed-ended questions. In the closed-ended question section, the aides were asked to respond to 19 usability questions using 5 point scales (1 = strongly

disagree, 2= disagree, 3 = neutral, 4 = agree, 5 = strongly agree) about the following items: board's design, portability, storage, cleanliness, quality, ease of use, exerted efforts, helpfulness, comfort, user/client safety, time used for preparing and transfer, learnability, and general satisfaction about the device. The average value of the responses was directly transformed into an average usability score that ranged from 1 to 5, where "1" means the response had the least fit to the usability description and "5" means it best fit the usability description. In the open-ended question section, the aides were asked to select their most preferred transfer method and were asked to describe the top three beneficial features of the preferred method as well as suggestions to improve this method. This survey is the first instrument to evaluate low-tech client transferring devices for home care aides.

2.6 Data analysis

The independent variable in this study was the transfer method, and the dependent variables included: 90 percentile hand force from the Amplitude Probability Distribution Function (Jonsson, 1982) for each hand, and the aides' feedback on the usability features during the transfers. We applied a mixed model in SAS 9.2 (V.9.2, SAS Institute Inc, Cary, North Carolina, USA) to identify significant differences in the hand force and usability scores for the various transfer methods, and we treated differences among aides as a random effect. In the statistical analysis of the usability questions, we used the Kruskal-Wallis test to examine our results from the mixed model. A change of one preference level was considered a meaningful difference in the usability rating. Qualitative comments on the open-ended questions were summarized and the frequency of the beneficial features was counted.

3. Results

3.1 Hand force

The 90th percentile hand forces during the wheelchair to bed and bed to wheelchair transfers are summarized in Tables 11 and 12. The 90th percentile left hand forces was higher in manual wheelchair-to-bed transfers than in the other transfers (Figure 4). The 90th percentile right hand forces using the Beasy board and wood board with Tyvek were lower than the manual transfer (Figure 5). The right hand force using the wood board with Tyvek was lower than wood board only transfer and marginally lower than the Roll Easy transfer during wheelchair to bed transfer. As to the bed to wheelchair transfer, the 90th percentile left (lead hand) and right hand (support hand) force using the manual transfer were higher than all other transfer techniques (Figure 6 and 7). The right hand force using the Beasy board transfer was marginally lower than using the wood board with Tyvek transfer.

From the video records and the hand force analysis, we identified that the home care aides performed a combination of lifting (vertical force vector) and sliding (horizontal force vector) during most of the device-based transfers. The leading hand (right) was lifting at the beginning of the wheelchair (low) to bed (high) transfer, where the boards formed an angle to the wheelchair due to the height difference between the bed. Then the action changed to sliding when the board was in a leveled position on the bed, at the end of the transfer. During the bed to wheelchair transfer, the video showed the aides' hands were lifting at the end of the transfer in order to keep the client balanced.

3.2 Usability survey findings

The average usability scores (AUS) resulting from the usability survey closed-ended question responses are summarized in Figures 8 to 10. Aides agreed that it was easy to place the Beasy board, Tyvek board or wood board into position compared with being neutral (AUS=3.2) about feeling easy to place the Roll Easy board under the client (Figure 10). A Kruskal-Wallis (Wilcoxon Score test) was applied and confirmed differences between transfer techniques.

The finding about effort used in the survey is consistent with the force measurement and the qualitative feedback from the open-ended questions, whereas they were neutral about exerting a lot of effort to use the manual transfer ($p<0.05$). It indicated that using the Beasy board requires less muscle exertion than the manual transfer. Meanwhile, there is a marginal difference ($p=0.1$) that the aides disagree on using a lot of effort during Beasy board transfer, while being neutral about using a lot of efforts using Roll Easy transfer (figure 9).

The aides agree it is easy to carry the wood board or wood board with Tyvek on public transportation (consistent with qualitative finding on the wood board with Tyvek), while being neutral about easy to carry the Roll Easy board on public transportation (Figure 10).

The responses to the open-ended question, *"If you were to tell another home care aide about this transfer method, what would you describe as its top 3 beneficial features*?" are summarized in Table 13:

The results suggest that majority of the aides (n=12, 75%) preferred boards with a sliding mechanism (Beasy, Roll Easy boards, wood+Tyvek). A majority of the aides

(n=14, 87.5%) preferred a device-based transfer rather than using a gait belt for manual handling. Almost half of the aides (n=7, 44%) selected the Beasy board as their preferred transfer method, and more than a third (n=6, 37.5%) of the aides thought of it as beneficial due to Ease of Use. The overall results in Table 13 suggest that, Beasy board has many more beneficial features than other transfer techniques. The Roll Easy board is the second most preferred transfer technique (N=4, 25%), where about one fifth (n=3, 18.8%) of the aides considered its Ease of Use, and thought it was easy to place under the client.

Some other results, though there were not significant differences, suggest that none of these transfer techniques make the aides worry about client falling during the transfer, nor did they find them difficult to learn how to use or required substantial time to prepare. Overall, all of the transfer boards are convenient to store in the client's home.

When looking at the total number of beneficial features described by the aides, the top 6 beneficial features were Ease of Use, Aides' Safety, Smooth Transfer, Shape and Design, Light Weight and Easy to place under the client, which account for more than 80% (39 out of 49) of all beneficial features mentioned by the aides. The top two most selected beneficial features are Ease of Use and the Aides' Safety.

4. Discussion

4.1 Hand Force.

The findings demonstrate that the usage of transfer devices in the simulated client transfer tasks substantially reduced force on both hands in comparison to the manual method for most transfer techniques ($p<0.05$). The right (lead) hand force while using the Roll Easy board and wood board during the low to high transfer was not significantly lower than the manual method.

The mean two hand forces (sum of left + right) during the wheelchair to bed and bed to wheelchair manual transfers was close to or higher than the NIOSH Recommended Weight Limits (RWL=226N for two hands, sum of left + right)(Waters et al., 1993) and were close to or higher than the industrial Maximum Acceptable Weight of Lift (MAWL) for females: 205.8N (using both hands lift from knuckle to shoulder, box width is 34 cm, vertical distance of lift is 25cm, one lift every 8hrs, 50 percentile of female population) (Snook and Ciriello, 1991).

Of all device-based transfers, the mean leading hand force while using wood board with Tyvek is the only technique below the NIOSH RWL. The mean leading hand forces using manual transfer were higher than the single hand MAWL (Female) and NIOSH limits. Considering the relatively light weight of the mock client (59.4kg/131 lbs) in our study, the actual hand forces while transferring a moderate or heavy weighted client may exceed the recommended MAWL or the NIOSH lifting limits. The findings suggest that manual lifting is risky and should be avoided, while using a wood board with Tyvek is less forceful than manual handling.

Our study results are similar to those of Zhuang et al.(Zhuang et al., 1999), where the nursing aide used similar hand forces to lift and reposition a client on the bed (no transferring). The mean two hand forces (sum of left + right) using the Beasy board to transfer heavy (757N) and light (570N) client in Zhuang's study were less than the correspondent hand force in our study (bed to wheelchair, high to low transfer). This might be due to the difference between the force vector measurement approach in Zhuang's study (vertical force measured by force plate on the ground) and the direct force measurement on the gait belt in our study (integrated vertical and horizontal hand force).

The comparison of the total hand force between the wood board with Tyvek, Beasy board and other transfer methods during the wheelchair to bed (low-high) transfer suggests that using boards with a movable sliding mechanism (such as wood board with Tyvek) has advantages in reducing hand force during low to high transfer. The observation from the video records and hand force analysis shows that aides often performed lifting during the device-based transfers, which might have contributed to the lack of significant differences between some device-based transfer and the manual transfer on the leading hand. The lifting activity during the device-based transfer might be due to the lack of compliance with the instructional requirement or inadequate practice with the sliding mechanism.

Even though a heavier simulated client would probably result in larger differences in the hand force contrast in device-based transfers, the finding suggests that transferring a client from high-low using a slide board substantially reduced the total hand force compared with transferring a client in the low-high direction. It is notable that home care

aides in the Markkanen (Markkanen et al., 2014) study recommended using mechanical beds that can be adjusted to form a level or a high to low transfer surface, thus improving ergonomics and safety for aides. However, there are two steps to be considered during a safe client transfer: One is the environment or the condition where the transfer is undertaken, the other is how to perform the transfer task itself safely. Using an adjustable bed contributes to optimizing transfer conditions, but it does not completely eliminate the need to perform the transfer. Transfer devices are still required to augment the aides own arm strength. Because mechanical beds are usually much more costly than a low-tech transfer board and are not commonly used in home care (Beer et al., 2014), they were not evaluated in this study. Therefore, considering the amount of hand force used to transfer a moderately lightweight client from a wheelchair to a bed and bed to wheelchair, the wood board with Tyvek and the Beasy board may have advantages over other device-based transfer methods as interventions to reduce hand force.

One of the concerns of this study is that there is lack of relevant hand force benchmarking for this type of work. NIOSH RWL and MAWL provide guidelines for healthy industrial workers under ideal conditions, and may not necessarily apply to client lifting and transfer task performed under conditions with restricted space (ex. between wheelchair and bed, or in a toilet).

4.2 Usability

Overall, the average usability scores about effort used during transfers was consistent with our hand force measurement. The Beasy board required less hand exertion than a manual transfer. Significant differences among the five methods were

found in 3 out of 19 usability items: easy to place under the client, effort to use and easy to carry. The relatively light weight of the wood board, with or without Tyvek, made it more portable and easier to place than the Roll Easy board. The Beasy board also had advantages in greater ease of placing the board under the client than the Roll Easy board, probably due to its sliding and rotary pad as well as its smooth shape. The lack of significant contrast in other usability items might be ascribed to the lack of power.

4.3 Limitations

One of the limitations was that the simulated home environment in this study may not reflect actual challenges that aides face in the home environment such as slippery floors and cluttered spaces. Other limitations include the small number of home care aides that participated, the lack of repeated measurement trials, and the small samples of transfer boards on the market. There are also numerous other tasks involving client transfers in the home that might require different methods and affect the results found here. Another limitation was we didn't collect information on home care aides' handedness. If handedness was a confounder, then for those who were lefty might use extra right hand force during low-high transfer, and thus increased the average right hand force value for all transfer techniques. This might introduce non-differential bias and lead the result towards to null during the hand force comparison between different transfer techniques.

5. Conclusion and recommendations

Both the Beasy board and the wood board with Tyvek covering have significant advantages over manual handling in reducing hand force during client transfers. Aides reported that the Beasy board had the highest number of beneficial features when compared to the other boards. The wood boards with and without Tyvek were easier to position under the client, easier to carry than the Roll Easy board, and also cost much less than other value-added designs (Beasy and Roll Easy). Simply adding another layer of low friction fabric on the wood board could substantially reduce the exerted hand force, compared with using the wood board alone. We suggest integrating a sliding mechanism into a transfer board design to reduce the friction between the client and the board surface. Additional recommendations include:

1. When a transfer board or other device is available, avoid manual lifting.
2. When accessible, use an adjustable bed or wheelchair to create a level surface or a downward slope, so that the client transfer can be performed on the level or from a high surface to a lower surface. Take advantage of gravity; avoid low – high transfers whenever possible.
3. Train home care aides to use a sliding action when transferring a client from one surface to another, rather than lifting the client.
4. Employ a gait belt with handles to enhance client maneuverability during a transfer.
5. Use low friction materials to modify wood transfer boards, in order to reduce the sliding friction.

While many hospitals and nursing homes are implementing technologies and practices to eliminate manual client lifting (so called "no-lift" policies) (American Nurses Association, 2013), technologies to eliminate client lifting in many home care settings are lacking. New, easy-to-use and economical technologies are needed to eliminate client lifting in home care. Until these can be implemented effectively, low-tech technologies need to be evaluated and made available in home care.

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Table 10: The type and weight (kg) of transfer boards used by home care aides

Type of boards	Beasy	Roll Easy	Wood	Wood+Tyvek
Pictures				
Weight	2.13	2.5	1.27	1.27

Table 11: Hand force (N) during transfer from wheelchair to bed (mean ± SD)

	n*	Manual	Woodboard	Roll Easy	Beasy	Wood+Tyvek
90 percentile left hand force	15	94.8±15.6	49.2±19.4	45.2±20.5	37.1±20.8	45.6±21.9
90 percentile right hand force	14	131.3±16.6	124.6±17.1	123.8±13.6	117.8±11.4	111.7±13.7

*Data for aide(s) were missing

Table 12: Hand force (N) during transfer from bed to wheelchair (mean ± SD)

	n*	Manual	Woodboard	Roll Easy	Beasy	Wood+Tyvek
90 percentile left hand force	15	114.8±18.3	85.8±13.9	80.8±12.9	74.6±18.1	80.8±14.4
90 percentile right hand force	14	75.4±9.7	32.6±13.7	28.3±13.9	25.4±12.1	36.6±18.9

*Data for aide(s) were missing

Table 13: Beneficial features of the preferred low-tech transfer techniques

	Beneficial features of the transfer techniques	MT†	BB	REZ	WB	WBT	Sum
	Preferred transfer method*	2	7	4	2	1	16
1	Ease of use	2 (12.5%)	6 (37.5%)	3 (18.8%)	2 (12.5%)	1 (6.3%)	14
2	Safe for aides	2 (12.5%)	2 (12.5%)	1 (6.3%)	2 (12.5%)		7
3	Fast/smooth transfer		3 (18.8%)	2 (12.5%)			5
4	Shape or design		4 (25%)	1 (6.3%)			5
5	Light Weight		3 (18.8%)			1 (6.3%)	4
6	Control/Easy to place under the client	1 (6.3%)		3 (18.8%)			4
7	Client safety		1 (6.3%)	1 (6.3%)	1 (6.3%)		3
8	Learnability		1 (6.3%)		1 (6.3%)		2
9	Easy to carry/storage		1 (6.3%)			1 (6.3%)	2
10	Material easy to clean		1 (6.3%)				1
11	Stable			1 (6.3%)			1
12	Simple/Need few equipment	1 (6.3%)					1
	Sum number of feature types	4**	9	7	4	3	

* Number of aides who selected a particular transfer board as their preferred method (Total 16 subjects)

** Types of the features described as the benefits for the technique (1 subject described 4 features)

† MT = Manual transfer, BB= Beasy board, REZ = Roll Easy board, WB = Wood Board transfer, WBT = Wood+Tyvek Transfer

V. Conclusion

1. Overall conclusion

1.1. Thesis summary

This study provided an ergonomic perspective on the physical workload of home care aides in the State of Massachusetts, U.S.A. Several approaches were used to conduct three studies: A cross-sectional survey of a large population of home care aides described home care aides' work organization and physical workload (Study 1), and investigated risk factors for low back pain (Study 2), low-technology transfer boards were evaluated as a tool for client transfers in Study 3.

1.2. What the thesis has accomplished

The survey collected home care aides' work organization data, information about musculoskeletal symptoms, and data about recent client visits. This provided descriptive statistics about home care aides' workload, work environment, and their clients' health conditions (Study 1). Further analyses focused on low back pain and its characteristics, risk modeling of the association between low back pain and work-related risk factors (Study 2). Lastly, the thesis – using biomechanics instruments and usability evaluation tools – proposed and piloted the usability assessment of low-tech transfer boards to transfer a client (Study 3). The thesis also proposed an outline of transfer board selection and use guidance (Appendix A) that can be used by home care agencies and aides and serve as a resource for future interventions.

1.3. Thesis major findings

The findings of the thesis suggested that aides directly hired by clients (CHAs) had less mobile clients with higher physical demands. The thesis also suggested that client handling activities, hazardous home conditions, and clients with limited mobility are risk factors for low back pain. Using transfer boards that feature an integral sliding mechanism or low-friction surface, and taking advantage of gravity (moving the client from a higher to lower elevation with a small incline) can reduce the physical demands during client transfer between wheelchair and bed. Manual client handling should be avoided.

1.4. Strength and limitations

The first two studies successfully captured a wide range of occupational characteristics, musculoskeletal strains and their work-related risk factors among the home care aides with a large population sample size and an overall strong response rate. One notable shortcoming of the cross-sectional study design is the lack of temporal direction (causality) between exposure variables and the low back pain outcome. However, the laboratory study (Study 3) provided strong scientific evidence of the plausibility for the underlying hypothesis, which demonstrated that manual client handling entails high hand forces and awkward postures that present high risks for low back strains. In addition, the quantitative and qualitative analysis of transfer boards for moving clients was the first study that evaluated the usability of low-tech client handling devices. One of the challenges in interpreting lab study results is the usability survey tools' validity, due to the absence of prior data on the psychometrics of the instrument.

1.5. Summary of study one

The first two studies were embedded in the Safe Home Care project survey. The first study documented the home care aides' work organization information and the workload, home environment, and client health information for up to five recent client visits. Home care aides' physical demands were characterized by frequent client handling activities, direct care activities, as well as cleaning and housework activities. Due to the different type of employment arrangement for agency-hired aides and client-hired aides, client-hired aides experienced higher physical demands during client visits and used client handling devices less than the agency-hired aides in the past year.

It is notable that visiting clients with limited mobility is associated with higher frequencies of client handling activities and other direct care activities. This is informative for future interventions, including evaluations of client health conditions during the planning of the care and relevant ergonomic risk evaluations. It is also important for home care agencies to recognize that they have advantages in establishing and enforcing policies that protect the aides, such as "no-lift" policies.

1.6. Summary of study two

The second study investigated the home care aides' low back pain, its characteristics and work-related risk factors. The reported prevalence of low back pain in the past 12 months is 34.9%; it was described as a frequent occurrence, moderately severe and most aides thought the pain was related to their home care work. Univariate analysis suggested that performing client handling activity alone is a persistent and strong risk factor for low back pain. Hazardous home environments, obese clients, or clients

with limited mobility would be indicative of increased levels of physical demands and thus risks for low back pain. The hypothetical multivariate model showed that risk factors for aides' low back pain included client handling activities, hazardous home conditions, as well as the length of work in home care. This confirmed that the physical strains experienced by home care aides depend largely on the condition and physical limitation of the clients (Galinsky et al., 2001).

Provided that the potential limitation in the physical task intensities calculation which would have diluted the robustness of our findings, we recommend that future studies include a comprehensive physical activity exposure measurement strategy. Also, more studies are expected to address the effectiveness of using client handling devices as interventions to reduce low back pain.

1.7. Summary of study three

The third study recruited sixteen experienced home care aides to perform client transfers between a wheelchair and bed in a simulated home environment, using four transfer boards. Firstly, we strongly recommend using an adjustable bed for home care client transferring in order to form a transfer that uses gravity instead of works against it. In most cases, hand forces exerted while using a transfer device were significantly lower than in a manual transfer. Trunk flexion velocities during use of transfer devices were consistently lower (safer) than in a manual transfer, regardless of the transfer direction. Aides perceived that boards with a sliding mechanism provided easier transfers than boards without a sliding mechanism.

An examination of the leading hand forces showed little difference between transfer boards. This might reflect that aides were relatively unfamiliar with the boards'

usage and therefore used more exertion than was necessary. If so, more practice might show a greater differentiation between boards. It is also possible that transferring much heavier clients would increase the hand forces required for different boards, and might resulted in a more clear contrast in hand force exertion between boards. In the study, we also noticed that high hand forces and awkward postures were evident not only during the client transfer but also during the placement of transfer devices under the client in preparation for a transfer. Future studies are expected to evaluate the physical workload during client repositioning as well.

In the usability evaluation survey, aides were asked to evaluate the experiences of using different transfer techniques throughout the transfer, whereas the biomechanical measurement only captured the hand force exertion during the transfer itself. Therefore, the inconsistent findings between the direct hand force measurement and self-reported exertion in the survey might be ascribable to a discrepancy between aides' perception towards efforts used and the objective measurement of the hand force during the transfer.

2. Recommendations for home care agencies

Caring for and moving less-mobile clients are physically strenuous and associated with the risk of low back pain. In order to alleviate these physically demanding tasks from the aides, and to protect aides them from preventable injuries due to manual client handling, it is suggested that home care agencies implement ergonomic risk assessments about clients' conditions and limitations and provide assistive devices when needed. Home care agencies are suggested to:

a) Initiate safety management plans to prevent MSDs injury among home care aides. This approach has been beneficial in the hospital setting and would reasonably be expected to have similar effects in home care (Hignett, 2003; Nelson et al., 2006).
b) Evaluate whether the client needs mobility assistance and determine whether client transfer assistive devices are needed for aides, before assigning aides to clients.
c) Provide and make assistive transfer devices accessible to the aides.
d) Train the home care aides to be able to know how to select proper transfer devices and know how to use the transfer devices safely during the transfer.
e) Train the home care aides to be able to identify and avoid client-handling-related ergonomic hazards during visits by using transfer devices during patient/client transfers.

3. Recommendations on select and use transfer devices

Based on our lab study, the following factors should be considered for the selection of low-tech transfer devices for home care use:

a) Ease of use.
b) Safety for the aide. For example, transfer devices with an integral sliding mechanism reduced the friction between the client and the board and make the transfer easier.
c) Thin (easy placement under the client) and wide (stable,).
d) Light in weight and easy to clean and transport.

e) Without introducing unexpected client falls and violating the intended purposes of the sliding boards, use low friction and durable materials that can reduce the work load during client transferring.

Other environmental factors also need to be considered while using the devices:

a) When accessible, use an adjustable bed or wheelchair to create a level surface or a downward slope, so that the client transfer can be performed on the same level or from a high surface.

b) Use a wheelchair that has removable armrests and footrests.

c) Employ a gait belt with handles to enhance client maneuverability during a transfer.

In our study, we found that the assurance of sufficient training and practice on the usage of transfer board is critical to effectively reduce the physical workload during client transferring. In our case, training home care aides to use a sliding action when transferring a client from one surface to another, rather than lifting the client could make a huge difference even within subjects themselves.

4. Recommendations for exposure measurement in future studies of home care aides

In order to obtain a more comprehensive understanding about the association between home care aides' physical exposures and musculoskeletal disorders outcomes, additional research efforts are strongly are recommended for the direct measurement of home care aides' physical exposure. With more resources, it would be desirable to shadow and observe postures, motions, handlings or tasks using PATH, REBA, or other exposure assessment methods.

As more and more body dynamics/posture measurement technologies are embedded into portable devices (i.e., cellphone or watch), direct measurement of home care aides' physical tasks is becoming technologically feasible. The technology could allow for a researcher to selectively track and record not only the low back or trunk dynamics, but also track exposure information on the neck, upper and lower extremity continuously for a scheduled time period. Thus, the duration, intensity (i.e., body angle changes, body segment velocity/acceleration), and the frequency of certain physical tasks could be measured in a more objective approach than using self-reported methods. Other physiological characteristics (i.e., heart rate) can also be conveniently obtained by using wireless technology.

In addition, technology will allow researchers to expand the ergonomic exposure measurements from client transferring tasks to a much broader physically demanding set of activities such as other direct care activity, housework or cleaning activities.

Furthermore, future research is also encouraged to improve the identification and the classification of different physical tasks so that it is convenient for researchers to distinguish different physical tasks with similar body postures.

5. Reference

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Appendix A

The outline of the low-tech transfer board selection guide

The outline of the low-tech transfer board selection guide

Interested audiences: Agency managers, and those who want to know how to choose low tech transfer device.

How this study was developed? -- A sketch of our study

Sixteen home care aides performed client transfer task using 4 different transfer devices and manual method to move client from wheelchair to bed and bed to wheelchair.

Why it is necessary to use transfer board?

1. Manual lifting a client is risky no matter one or two aides were helping to move.
2. Sophisticated or large powered mechanical lifts are either too expensive for the client's family, too large to be carried from one client to the next, or to fit in the client's home.
3. Using the board could reduce hand forced while transferring (from high to low transfer).
4. Reducing compression force on the low back and thus reduce the physical work load.

What features need to be considered when purchasing a low-cost transfer board?

1. Ease of use.
2. Safe for the aide. The transfer devices contain sliding mechanism to reduce the friction between the client and the board.
3. Thin (easy to be placed under the client) and wide (stable).
4. Low friction and durable material (ex. Tyvek material) that can be placed on the wheelchair to reduce the work load during repositioning.
5. Using wheelchair that has removable armrest and foot rest.

6. Light in weight and easy to clean.

What environmental setting or transfer technique will be helpful while performing the task?

1. Always take advantage of gravity and try to slide from high to low position.
2. Use a gait belt that has handles to enhance grasping.
3. No lifting, take full advantages of the "sliding".
4. Keep back straight and knee bent to reduce the moment on the low back
5. Placing the wheelchair at a certain angle (45°) to the bed so that there will be a space and slope between them.
6. Lift one leg of the client across over the other leg in order to place the board easily under the client.

What other message should managers and users take home?

1. Make sure there is always sufficient training and practice on how to use the selected board.
2. Failure to master the correct board usage method may counteract the benefits of using the transfer devices.

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EDUCATION

Sept 2011- May 2016 — University of Massachusetts Lowell, Massachusetts, U.S.A – Sc.D. – Occupational safety and ergonomics

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Mar 2007 - July 2009 — Industrial Engineer: Bosch Rexroth Company Beijing, P.R of China

June 2006 - Jan 2007 — Operation Enhancement Engineer: SMIC Beijing, P.R of China

HONORS / AWARDS

2015 — Human Factor and Ergonomic Society 2015 Conference - First Year Attendee Award –Human Factor Ergonomic Society, 2015

2014 — Harvard School of Public Health, Educational Resource Center, Research Project: Evaluation of Safe Patient Handling Devices for Use by Home Care Aides. No. 2 T42 OH008416-09, (NIOSH)

2013 — Norm LaMontangne Scholarship, American Society of Safety Engineer Greater Boston Chapter, University of Massachusetts Lowell

2012 — Professional Development Award, Graduate Student Association, University of Massachusetts Lowell

PUBLICATIONS

Sun, C., Buchholz, B., Quinn, M., Punnett, L., Gallegan, C., Gore, R., Ergonomic evaluation of low-tech transfer devices by home care aides (Submitted to Applied Ergonomics)

Sun, C., Buchholz, B., Punnett, L., Gallegan, C., Quinn, M., Evaluation of low-tech client transfer devices used by home care aides. (Podium presentation at HFES Annual Conference 2015)