Home Modification Information Clearinghouse

Evidence Based Research

The Effectiveness of Ceiling Hoists in Transferring People with Disabilities

Y. M. Jung & C. Bridge

Abstract

Objectives: This systematic review aimed to investigate the effectiveness of ceiling hoists and the benefits over other handling methods in lifting and transferring people with physical disabilities. This research will assist with the decision-making by potential users in selecting a safe and effective transfer method.

Design: The Home Modification Information Clearinghouse Systematic Review Protocol guided the entire process of this research. Its data search strategy was developed to ensure that all the important and relevant sources of information are covered. This systematic literature review incorporates searches of conventional data sources such as electronic databases and journals as well as data from legislation, regulatory documents and manufacturers' specifications. Specific inclusion and exclusion criteria were developed to ensure irrelevant studies were eliminated, maximising the reliability and validity of the review.

Outcomes of search: Twenty-three articles were examined in this systematic review. The majority of studies reviewed were from Canada, the United States of America (USA) and the United Kingdom (UK), with no previous Australian research found in the database searches. The majority of resources reviewed focused on the use of ceiling hoists to reduce the injuries and physical stress of care-givers, with less concerns being given to care-recipients. This review largely addresses the use of ceiling hoists within formal health care settings such as hospitals as they accounted for the majority of facilities reviewed in the research.

Results: This review identified strong evidence that ceiling hoists significantly decreased musculo-skeletal injuries and physical stress for care-givers. Despite a few contrary outcomes, when compared to mobile hoists and manual handling, ceiling hoists were the preferred option for both care-givers and the care-recipients. Ceiling hoists required less set-up time to fulfil the transfer task than mobile hoists. Improved manoeuvrability and reduced susceptibility to spatial restriction are well documented advantages of ceiling hoists. However, disadvantages were noted in that ceiling hoists have coverage limitations and still require some manual handling to prepare for a transfer. In spite of the relatively expensive instalment cost, ceiling hoist systems were found to be more cost-effective in the long-run.

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In producing this systematic review, the authors gratefully acknowledge the contribution both from the research review panel who gave timely and useful feedback and from the ceiling hoist industry companies who generously assisted with helpful information and materials. We also thank the Disabled Living Foundation for its permission of reproduction of hoist system diagrams.

Liability Statement

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Problem Statement

What benefits can older people with mobility limitations, younger people with physical disabilities, and their care-givers expect in terms of safety and independence from installing a ceiling hoist at home? Are ceiling hoists an effective option for moving people with severe mobility limitations?

Areas of Concern

This research strategically focuses on the following topics: sustainable care, use of assistive technologies, reduction of physical and non-physical stress among care givers, and safe transfer solutions for people with mobility limitations.

Background

In 2003, one in five people in Australia (3,958,300) reported having a disability that lasted for at least six months and restricted everyday activities (ABS, 2003). Physical disability accounted for the majority (84%) of disability, with the remainder (16%) associated with mental or behavioural disorders. Most of those with a disability (75.8%) had core activity limitations in mobility, for example, getting into or out of a bed or a chair, moving about the usual place of residence, and going to or getting around a place away from the usual residence, and in self-care, that is showering or bathing, dressing, eating, and toileting. People who suffered profound or severe activity limitations and needed assistance to perform core activities accounted for 33.4% of people with disabilities. Combined with the demand for care assistance, and with a mere 4.4% of the total people with disabilities housed in cared accommodation (including hospitals and nursing homes), there were as many as 2.6 million household carers (13% of the total population) of people with disabilities.

Ageing of the population in Australia means there will be growth in the number of people with mobility limitations as there is a strong linear correlation between disabilities and ageing (Bridge, Phibbs, Kendig, Mathews, & Bartlett, 2006). The ‘ageing in place’ policy which encourages elderly people to remain living in their homes within their local communities, raises the issue of the availability of care-givers to provide mobility assistance to people with severe functional decline in later life. However, it is likely to become more difficult for local communities to satisfy the increasing care needs of people with disabilities who require assistance. In addition, it has been reported that the physical demands of caring result in acquired disability among care-givers (Bridge et al., 2006). It is evident that discomfort and injuries among care-givers can have negative impacts on caring performance and, as a consequence, result in decreased safety and comfort of the people who are receiving care. Therefore, a sustainable care strategy should be able to reduce the risk of injury among care-givers handling people with disabilities.

As part of a safe handling approach that aims to decrease physical exertion of care-givers, various assistive technologies have been devised and an increased interest in ceiling hoists has been identified (Clark, 2003; Fischl, 2006; Nelson & Baptiste, 2004; Saville-Smith, James, Fraser, Ryan, & Travaglia, 2007). While ceiling hoists are not widely used in private homes at this point in time, a number of health care facilities have adopted this system (Doman, Rowe, Tipping, Turner, & White, 2002), because this technology is expected to support vertical and lateral transfers with minimal care-givers’ efforts. However, as a relatively recent development, there has been acknowledgement that the effectiveness of ceiling hoists is under-researched, and there is little evidence-based agreement regarding which mechanical lifting device technology is optimal (Ronald, Yassi, Spiegel, Tate, Tait et al., 2002).

Installing an assistive transfer device is an important home modification issue. An assistive transfer device aims to help older people maintain their independence, yet they are a low priority in care strategies (King's College London and the

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University of Reading, 2004). Further research is required to examine whether ceiling hoists have actual effects on the reduction in care-givers' physical burden and what kind of advantages or disadvantages they have compared to pre-existing traditional methods. This research examines the possible contribution of assistive technology to the importance of home modification projects. The outcomes of this research are expected to provide policy implications for a wider introduction of ceiling hoists in private home settings.

Risks of Manual Handling

Although lifting aids and equipment have been developed to assist in handling people with mobility impairments, manual handling remains the most common approach (Nelson & Baptiste, 2004). Manual handling is "any activity requiring the use of force exerted by a person to lift, push, pull, carry or otherwise move, hold or restrain any object" (State of Victoria, 1999, p. 2). Mobility-related tasks that require direct assistance from care-givers primarily include vertical transfers of a person and lateral transport of the person to and from a destination. Specifically, manual handling involves;

- repositioning and turning a person in bed and in chairs;
- lifting and holding the person's extremities;
- moving the person to a chair an assistive device, bath, and toilet (Nelson, Lloyd, Menzel, & Gross, 2003).

Lifting and repositioning people during bed to chair transfers were ranked as the most stressful tasks by Owen & Garg (1989). Manual movement of people with mobility limitations can be not only physically demanding, but also clinically risky to both care-givers and people receiving care (Nelson & Baptiste, 2004).

In the face of widespread manual handling activity, research has documented ergonomic risks such as the high incidence of musculo-skeletal injuries and lower-back pain[1] among nurses and care-givers. Direct patient lifting and transferring are regarded as the main causes of low-back pain among nurses (French, Flora, Ping, Bo, & Rita, 1997; Owen, 1985; Stubbs, Buckle, Hudson, Rivers, & Worringham, 1983), and these tasks expose nurses working in residential aged care and hospitals to one of the highest rates of work-related injuries (French et al., 1997). A study by Jensen (1987) revealed among twelve occupations studied, nursing aides and attendants had the highest incidence rates of back sprains and strains. According to another study, musculo-skeletal injuries occurred over 1.5 times more in home care service workers compared with all other employed women (Ono, Lagerstrom, Hagberg, Linden, & Malker, 1995).

The risks of manual handling are not restricted to the physical injuries among care-givers. The linear relationship between manual handling and non-musculo-skeletal physical stress such as headache, period pain and fatigue (Smedley et al., 1995; Tam & Yeung, 2006) or non-injurious physical discomforts to some parts of the body (Garg & Owen, 1992) has also been well examined. Handling provided by injured and uncomfortable care-givers could result in fear and collateral injuries among people receiving care such as damage in pressure areas, fractures and bruises from being dropped (Tuohy-Main, 1997). In particular, in private home settings where most carers are untrained, manual handling can lead to the loss of dignity and safety when persons are lifted under the arms and effectively dragged from bed to chair and commode (Tuohy-Main, 1997). To summarise, manual or inappropriate handling can affect quality of care (Retsas & Pinikahana, 2000) and have a negative impact on the dignity of the persons handled (U.S. Department of Labour, 2002).

1. Lower-back pain is defined as "pain lasting for longer than a day in an area between the twelfth ribs and the gluteal folds" (Smedley, Egger, Cooper, & Coggon, 1995).

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Implementation of the No-lift Policy in Healthcare Settings

A working solution to the prevalence of back pain among care-givers working in healthcare facilities is the current system of training of care-givers for safer manual handling. Body mechanics and training in lifting techniques have been employed as a preventive measure against work-related injuries, however research (Daltroy et al., 1997; Garg & Owen, 1992; Lloyd, 2006; Stubbs, Buckle, Hudson, & Rivers, 1983) indicates that educational programs alone for manual handling skills fail to prevent injuries in formal care settings in the long term, although they do have a short-term impact on reducing the frequency and severity of musculo-skeletal injuries.

The persistence of the high incidence of work-related injuries resulted in the establishment of a 'no-lifting policy'. The key concept of the no-lifting policy was to eliminate manual lifting, along with the implementation of innovative lifting programs (Edlich, Winters, Hudson, Britt, & Long, 2004) and support the maximum use of mechanical aids in formal care settings. Initiated in the United Kingdom in 1992, the Manual Handling Operations Regulations (1992) stipulated the minimum ergonomic standards with a view to reducing the risks associated with manual handling. These regulations were then embodied as a code of practice guidelines by the Royal College of Nursing in 1996 (Royal College of Nursing, 1996). In Australia, the Victorian branch of the Australian Nurses Federation (ANF) adopted a 'No Lifting Policy' in 1998 (Engkvist, 2006; Retsas & Pinikahana, 2000) which stated that "the manual lifting is to be eliminated in all but exceptional or life-threatening situations" (Australian Nursing Federation, 1998, p. 2). The ANF encourages people with mobility limitations to assist in their own transfers and use mechanical handling aids whenever possible to help reduce the risk of injuries. The no-lifting policy is regarded as representing the cultural paradigm shift (Edlich et al., 2004) in the way people with mobility limitations and handled and moved from place to place.

Use of Ceiling Hoists

With the implementation of the no manual lifting policy, the use of assistive technology has increased (Cooksey, 2004; Lloyd, 2006; Marras, Davis, Kirring, & Bertsche, 1999; Smedley et al., 1995) in that assistive technology is used to lift and transfer those who are unable or, only partially able, to bear weight between bed, chair and toilets (Evanoff, Wolf, Aton, Canos, & Collins, 2003). These mechanical devices are perceived to provide technical solutions to the potentially harmful physical stresses of manual handling and more comforts for people transferred by devices compared to manual handling (Evanoff et al., 2003; Zhuang, Stobbe, Hsiao, Collins, & Hobbs, 1999).

In general, assistive technologies supporting mobility and transfers can be categorised as mobile hoists and ceiling/overhead hoists, although a variety of models and variations are available on the market. Mobile hoists play the same role as ceiling hoists in assisting with transfers of people, with the outstanding difference being that care-givers have to push mobile hoists on their wheels to move them from one place to another. Lifting using mobile hoists can be achieved either by a hydraulic hand pump or by battery power. Ceiling hoists are different from floor-based mobile hoist in that they are operated using a powered lifting mechanism and they are suspended from mounted tracks fixed to the ceiling. The hoist allows the person with a disability to be placed in a sling which is suspended from a track and then transferred vertically and horizontally within the coverage of the track. There are two types of ceiling hoists, depending on the lifting unit: fixed or portable. While fixed hoists are permanently attached to a ceiling track, portable hoists can be attached and detached from the ceiling tracks.

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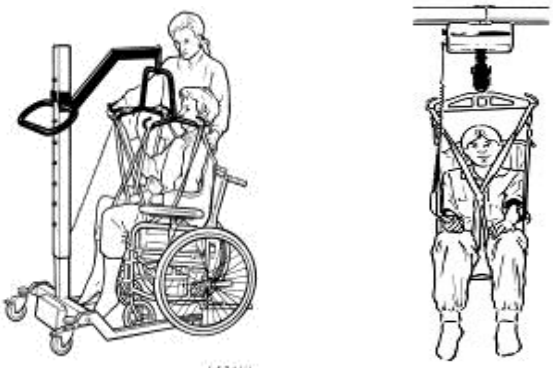

Figure 1. Mobile (left) and ceiling (right) hoists[2]

Ceiling hoists are considered to have many advantages over traditional manual handling and mobile hoists in that they can accomplish transfers in limited spaces with fewer care-givers (Lloyd, 2006). Ceiling hoists do not occupy floor space and care-givers can be free from physical exertions during the transfer. By installing ceiling hoists, it is expected that there would be a significant reduction in the amount of physical activity in handling people with physical disabilities (Hall, 2002). Mobile hoists also contributed to the reduction in injury rate and musculo-skeletal discomfort (Collins, Wolf, Bell, & Evanoff, 2004; Li, Wolf, & Evanoff, 2004; Nelson & Baptiste, 2004; Ulin et al., 1997). However, Garg and Owen (1992) gave opposing evidence that some mobile hoists did not result in reduced physical stress on care-givers, as the motions required to place and remove the slings underneath the persons transferred, raise and lower the hoists and prevent the probable sway of the persons in slings can cause postural stress. Despite the use of mobile hoists, demanding physical exertions still remain, particularly in pivoting and lateral movement when the person is loaded and being moved (Villeneuve, 1998). Hall (2002) summarised the advantage of ceiling hoists over mobile hoists as follows: "All that is required of the handler is to operate a handset and guide the carry bar into place, without the need to support the weight of either the client or the carry bar. This reduces the pushing and pulling forces that can be involved in moving a mobile hoist into position. Furthermore, because an overhead hoist uses mains electricity, there is no need for bodily force to be used in manually 'pumping' a hydraulic hoist or removing a battery for recharging purposes" (Hall, 2002, p. 490).

Evidence Based Practice Search Methodology

Question refinement strategy

The Protocol guidelines for systematic reviews of home modification information to inform best practice (Bridge & Phibbs, 2003) developed by the Home Modification and Maintenance Information Clearinghouse guided this systematic review. The outstanding advantage of this protocol is that it fits the home modification and occupational therapy perspective, focusing on the triangular composition of person-environment-activity. Along with the traditional systematic review data sources of peer-reviewed journal articles, this protocol is inclusive of legislation and regulatory documents and manufacturer specifications.

Complying with the Home Modification Information (HMinfo) Clearinghouse's systematic review protocol, the research question was refined into an operational format which comprises five key areas; problem, intervention, comparison,

[2] These pictures were reproduced with permission of the Disabled Living Foundation.

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outcome and target population. This format ensures that all the important and relevant information about the effectiveness of ceiling hoists is covered.

Table 1. Researchable question components

Problem				
Effectiveness	Ceiling hoist	Manual handling	Increased transfer safety	People with mobility limitations
		Mobile hoist	Increased independence	
			Improved quality of care	

The list of keywords and relevant synonyms in each area were extracted from a thesaurus and a preliminary search was made on electronic database and search engines. The search terms were structured based on the person, environment and activity variables. They were used to develop a matrix form which records and codes all the reviewed material.

Table 2. Search Terms

Environment		
Ceiling hoist	Old/older	Lift
Ceiling lift	Aged	Transfer
Ceiling mounted lift	Elderly	Bed to chair
Lifting equipment	Mobility	Bed to toilet
Overhead ceiling lift	Physical	
Mechanical lifting device	Disability	

Search strategies for identification of publications

HMInfo's systematic review protocol has established a wide range of electronic databases to ensure that a comprehensive search was undertaken and all articles of relevance were searched. All the following databases, which have been identified as having the highest potential relevance, were searched. Additionally, the Google search engine was used to scope the information available on the Internet.

- HMinfo Library
- Ageline (Ageing in psychological, health-related, social, and economic
- AMED (allied and complimentary medicine)
- APA-FT: Australian public affairs
- APAIS - Health
- ARCH (Architecture)
- Avery Index to Architectural Periodicals:
- BUILD: Australian Building Construction and Engineering Database
- CAB Abstracts (agriculture, agronomy, crop protection, dairy science, and environmental
- Geobase (physical and human geography, geology, mineralogy on the Science Direct platform)
- Health and Society
- Inspec (physics, electronics, electrical engineering, computer)
- LexisNexis (legal, news, business information service)
- Medline via Ovid (allied health, health care, medical, biological, physical sciences)
- Mediascan (selective topics in Australian newspapers)
- Oshrom – HSELINE, MHIDAS, RILOSH, CISDOC,

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degradation)

- Cinahl (nursing and allied health)
- Cochrane Controlled Trials Register
- Current contents via Ovid (science, social sciences, arts and humanities)
- Dissertation & Thesis Full Text
- EVA: Environmental abstracts
- Expanded Academic Index ASAP (humanities, social sciences, environment, science & technology)
- Family (family and society)
- NIOSHTIC (health, safety, toxicology, environmental health, biohazards)
- Proquest 5000
- PubMed (medical and life sciences)
- Science Direct (life, physical, medical, technical sciences)
- Sociofile/Sociological abstracts
- University of Sydney Theses
- Web of Science (science, social science, arts and humanities)
- Google Web Search

In relation to manufacturers' specifications, the databases of the Independent Living Centres Australia (ILC) was searched to obtain ceiling hoist manufacturers' and suppliers' details. Personal correspondence was sent to a selection of ceiling hoist manufacturers regarding the advantage and evidential proof of the effectiveness of installing ceiling hoists. For legislative and regulatory documents, the Australian Nursing Federation in Australia, the Health & Safety Executive in the UK and Occupational Safety & Health Administration in the USA were searched.

Operators

The following operators were used in the electronic databases to expand or limit the search.
AND, OR, NOT, WITH, NEAR, IN, ADJ, FREQ, SAME, W/nn, PRE/nn

Truncation symbols

Along with the operators, the following symbols were used during the electronic database searches.
*, $, ?, # (dependant upon database searched)

Inclusion & exclusion criteria

Inclusion and exclusion criteria were consistent with the HMinfo's systematic review protocol. Material was included if it was: (a) accessible through the University of Sydney Library network or the World Wide Web, (b) written in English, (c) a humanity study, (d) published after 1970 on the ground that the use of electronic assistive technology for the transfer of people with disabilities is a relatively recent phenomenon.

A number of materials were deemed inappropriate to be reviewed. Materials such as general or whole of subject books, editorials and conference abstracts were not included in this review. Manufacturers' specifications did not contain evidential proof for the effectiveness of ceiling hoists, offering only information and instructions for installation of the systems, and were therefore excluded from this review. Some regulatory documents including Health and Safety Executive (1998) were excluded as they related to generic lifting equipment, intended more for industrial hoists. They were not directly relevant to the efficacy of ceiling hoists for human transfer. International Standard 10535 (2006) dealt with the hoists for the transfer of people with disabilities, but the major concerns were the technical requirements and

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test methods for the hoists. Documents that described only the features or characteristics of ceiling hoists were also excluded as they did not satisfy the methodological criteria.[3] Studies (Nussbaum, Chaffin, & Baker, 1999; Nussbaum, Chaffin, Stump, Baker, & Foulke, 2000; Resnicka & Chaffin, 1997) which applied scientific approaches but were not relevant to human handling were also excluded.

This systematic review also excluded studies in which the objects of examination were equivocal in relation to the terms used for ceiling hoists and mobile hoists, calling the devices for instance generic mechanical lift, technical lifting aids or transfer equipment. In general, mechanical lifts referred to mobile lifts or floor lifts. Studies where distinction between "mobile" and "ceiling hoists" was clear yet it was difficult to separate the effects of the individual devices due to combined intervention (Engkvist, 2006; Nelson, Matz et al., 2006; Rolfson, 2004), these were also rejected for review. The following figure illustrates the search process and the final number of articles included in this study.

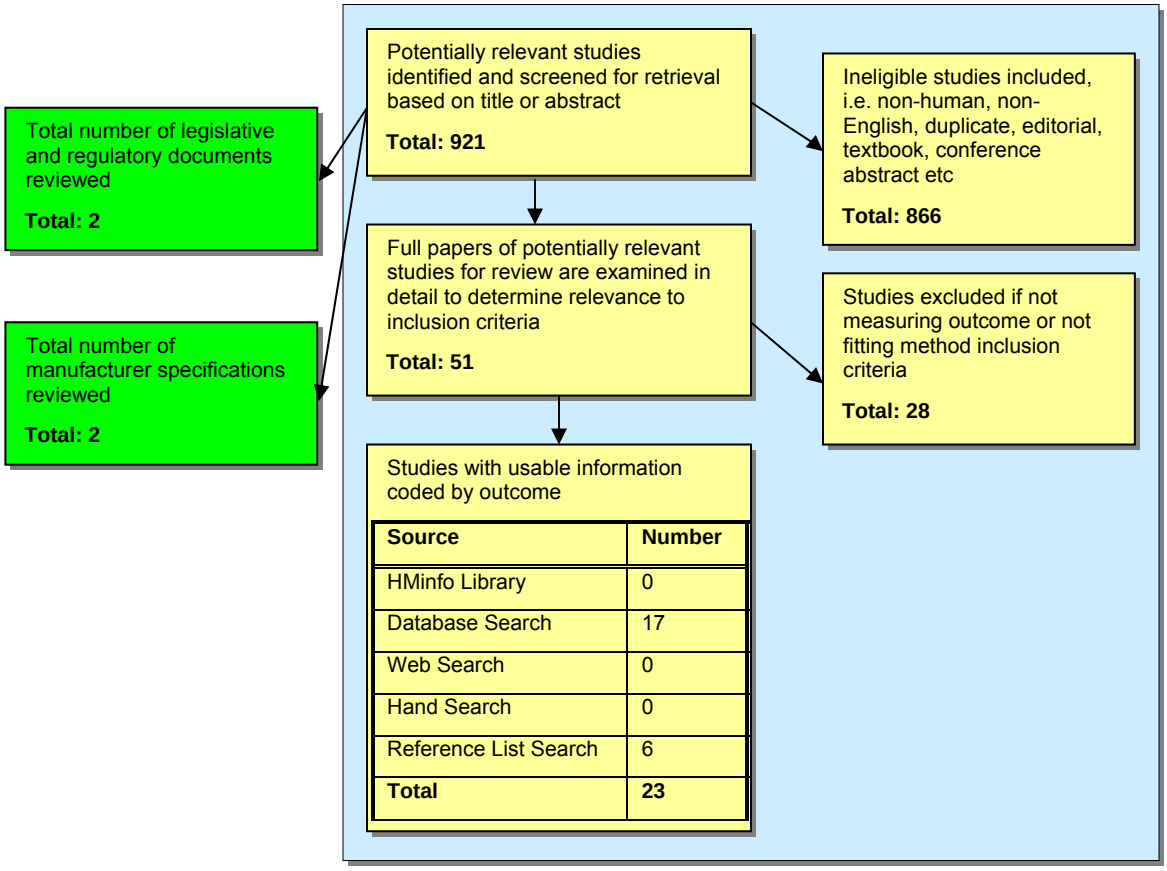

Figure 2. Review process flow

[3] A systematic review typically is associated with hierarchies of evidence (Bridge & Phibbs, 2003), which are based on the methodology employed. In conjunction with the methodology, a judgement could be made of the validity of the study. This systematic review applied seven levels of methodology, with systematic review being the highest and anecdotal evidence the lowest (see the analysis matrix in the Appendix 2). Materials applying methodologies that did not fit any levels of the systematic review methodology were deemed to lack evidence and, thus, excluded.

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Outcomes of Search

The stated research problem required information and knowledge across a number of disciplines including building and construction, biomechanics and human movement. The electronic databases that produced relevant material included: Ageline, AMED, Cinahl, Mediline, and OSH-ROM. Approximately a quarter of the studies reviewed were from reference lists. In total 23 papers were reviewed - see Appendix 2.

The studies reviewed covered a time span of 17 years. The earliest study was published in 1989 and the most recent in 2006. The majority (83%) were published after the turn of the century (2000), which indicates that the interest in ceiling hoists is a very recent trend. The following analysis examines the results in terms of nationality, person, activity and environmental variables, and methodologies employed.

Nationality

Figure 3 illustrates the breakdown of the material reviewed by the authors' country of origin. Although this systematic review only included sources written in English, it is acknowledged that a very small pool of nations including Canada, the United States of America (USA), and the United Kingdom (UK) is leading research on technological transfer solutions. The surprising result is that no research on ceiling hoists conducted in Australia could be included in this review, despite Australia having similar health care practices to the countries where research is being undertaken (Bridge et al., 2006). This is not due to a total lack of research on ceiling hoists in Australia; some studies were excluded on the grounds that they did not satisfy the methodological criteria of this review. For example, the study by Shepherd et al. (2007) was excluded as the attribute of ceiling hoists could not be separated from those of mobile hoists. Engkvist (2006) and Pinakahana (2000) were deemed to be less relevant because their main focuses of investigation were the no-lifting policy or manual handling. Engkvist (2006) evaluated the wider no-lifting policy program, with mobile hoists being used as intervention equipment, while Pinakahana (2000) studied manual handling exclusively. It is not assumed that the outcomes from the Australian research will be substantially different from those of other countries. However, this finding clearly points to the necessity for extensive research to explore the effectiveness of introducing new technology in formal and informal care settings.

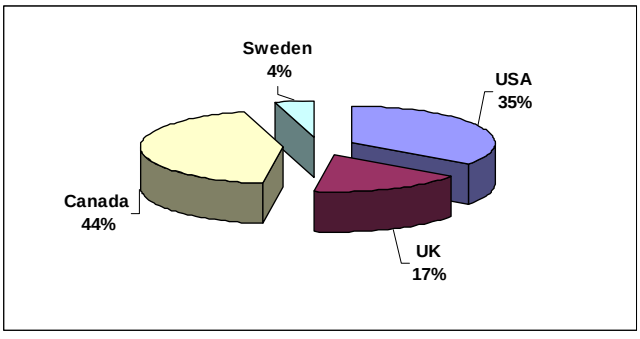

Figure 3. Nationality of literature reviewed

Analysis outcomes of content variables under review

The effectiveness variables identified in this systematic review were categorised into physical stress of care-givers, non-physical stress of care-givers, comfort and safety of care-receivers, transfer time, cost and others. This category was established based on the preliminary literature review and served as a framework for evaluation of the ceiling hoist

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intervention. The greatest concern of the resources reviewed was whether or how much ceiling hoists could reduce physical stress among care-givers. Most (83%) of the papers examined changes in the incidence of musculo-skeletal injuries and related physical stress among care-givers after implementing ceiling hoist-assisted handling. Relatively less interest has been taken in the other variables such as non-physical benefits, transfer time, and cost. It should be noted that to date, priority has been given to the safety and comfort of care-givers rather than care recipients. This result suggests that more research investigating the efficacy of ceiling hoist for people transferred, should be conducted in the interest of a balance between information regarding care-givers and care-receivers.

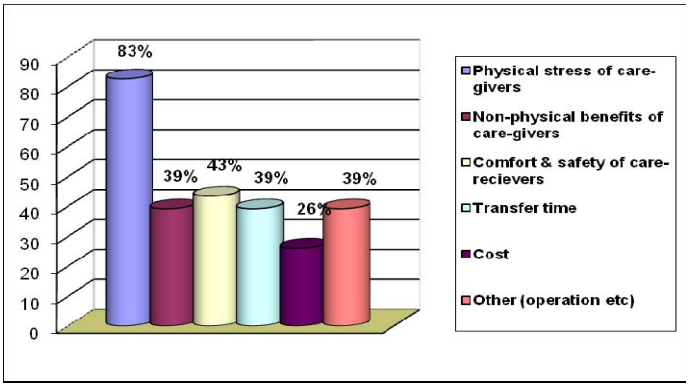

Figure 4. Effectiveness variables

The variables within each study reviewed were coded as activity, person or environment. The variables identified as 'activity' included lift (vertical handling), transfer (lateral handling), repositioning (pulling or pushing in the bed) and general handling. The breakdown of handling activity is pertinent as it is expected that different handling methods require a differing pattern of activities which, will have various impacts, on the outcomes of the method employed. In addition, even with the same method, different action will require various movements by care-givers and levels of force from parts of the body. A large percentage of the studies (82%) reviewed, examined the physical exertion of care-givers when using ceiling hoists through a range of handling activities. Lifting was the main focus, followed by transfer and repositioning, with lifting cited as the main cause of back injuries experienced by care-givers (Wicker, 2000).

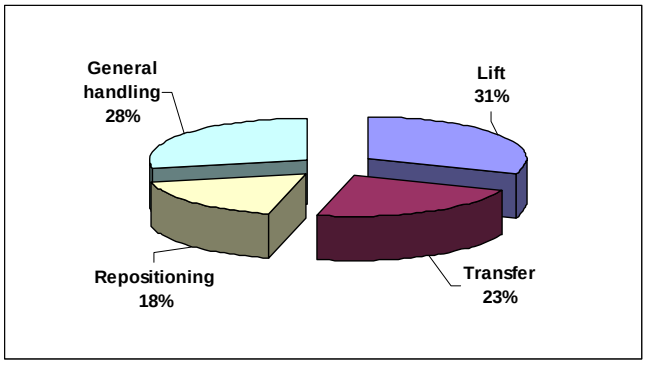

Figure 5. Activity related variables

In relation to the persons who were identified in this review, it was expected that person-related variables would give broad information about which kind of disability ceiling hoists have been used for. However, the outcome was insufficient to understand the use of ceiling hoists by types of disability. About half of the studies (52%) did not identify the characteristics of the users' disabilities, with several studies (16%) employing people with no disability or a

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mannequin as experiment subjects for laboratory simulations. Based on the studies that identified the disability types, ceiling hoists were, in general, used or introduced for those who were aged or people with spinal injuries and cerebral palsy.

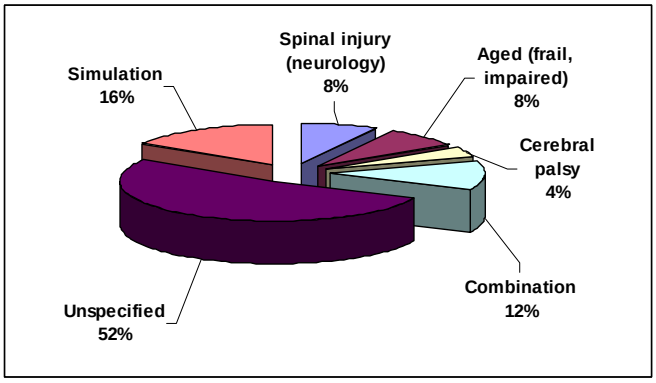

Figure 6. Person related variables

Except for the studies that did not specify the place of the research or a laboratory for scientific tests, hospitals accounted for the majority (53%) of the facilities. This does not necessarily indicate that ceiling hoist systems have been adopted most by hospitals rather that hospitals were more commonly reported as participating in the research examined in this systematic review. However, it is acknowledged that hospitals have been the major consumers of ceiling hoists. This is unsurprising as ceiling hoists were devised to serve people who suffer from severe mobility limitations. The issue that should be given noted regarding the implication of this result is that ceiling hoist systems have not been widely used in private homes. Ceiling hoist systems were initiated because of the high incidence of back injuries among nurses in formal care settings; based on this, it is surmised that ceiling hoists were not an important consideration for people who receive care at home and their care-givers. This outcome raises academic and policy development issues for a wider application of the system, particularly in conjunction with the policy of 'ageing in place' and home modification.

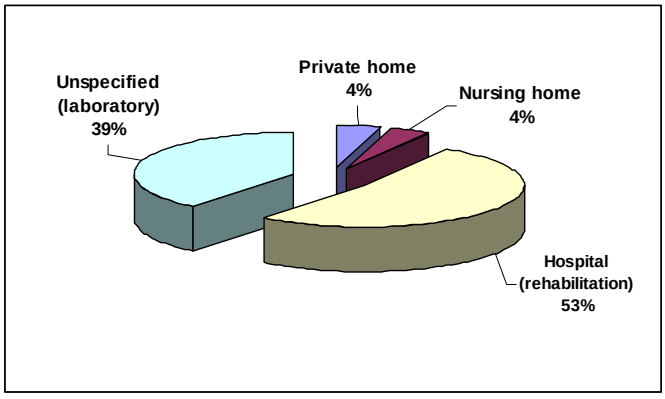

Figure 7. Environment related variables

Quality of evidence for attributing outcomes

It is regarded that a high form of research evidence has been located in this systematic review. About two out of three studies (66%) included in this review employed quasi-experimental research designs, that represented a higher level in the hierarchy of evidence (Baldwin, Wallace, Croucher, Quilgars, & Mather, 2002). Many experimental studies made

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efforts to establish true experimental design (Randomised Control Trial), establishing an experimental and a control group. However, it was practically impossible to apply both random sampling and random assignment, and control the external influences. Five studies applied a motion analysis system using, for instance, an electronic myograph to record the level of physical exertion. Expert opinion comprised 17% of the total, followed by anecdotal evidence 9% and systematic review and case study 4% each. Figure 8 illustrates the methodology types of the included articles.

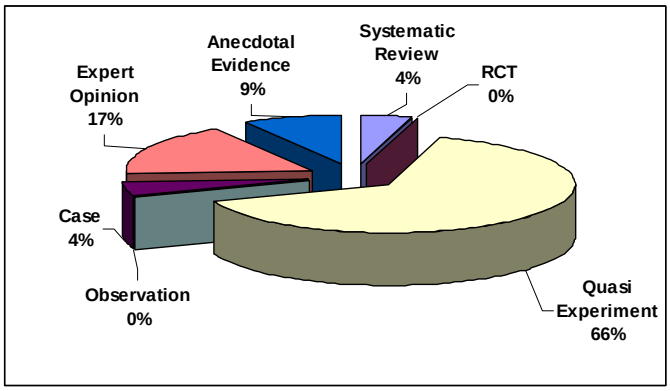

Figure 8. Methodology

Effectiveness of Ceiling Hoists

Most of the studies that examined the effectiveness of ceiling hoists focused on limited aspects. For a comprehensive evaluation on the effectiveness of ceiling hoists, a reliable and inclusive evaluation framework needed to be developed. This review established a framework, based mainly on the studies of Garg et al. (1991) and Nelson et al. (2006). While not including ceiling hoist intervention, Garg et al. (1991) highlighted the comparison between manual and mobile hoists, and set the first comprehensive framework for ergonomic evaluation of handling methods. The latest synthetic design was found in the study by Nelson et al. (2006). Both studies provided essential standards of evaluation to reach an ideal solution for the handling of people with mobility limitations. The frame of this review includes the following aspects of the efficacy of ceiling hoist: physical stress of care-giver, non-physical benefits of care-giver, safety and comfort of care-recipient, dependency of care-recipient on care-giver, transfer time, spatial utility, and cost-effectiveness.

Physical stress of care-giver

Musculo-skeletal injuries

One of the major expectations regarding the use of ceiling hoists would be a decrease in musculo-skeletal injuries among care-givers, as this has been the overarching reason for introducing ceiling hoist systems. As a whole, the research included in this review (Chhokar et al., 2005; Engst, Chhokar, Miller, Tafe, & Yassi, 2005b; Ronald, Yassi, Spiegel, Tate, & Mozel, 2002; Silverwood & Haddock, 2006; Spiegel et al., 2002; Villeneuve, 1998) has provided supporting evidence for this, reporting similar results that ceiling hoist interventions significantly reduce the incidence and perceived risk of injuries. In particular, injury reduction was obvious in split-level facilities, as Miller et al. (2006) observed a 70% decrease in injury claims, compared with the control group that experienced a 241% increase. However, it is worthy of note that the effectiveness of ceiling hoists in reducing injury differed depending on handling tasks. Compared with apparent injury reduction by the use of ceiling hoist in lifting and transferring (Engst, Chhokar, Miller, Tafe, & Yassi, 2005a; Spiegel et al., 2002), the injury occurred during repositioning decreased relatively less (Spiegel et al., 2002) or did not change significantly (Ronald, Yassi, Spiegel, Tate, & Mozel, 2002). Rolling a person either toward or away, to prepare for a transfer, is considered to be the most stressful action when using ceiling hoists

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(Zhuang, Stobbe, Collins, Hsiao, & Hobbs, 1999). The ceiling hoist's less-effectiveness in reducing injury during the repositioning task was contradicted by the longer term pre and post evaluation of ceiling hoist intervention by Chhokar et al. (2005) which, demonstrated that the incidence of musculo-skeletal injury decreased significantly in all the handling tasks including repositioning. However, it is admitted that injury reduction by ceiling hoist in repositioning can be identified in a longer-term observation than in lifting and transferring.

Physical stress: potential risk factors

Physical stress relating to ceiling hoists has been examined in two ways: either through care-givers' ratings of perceived exertion or using measurement technologies such as an electro-myograph.[4] Regardless of the method of measurement, the level of physical activity and bodily force required for transfer were considerably reduced by choosing ceiling hoists, compared with manual handling and mobile hoists. According to the study by Holliday et al. (1994), care-givers perceived that physical exertion decreased significantly by about 20% with the use of ceiling hoists compared to mobile hoists. The use of ceiling hoists were found to reduce not only back pain but also care-givers' perceived risk of injury and physical discomfort to body parts such as neck, shoulders, upper and lower back, arms, and hands (Engst et al., 2005b; Miller et al., 2006; Smith et al., 2002). The study by Ljungberg et al. (1989), one of the earliest scientific studies to examine the efficacy of ceiling hoists, revealed that ceiling hoists reduced the lifting work by approximately 50% compared with traditional lifting methods including manual lifting and mobile hoists. They observed that cumulated forces and total time required for lifts also dropped significantly. Using a 3-D electromagnetic tracking system, Nelson et al. (2003) verified the reduced postural demands over mobile hoists, demonstrating that the implementation of ceiling hoist handling significantly reduced the lumbar force and joint moment[5] of shoulders by 58% and 57% respectively during bed-to-chair transfer. The laboratory experiments conducted by Keir and MacDonell (2004) which used surface EMG (electro-myograph) data, also established that ceiling hoists required the least muscle activation, followed by floor lifts. Combined with the transfer time, they concluded that transfer using the mobile hoists required the most muscle activity. Decreased spinal and lower back load with the use of ceiling hoists was supported by the laboratory tests of Santaguida et al. (2005) and Zhuang et al. (1999).

With a wider acceptance of reduced physical exertion with ceiling hoists, it is also noteworthy that a ceiling hoist is more effective in dealing with heavier persons. Combined with an ergonomic technique, ceiling hoist could also reduce physical stress during repositioning task. Rolling them away requires less lower-back compressive force than rolling them toward before placing the sling under the person (Zhuang, Stobbe, Collins et al., 1999). Thus, the effectiveness of a ceiling hoist's physical stress reduction can be maximised in combination with a heavier person transferred and the pushing motion.

Absence from work

Observed injury, non-injurious physical tiredness, pain and symptoms may result in absence from work. Absence of a care-giver is directly linked with the reduction of care and recruitment of replacements, resulting in extra cost. Research has indicated that decreased physical stress associated with ceiling hoists has led to a decrease in physical pain, doctor's visits, medication use and painful manual lifting work for carers (Ronald, Yassi, Spiegel, Tate, & Mozel, 2002; Silverwood & Haddock, 2006) and, as a consequence, a reduction in the rate of employee absenteeism due to injury. Silverwood and Haddock (2006), Chhokar et al. (2005), and Villeneuve (1998) identified a significant decrease in the

4. Bipolar surface electrodes were affixed over the parts of the body to record physiological responses generated by muscle cells when these cells contract, and also when the cells are at rest (Keir & MacDonell, 2004).
5. Lumbar force refers to the pressure placed on the inter-vertebral discs due to forces generated during lifting or maintaining a posture, and joint moment means a force that produces or tends to produce rotation (Nelson et al., 2003).

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number of work days lost during pre and post intervention. Similarly Miller et al. (2006) observed a decrease of 18 days, while there was an increase of 499 days lost in a comparison group at the end of one year intervention.

Non-physical benefits to care-givers

Most of the research on ceiling hoists has focused on the reduction in physical risk factors for care-givers. As a result, there is less evidence on, for example, improvement in care-givers' comfort and satisfaction based on surveys of care-givers. Although an earlier study by Holliday et al. (1994) could not identify the significant difference in care-giver comfort with ceiling hoists, most of the recent research (Engst et al., 2005b; Miller et al., 2006; Nelson et al., 2003; Villeneuve, 1998) reported an improved subjective comfort among care-givers. A survey of hospital nurses who experienced ceiling hoists conducted by Engst et al. (2005) demonstrated that ceiling lifts were the most favoured (71.4%) during the transfer between bed and chair, compared with manual transfer (25.7%) and floor lift (2.9%). Job satisfaction also increased significantly after ceiling hoist intervention. Miller et al. (2006) indicated enhanced job satisfaction among staff working in a long-term care facility, showing that that 75% of those who had experienced ceiling hoists ranked ceiling hoists first as a preferred transfer method, the majority of whom (82%) agreed that ceiling hoists have made their jobs easier to perform. Santaguida et al. (2005) and Villeneuve (1998) also observed higher unequivocal preference for ceiling hoists among care-givers rather than free-standing mobile hoists as ceiling hoists were perceived to be safer and more comfortable for people transferred. Another reason for a greater preference for ceiling hoists was that ceiling hoists improved the efficiency of lifting and transferring activities and the subsequent quality of care. According to Edlich et al. (2004, p. 526), ceiling lift systems allow care-givers more free time in handling people with disabilities, and as they require less assistance in executing the transfer, this facilitates more time to provide care. Compared with mobile hoists, the total time saved when using ceiling hoists amounted to approximately 50% of one full-time staff per nursing unit (Holliday et al., 1994).

Safety and comfort of the care-recipients

However beneficial to care-givers it may be an assistive device that makes the care-recipients feel unsafe or uncomfortable would only be partly successful. Safety of the care-recipient and access to high quality care should be the overarching priority when choosing assistive technology (Yassi & Hancock, 2005). Garg and Owen (1992) previously reported that some mobile hoists do not necessarily increase comfort and security for the care-recipients, compared with manual methods, because the lateral swing during the transfer makes the care-recipient feel uncomfortable and insecure. As a whole, evidence suggests that ceiling hoists have advantages over other methods in terms of user safety and comfort. Many studies reported increased comfort during transfers and identified a preference for ceiling hoists among the care-recipients (Ronald, Yassi, Spiegel, Tate, & Mozel, 2002; Smith et al., 2002; Villeneuve, 1998), as it is believed that ceiling hoists also facilitate dignity, comfort and safety (Steed & Tracey, 2001a). Engst et al. (2005) reported that most staff (about 85%) believed ceiling hoists to be safe and effective for the care-recipients. A survey with residents in a long-term care facility by Ronald et al. (2002) indicated that residents' satisfaction increased from 80% to 95% after ceiling hoist installation and their comfort during movement also increased. This was particularly true for larger persons who require higher levels of assistance when transferring and are more likely to be of risk of falling (U.S. Department of OSHA, 2002). Persons can be raised high enough by ceiling hoists to be safe from obstacles, which can prevent tissue damage caused by the body coming into contact with solid and rough obstacles (Collins, 2002). However, research has not come to a complete agreement about this matter as opposing results have been identified. Holliday et al. (1994) and Santaguida et al. (2005) could not determine significantly improved comfort of

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the care-recipient with ceiling hoists, compared to mobile hoists. Ceiling hoists were also perceived as unstable by some care-recipients.

By installing ceiling hoists, care-recipients can expect accompanying positive effects to their physical opportunities. Ceiling hoists allow people who were bedridden or in the chair to broaden their sphere of action, which leads to improvement of physical function including muscle strength, digestive tract, and so forth (Anonymous, 2004). Ceiling hoists were effective for clinical purposes, particularly for vestibular activities, as particular hoists can be used to assess standing tolerance, balance and orientation as well as working practice (Hall, 2002).

Dependency on care-giver

One of the advantages of using mechanical devices, is that they require fewer care-givers to fulfil the transfer tasks, decreasing care needs of people with disabilities. Evidence suggests that ceiling hoists can safely lift and transfer people with mobility limitations with the least additional help; portable hand controls allow the person transferred to operate the device independently during the transfer (Hall, 2002). The study by Holliday et al. (1994) showed that ceiling hoists allowed transfer to be performed independently by one nurse, although on occasion assistance was needed for executing the lift, whereas transfer using mobile hoists required the equivalent of one and a half staff. Smith et al. (2002) and Silverwood and Haddock (2006) also concluded that compared with manual handling, even less staff are needed to manage a person with the use of a ceiling hoist. Their observation suggests that with the use of a ceiling hoist, one nurse can fulfil the lifting and transferring tasks, which required two to four with the absence of assistance from a hoist. If people with reasonable levels of mobility can fit the sling themselves, independence in preparing for transfer is possible (Steed & Tracey, 2001b). With less assistance from care-givers, people receiving care can increase their feeling of self-control, increasing a sense of independence (Villeneuve, 1998). An increased participation in daily activities coupled with a decreased dependency on care-givers, gives people with mobility limitations an improved self-esteem resulting in an improved quality of life (Anonymous, 2004).

Transfer Time

Some research has examined the transfer time of various handling types, but there has been little numerical comparison between transfer methods to provide evidence in favour of ceiling hoists. Garg et al. (1991) revealed earlier that some mobile hoists took longer (on average 150 seconds) than a two-person manual lift (on average 15 seconds) between bed and chair transfers. This would make sense because lifting using mechanical devices requires time for locating the equipment, preparing the person and sling, and removing the sling to take down the person. Ceiling hoists are expected to require similar time to mobile lifts.[6] Santaguida et al. (2005) discovered that applying and removing the sling occupied 59% of the total transfer time when mechanical devices were used. This process can be omitted in manual lifting therefore leading to a reduction in time taken.

In terms of the comparison of transfer time between ceiling and mobile hoists, a pilot survey by Holliday et al. (1994) did not detect significant difference in the actual speed of lifting itself between ceiling hoists and mobile hoists. Contrasting laboratory tests have been conducted to compare the transfer time between overhead and floor devices during bed-to-chair transfers. While Smith et al. (2002) and Keir & MacDonell (2004) illustrated that ceiling hoists needed only two

6. ISO 10535 (2006) recommends that the speed of the horizontal movement when using ceiling hoists should be limited to 0.3m per second in the interest of safety.

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thirds of the time required for floor-based mobile lifts during bed-to-chair transfers, Santaguida et al. (2005) detected no significant time differences between the two devices. However, expert opinions and a systematic literature review (Nelson & Baptiste, 2004) suggest that ceiling hoists require less time for transfers than mobile hoists. In a real situation such as in a crowded hospital ward or furnished home room, the length of time required by mobile hoists may increase while negotiating obstacles on the floor and moving furniture (Webster, 2001). This indicates that time does not have to be compromised for safety to carry out faster transfer when using ceiling hoists (Edlich et al., 2004). Having the ceiling hoists 'at hand' can reduce the time needed to locate a mobile hoist, particularly in a large environment or where hoists are shared between different areas (Hall, 2002) such as hospitals or residential care facilities.

Spatial utility

Spatial restriction is associated with the risk of injury to the care-givers (Hignett, 2000), thus provision of appropriate space is an important requirement for well-being and safety in handling people with mobility limitations. A survey with nurses working in hospital wards (Moody, McGuire, Hanson, & Tigar, 1996) reported that nurses had difficulty using some mobile hoists due to spatial constraints. While there has been limited evidential proof on spatial utility of ceiling hoists, it is agreed by experts that ceiling hoists can overcome spatial and environmental restrictions; such as storage problems. People can lift and transfer a person using a ceiling hoist regardless of how the room is furnished as a ceiling hoist does not require a lot of space to store and manoeuvre (Steed & Tracey, 2001a). Ceiling hoists can operate even with thresholds and deep pile carpet (Anonymous, 2004), which are the primary barriers for mobile lifts. Video simulation tests on the spatial requirements for mobile hoists and ceiling hoists conducted by Hignett and Keen (2005) concluded that ceiling hoists do not only occupy less storage space, but also require significantly less operational space than mobile hoists for both chair-to-bed (about 78%) and floor-to-bed (about 81%) transfers. This indicates that ceiling hoists have superior manoeuvrability within smaller environments not able to accommodate mobile hoists.

Ceiling hoists also have the advantage of allowing easier lateral transfer of a heavy person since floor-based mobile lifts can be difficult to move when loaded. A ceiling hoist's multi-tracking system allows a person to be lifted from any point within the coverage area (Collins, 2002). It is also possible for ceiling hoists to find vertical 'pick up points' at any height between the floor and ceiling (Hall, 2002). Less susceptibility to environmental restrictions is a feature of ceiling hoists that contributes to an improved spatial utility compared with mobile hoists.

Cost-effectiveness

One of the first concerns about installing a ceiling hoist is the affordability, as ceiling lift systems are costly (Clark, 2003). Some research investigated the payback period which refers to the time required to recover the initial cost of purchase, installation and training. They showed considerably different payback periods, from 0.82 years to 9.6 years, depending on the method of calculation. However, research results, in general, shared the opinion that it does not take long to recover the investment cost thus, making ceiling hoists cost-effective (Nelson & Baptiste, 2004). Silverwood and Haddock (2006) observed a 70% decrease in workers compensation costs in the first year after the installation of ceiling hoists. The cost-benefit analysis by Chhokar et al. (2005) of the ceiling lift project, based on the comparison between compensation claims costs and initial investment costs, found from 0.82 years to 2.50 years to reimburse the costs. The post ceiling hoist intervention evaluation by Spiegel et al. (2002) reported 69% of cost reduction in lifting and transferring and 45% in repositioning. The evaluation incorporated the insurance contribution from both reduced musculo-skeletal injury incidence and reduced duration of claims to estimate a reimbursement period from 1.97 years

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to 3.85 years. Villeneuve (1998) also observed substantial savings in worker's compensation, estimating that installation of a ceiling hoist system would finance itself within a period of 5 years. The longest reimbursement period estimation was made by Engst et al. (2005) of between 6.5 years to 9.6 years. Although the installation of ceiling hoists costs a substantial sum of money in the beginning, it is regarded as financially justifiable through savings from reduced injuries and disabilities among care-givers.

Discussion

Since ceiling hoists are mounted overhead, they are easier to store and require less room to operate than floor lifts. They are more effective in reducing the risk of injury to care-givers than mechanical floor lifts or manual methods of handling (Chhokar et al., 2005). With the improved manoeuvrability, ceiling hoists are an effective transfer tool, particularly in small-spaced environments and multi-level facilities. Requiring less physical activity, ceiling hoists appear to have obvious benefits in terms of injury prevention, efficiency of handling, and decreased dependence of people in care. When considering the most common cause of injury to the back is repeated lifting of small loads rather than one-off lifts of excessive loads (Wicker, 2000), and the use of ceiling hoists decreases the frequency of lifting and the accumulated load on the body, ceiling hoists are seen to offer a blueprint for prevention of injuries among care-givers.

Despite some irrefutable advantages of ceiling hoists, there are various effects and unresolved issues requiring further investigation. Ceiling hoist systems are not a panacea for the handling of people with disabilities (Nelson et al., 2004), and back injuries continue to occur despite the use of modern transfer equipment (Roche, 1999), although fewer in frequency. Reports by Engst et al. (2004) and Ronald et al. (2002) that ceiling hoists had no effect on musculo-skeletal injuries associated with repositioning tasks imply that ceiling hoists may not be the most ideal approach, at least, for repositioning. Although multi-directional track system, (a more sophisticated system than a straight track which assists movement in one direction), can facilitate repositioning tasks both up and down and side to side (Silverwood & Haddock, 2006), an answer to the question regarding injury reduction with ceiling hoists in repositioning is still pending. In addition, the control of the hoist remains one of manual pushing; at this point, there are no commercially available patient ceiling hoists that allow the sling to be remotely driven once the user is elevated.

The outcomes of Keir and MacDonell's experiment (2004), if preliminary in nature, have raised another controversial issue. They concluded that accumulative musculo-skeletal activity was directly proportional to the transfer time and was the lowest during manual transfer, followed by ceiling lifts, with floor-based mobile lifts being highest. The results are contrary to the rationale of the no-lifting policy, which encourages the use of mechanical devices in order to minimise physical exertion of care-givers. Although ceiling hoists are seen to reduce the spinal load and lower back injuries, prolonged transfer time may influence the amount of stress in girdles and joints (Santaguida, 2001). There would be no work requiring no physical activity, and physical exertion itself would not necessarily lead to musculo-skeletal injuries. However, the "trade-off between muscle activity and transfer time" (Keir & MacDonell, 2004, p. 303) requires special attention to be paid to probable injuries in other parts of the body rather than the back and the spine.

Some studies raised safety concerns with the use of ceiling hoists. Rolfson (2004) argued that repetitive use of a hammock-like sling during bed to chair transfer can lead to back-pain among the persons transferred; ceiling hoists are used in conjunction with any type of slings. "Current sling systems generally hold the persons transferred in a static, slumped position with a flexed back. When a person is lowered into a chair, unless the chair is titled back in an unsafe way, their flexed back prevents their pelvis from nesting into the back of the chair" (Rolfson, 2004, p. 4). The persons in

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slings might also be exposed to the risk of pressure sores and skin tears depending on the sling used and its material. It is a hypothetical extension of this line of thought that, an increase in back injuries among the persons transferred with the use of ceiling hoists, would lead to an 'injury shift' from care-givers to care-receivers. This zero-sum transition of injury from one group to another would not be a beneficial result.

Future Research

It should be noted that no Australian research was included in this systematic review, although there has been a substantial amount of research on ceiling hoists from countries which have similar care systems to Australia. In Australia, the no-lifting policy was officially established by the Australian Nursing Federation in 1998, and currently a number of health care facilities have implemented this policy. It is a matter of course that in the meantime, the ceiling hoist system has been increasingly accepted by the facilities as a part of the no-lifting program. Compared to a relatively long history[7] and the growing use of ceiling hoists, the lack of research on the system in Australia is surprising. Hence, it is strongly recommended that scholars in this field conduct more empirical research on the modern technological transfer solutions that reflect the Australian health care context.

As well as a quantitative increase in research, more stringent research design is required to separate the effects of ceiling hoists from other lifting and transfer intervention. Different assistive technologies have been often incorporated into a broad educational programs, and sometimes no clear distinction was made between mobile hoists and ceiling hoists in the analysis of effectiveness of mechanical devices. This lack of distinction has made it difficult to attribute success or failure to one specific intervention. Therefore, clear distinction is required in designing research for differentiation of the value of the specific intervention. Future research applying a direct comparison between the usefulness of the three distinctive methods: manual transfers, mobile hoist based, and ceiling hoist based handling is required. Many comparison studies have been designed to contrast limited methods, for example, between manual handling and mobile hoists or between mobile hoists and ceiling hoists. The last consideration of research design should refer to the time-lag effect. As is common in the evaluation of an intervention, ceiling hoist intervention takes time for its potential effects to be evident. In effect, this review observed the discrepancy of results due to the difference in the duration of examination. The efficacy of intervention is better represented by longer-term evaluation of outcomes, and short-term follow-up is less likely to demonstrate the true effectiveness of the intervention.

Based on the literature review, this study suggests the redirection of the research orientation. It is acknowledged that no-lifting legislation and high-tech assisted handling of people with disabilities was initiated by the safety needs of nurses and care workers. As a result, more research has focused on care-givers' health, and care-giver biased research has resulted in the relative lack of interest in comfort and safety of the care-recipients (see Figure. 3). Therefore, more attention needs to be paid to the needs of care-recipients to create a balance between the driving forces of the implementation of the ceiling hoist system. A facility-centric research pattern should be also discussed. Most of the research has been conducted in formal care settings such as hospitals, as illustrated in Figure 6. It was noted that that group facilities provide a better environment for testing the efficacy of ceiling hoists than private homes

7. Australia is not a late starter in this field. The UK first enacted a national no-lifting policy in 1992. In Australia, the ANF implemented a no-lifting policy based on the UK policy (Retsas & Pinikahana, 2000). It is not until 2003 that the USA and Canada released the no-lifting guidelines (Nelson, Baptiste, Matz, & Fragala, 2007).

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in terms of the sample size and laboratory treatments. Although a substantial difference in the effectiveness of ceiling hoists is not expected depending on environmental context, different care settings may pose different considerations to safe and effective handling. This may be pertinent because more emphasis is put on aesthetics than safety in private homes (Tuohy-Main, 1997). Apart from the implications drawn from hospital-based research, future research is required to examine the applicability of the ceiling hoist system to private home care as a part of a home modification project.

As mentioned previously, this systematic review analysed materials with relatively higher forms of evidence. However, it is admitted that the diversity in the models of ceiling hoists has not been fully considered in the studies reviewed. There are a variety of designs within ceiling hoist systems: fixed or portable according to the portability of the lifting unit; single or multiple track system; and straight or multi-directional track systems. There are also a variety of auxiliary devices, for example, there are a number of sling types. Different types of ceiling hoists are expected to have different effects on the handling of people with disabilities, depending on their size, shape, weight capacity and so forth. Hence, the remaining areas to be researched include various values of the design attributes of ceiling hoists.

Policy Implications

With the identified positive impacts of ceiling hoists on both the quality of care and the safety of health care workers, it has been noted that even when ceiling hoists are accessible, research shows that they are not widely used in health care facilities (Bogue, 2001). Caregivers indicated their reluctance to use mechanical lifting systems were the result of a combinations of a long tradition of manual handling practice, colleagues who did not operate them correctly (then defaulting to a manual lift), uncertainty of process and lack of confidence in using the lifting systems which reinforced a resistance to the use of ceiling hoists. In order to promote a wider use of ceiling hoists in the private care setting education, in conjunction with regulatory measures, need to be implemented. No disagreement has been found in relation to the necessity and purpose of the no-lifting policy. Thus, the home care setting would also benefit from the 'no-lifting policy'. Unlike group facilities where multiple care givers are available, at home the loss of a care-giver through injury is a critical incident. Further, the enforcement of a care-recipient's 'right' to choose an appropriate transfer system should be considered. Education and training in the use of mechanical aids are both essential for familiarising consumers and carers with the equipment, and imperative to prevent damage caused by misuse (Collins, 2002).

An administrative support system is also necessary. Most of all, immediate attention should be given to financial assistance for home users. Ceiling hoists may require a permanent structural alteration (Steed & Tracey, 2001) and the initial expense of installing and on-going maintenance costs can be a major barriers to potential consumers in the purchase and installation of ceiling hoists (Bogue, 2001). In addition, an assessment procedure through which appropriate administrative solutions can be recommended needs to be set up. Establishment of standardised assessment protocol (Nelson & Baptiste, 2004) can help assess the physical needs and health status of consumers to assist them with deciding whether they need assistive technology, or which technology provides the best potential, taking their needs and usability into account.

Although ceiling hoists have improved the safety of care-givers and quality of care, on their own they can not be the ultimate solution for the handling of people with mobility limitations. Mechanical lifts can not completely eliminate all the risks in a carrying environment (Collins, 2002; Nelson, Fragala, & Menzel, 2006), and "in any lifting situation, the

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dangers remain including the potential for back and shoulder injuries to care-givers and for falls for the patent" (Clark, 2003, p. 30). Ceiling hoists do not eliminate the persons' need to be handled manually in order for the sling to be inserted and removed. Nelson et al. (2003) indicated that the cause of musculo-skeletal injury is multi-factorial, and the incidence of musculo-skeletal injury is a function of three factors; host (physical/functional status of the person with disability), agent (care-giver and equipment) and environment (home design and structure). Ceiling hoists comprise only one of the agents. In this vein, manual handling techniques based on biomechanics, other types of handling technology including mobile hoists and architectural considerations need to be combined to maximise the efficacy of ceiling hoists. Keir and MacDonell's (2004) observation that experienced handlers required significantly less muscle activation than novice handlers when using ceiling hoist clearly points to the importance of the manual handling technique. Also, the efficacy of mobile hoists is still valid due to the coverage limitation of ceiling hoists (Rush, 2004). In consideration of architectural concerns, strong ceiling joists are a prerequisite before a ceiling track is installed (Disabled Living Foundation, 2006).

Conclusion

With the introduction of the no-lifting policy, the use of mechanical devices has been recommended as an alternative to manual handling methods in health care practices. Recently, increasing attention is being given to the ceiling hoist system as a safe and effective transfer method. This systematic review aimed to investigate the effectiveness of ceiling hoists and the advantages of them over other handling methods in lifting and transferring people with physical disabilities.

This review identified strong evidence that ceiling hoists significantly decrease musculo-skeletal injuries and physical stress among care-givers in formal settings. Despite a few contrary outcomes, ceiling hoists were given a far higher preference from both care-staff and the care-recipients, compared with mobile hoists and manual handling, as they increased care-staff's subjective comfort and job satisfaction, and improved dignity and safety for the care-recipients during the transfer. Ceiling hoists required fewer care assistants to fulfil the transfer task and less time than mobile hoists. Improved manoeuvrability and less susceptibility to spatial restrictions of ceiling hoists have also been well documented. In particular, ceiling hoists established their true merits in transferring heavy persons in small-spaced environments with thresholds and carpeted floor. In spite of the high up-front instalment costs, the ceiling hoist system was found to be cost-effective in the long term.

However, it should be noted that there are many under-researched issues regarding the usability of ceiling hoists. They include the injury reduction effect during the repositioning task, transfer time and potential back pain among the care-recipients. Established research results should be confirmed through further studies using a more rigorous research design. Variation in the types and designs of ceiling hoists make a difference to the outcome of the research. Design attributes of ceiling hoists need to be further examined in future research.

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Appendix 1: Articles from Database Search

Databases	Retrieved	Reviewed	Included
HMinfo Clearinghouse	3	3	0
Ageline	189	6	1
AMED (allied and complimentary medicine)	46	4	1
APA-FT: Australian public affairs	0	0	0
APAIS-Health	0	0	0
ARCH (Architecture)	0	0	0
Avery Index to Architectural Periodicals	0	0	0
BUILD: Australian Building Construction and Engineering Database	0	0	0
CAB Abstracts (agriculture, agronomy, crop protection, dairy science, and environmental degradation)	0	0	0
Cinahl (nursing and allied health)	266	10	4
Cochrane Central Register of Controlled Trials	0	0	0
Current Contents Connect	0	0	0
Dissertation & Theses Full Text	1	0	0
EVA: Environmental abstracts	0	0	0
Expanded Academic Index ASAP (humanities, social sciences, environment, science & technology)	0	0	0
Family (family and society)	0	0	0
Geobase (physical and human geography, geology, mineralogy (on the Science Direct platform)	0	0	0
Health and Society	0	0	0
Inspec (physics, electronics, electrical engineering, computer)	0	0	0
LexisNexis	0	0	0
Medline via Ovid (allied health, health care, medical, biological, physical sciences)	296	13	10
Mediascan (selective topics in Australian newspapers)	0	0	0
Oshrom – HSELINE, MHIDAS, RILOSH, CISDOC, NIOSHTIC (health, safety, toxicology, environmental health, biohazards)	1	1	1
Proquest 5000	60	4	0
PubMed (medical and life sciences)	8	0	0
Science Direct (life, physical, medical, technical sciences)	2	0	0
Sociofile/Sociological abstracts	1	1	0
University of Sydney Theses	0	0	0
Web of Science (science, social science, arts and humanities)	1	0	0
Google Web Searching	26	1	0
Results	*900*	*43*	*17*

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Appendix 2: Ceiling Hoist Analysis Matrix

Reference	Nationality	Main Findings	Process & Issues	Effectiveness						Person						Activity				Environment				Method						
				Physical stresses	Non-physical benefits	Patient comfort & safety	Transfer time	Cost	Other (operation etc)	Spinal injury (neurology)	Amputee	Aged (frail, impaired)	Cerebral palsy	Combination	Other / unspecified	Lift (vertical)	Transfer (lateral)	Repositioning	General handling	Private home	Nursing home	Hospital (rehabilitation)	Unspecified (laboratory)	Systematic Review	RCT	Quasi Experiment	Observation	Case	Expert Opinion	Anecdotal Evidence
(Anonymous, 2004)	USA	The advantages and disadvantages of mobile or floor lifts versus ceiling mounted lift system.	It lacks evidence, but it deals with the advantages of ceiling hoist from the perspective of patient.	●					●				●	●					●	●										●
(Chhokar et al., 2005)	Canada	Overhead lifting devices have long-term implications in reducing the risk of MSI to nursing staff, compensation costs, and time loss.	Pre and post intervention analysis using MSI claims records. The absence of a control group makes it difficult to ascertain the direct influence of the overhead lifting devices.	●				●							●	●	●	●				●				●					
(Clark, 2003)	USA	Ceiling mounted lift system has advantage over floor-based mobile lifts in terms of better space usage and ease of operation.	It is a collection of manufacturers' remarks about ceiling hoists. Hence, it lacks evidence. However, it presents additional issues to maximise the advantages of ceiling hoists.	●					●						●			●					●						●		
(Collins, 2002)	UK	The X/Y ceiling track can lift a person from any place and lift a tall person to locate at high places such as armrests etc.	Comparison between several types of hoists lack evidence. It is not based on appropriate research results.				●		●						●			●					●						●		
(Edlich et al., 2004)	USA	Focus has been placed on innovative injury prevention programs, including the use of mechanical devices, as an alternative to training in body mechanics.	It is close to the product specification or introduction to the Guldmann's ceiling hoists solution and system. Hence, it lacks evidence.	●	●		●								●			●					●						●		

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Reference	Nationality	Main Findings	Process & Issues	Effectiveness						Person						Activity				Environment			Method						
				Physical stresses	Non-physical benefits	Patient comfort & safety	Transfer time	Cost	Other (operation etc)	Spinal injury (neurology)	Amputee	Aged (frail, impaired)	Cerebral palsy	Combination	Other / unspecified	Lift (vertical)	Transfer (lateral)	Repositioning	General handling	Private home	Nursing home	Hospital (rehabilitation)	Unspecified (laboratory)	Systematic Review	RCT	Quasi Experiment	Observation	Case	Expert Opinion	Anecdotal Evidence
(Engst et al., 2005)	Canada	Based on before and after implementation analysis, ceiling hoists have advantages in staff preference, injury reduction, and compensation costs.	It set up a quasi-experimental design and comparison group for scientific evaluation. Survey (n=34 in intervention group and n=16 in comparison group) and injury data were used. However, it depends on the shorter-term (1 year) observation after treatment.	●	●			●							●				●			●				●				
(Hall, 2002)	UK	Ceiling hoists have advantages over mobile hoists in terms of reduction of physical activity, time saving, ease of use, and increased vertical and lateral coverage.	It focuses the benefits of ceiling hoists over mobile hoists. Three cases have been presented to support the advantages of ceiling hoists. However, relevancy of the cases to the argument is weak.	●		●	●		●	●				●					●			●						●		
(Hignett & Keen, 2005)	UK	Significantly more room in needed to operate a mobile hoist than an overhead ceiling hoist for both chair-to-bed and floor-to-bed transfers.	Two patient handling transfers were analysed from chair-to-bed and floor-to-bed. Video simulation data (n=10) were collected to plot and measure the space required for each tasks. Data collected were statistically compared using t-test.						●						●	●	●					●				●				

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(Holliday et al., 1994)	Canada	This early pilot study showed that while ceiling hoist system has advantages over wheeled mechanical lift in terms of number of staff for transfer, physical exertion, difference were not detected in caregiver comfort, time taken for lift and resident comfort.	Pre and post intervention comparison using self-administered questionnaires and videotaping data was conducted. However, sample sizes were small (n=18 for residents and n=22(before) / 34(after) for nursing staff) and observation period after trial short period (9 months) observation.	●	●	●	●					●					●						●				●			
(Keir & MacDonell, 2004)	Canada	Muscle activities were lowest using the ceiling lift, increasing with the floor lift, which were lower than manual transfers. The difference in the muscle activity patterns between the experienced and novice handlers was also identified.	This study analysed surface EMG(electro-myograph) data from 7 participants, to examine muscle activity patterns during the transfers from bed-to-wheelchair and wheelchair-to-bed. However, preliminary in nature, generalisation is limited due to the short duration of the tests, small sample size, and the varied skill levels of participants.	●			●									●	●	●	●				●				●			
(Miller et al., 2006)	Canada	This study demonstrate that ceiling hoist installed at a multi-level care facility reduced patient handling injuries and decreased perceived risk of injury among staff.	This study set up a quasi-experimental pre-post intervention design. However, sample size was too small (n=45 for intervention and n=29 for comparison) to make general conclusion, and it did not control the influence of exterior factor due to the move of the facility.	●	●										●	●	●	●				●				●			

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(Nelson & Baptiste, 2004)	USA	Ceiling hoists require less time for transfers than floor based mobile lifts and are a lucrative investment.	This is one of rare evidence-based practices, examining ceiling hoists. However, it spared very little attention to ceiling hoists, as the purpose of this article was to organize broad strategies to reduce MSI in care providers.	●			●	●							●	●		●	●				●	●							
(Nelson et al., 2003)	USA	Biomechanical tests were conducted in nine high risk patient handling tasks. Ceiling hoists contributed to the significant improvement in lumbar force, joint moment and subjective comfort.	In the 3 year laboratory study, data were collected using 3-D electro-magnetic tracking system, surface EMG, and questionnaires . Total participants were 134 (n=71 in the control group and n=63 in the intervention group).	●	●										●	●		●					●			●					
(Ronald et al., 2002)	Canada	Installation of ceiling hoists reduced the MSI caused by lifting/transferring, but did not in repositioning. Job Perception of staff and residents towards ceiling hoists improved significantly.	The incidence of MSI was analysed during a 3 year period before installation and a 1.5 year follow up period. Surveys with staff (n=58) and residents (n=40) were conducted for preference and perception on patient handling methods. However, short post-treatment period and absence of control group are some defects for generalisation.	●	●	●	●		●						●	●		●				●				●					

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(Ljungberg, Kilbom, & Hägg, 1989)	Sweden	The lifting work in modern setting with ceiling hoists was less than 50% than in traditional ward where manual and mobile hoists had been typical.	Technical devices such as ECC electrodes spiro-metre were applied to subjects (n=18) to measure physical exertion in different settings. However, it could not control the effect of other environment, as the wards to be compared were different in their space and work organisation.	●											●	●						●				●					
(Santaguida, Pierrynowski, Goldsmith, & Fernie, 2005)	Canada	The results of this study showed a significant difference in overhead ceiling hoists versus floor devices that resulted in decreased load to the low back. Also, nurses ranked ceiling devices higher than floor ones, which was consistent with the differences in spinal loads.	This study tested the spinal loads between various patient transfer methods, partitioning the transfer into seven phases from sling application to sling removal. Bio-mechanical data were collected using 3-dimension technology and self-administered questionnaire was used for ratings of perceived exertion (RPE). However, the sample size (n=5) was too small.	●	●	●									●	●	●	●						●				●					
(Silvenwood & Haddock, 2006)	Canada	The installation of the XY-gantry ceiling hoist system decreased injury, pain, fatigue, time loss and injury cost.	A survey with nursing staff (n=unknown) was conducted, and workers compensation claims were analysed. Absence of sample size is a decisive flaw of this study.	●	●	●		●							●				●			●				●					

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Reference	Nationality	Main Findings	Process & Issues	Effectiveness						Person						Activity				Environment				Method							
				Physical stresses	Non-physical benefits	Patient comfort & safety	Transfer time	Cost	Other (operation etc)	Spinal injury (neurology)	Amputee	Aged (frail, impaired)	Cerebral palsy	Combination	Other / unspecified	Lift (vertical)	Transfer (lateral)	Repositioning	General handling	Private home	Nursing home	Hospital (rehabilitation)	Unspecified (laboratory)	Systematic Review	RCT	Quasi Experiment	Observation	Case	Expert Opinion	Anecdotal Evidence
(Smith et al., 2002)	USA	Based on the evaluation patients and nursing staff, ceiling lift was preferred over the floor lift in terms of ease of movement, ease of positioning and repositioning after transfer, number of nurses required, musculoskeletal use, time required for transfer.	Patients and nursing staff evaluated two lifting systems using 5 Likert scale. However, this paper did not show the sample size and the detailed numerical outcomes.	●		●	●		●	●								●				●				●					
(Spiegel et al., 2002)	Canada	The ceiling lift intervention decreased the incidence of lift and transfer claims by 58% and the costs per 100,000 hours worked by 69%. Payback period was estimated from 1.97 years, if claims continued, to rise to 3.85 years.	All costs and benefits attributable to the intervention of ceiling hoists were measured for a 1 year period preceding and following the intervention.	●				●								●	●	●	●			●				●					
(Steed & Tracey, 2001)	UK	Ceiling hoists can facilitate patient dignity, comfort, safety and independence. There are no storage problems with ceiling hoists but it may require permanent structural alteration of the accommodation.	It gives an overview of the hoists and slings that are available. Thus, it relies on author's expert opinions for effectiveness of ceiling hoists.			●			●						●			●					●						●	
(U.S. Department of OSHA, 2002)	USA	With ceiling lifts in place, patient safety and dignity improved a lot.	A nursing home case study was added as an appendix with some anecdotal interviews with residents. Hence, it lacks evidence. Also, it was hard to separate the effect of ceiling hoists among the ergonomic programs.			●	●					●						●			●										●

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				Physical stresses	Non-physical benefits	Patient comfort & safety	Transfer time	Cost	Other (operation etc)	Spinal injury (neurology)	Amputee	Aged (frail, impaired)	Cerebral palsy	Combination	Other / unspecified	Lift (vertical)	Transfer (lateral)	Repositioning	General handling	Private home	Nursing home	Hospital (rehabilitation)	Unspecified (laboratory)	Systematic Review	RCT	Quasi Experiment	Observation	Case	Expert Opinion	Anecdotal Evidence
(Villeneuve, 1998)	Canada	As a comparison between mobile and ceiling lifts, it revealed high preference to ceiling lift among staff and patients, with 97.5% of staff respondents selecting ceiling hoist.	A variety of methods were employed. A survey with staff (n=121), interviews with patients and management, observations and video recordings were conducted.	•	•	•	•	•	•					•					•			•				•				
(Zhuang, Stobbe, Collins et al., 1999)	USA	It is hard to compare physical stress between assistive devices tested. However, this study demonstrate that rolling the patients away (push) required less back-compressive force than rolling them towards before placing the sling under the patients. Patient weight is an important factor in determining the physical stress during patient handling and physical stress reduction in pushing is clearer in handling heavier patient.	In this laboratory test, nine nurses were recruited from local nursing homes and two elderly persons participated as resident. A 3-D motion analysis system was used to register the body postures and joint angles of the nurses. However, the results were not presented to clearly separate the effectiveness between assistive devices because authors showed the results by handling activity-device category combination.	•											•	•		•						•							

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