Introduction

Manual handling, and particularly lifting, are believed to be important contributors to injuries and disabilities suffered by thousands of Australians and resulting in substantial medical and lost production costs (Straker 1998). Due to the financial and human cost of these injuries, considerable effort has been expended by industry and health advisers such as physiotherapists, in attempting to reduce the injuries associated with lifting. These efforts have generally been worker training, worker selection or work design.

Physiotherapists have often been involved in training workers in correct lifting techniques. The amount of effort the profession has made in this one option is perhaps disproportional to its potential benefit, but there are several reasons why physiotherapists are involved in lifting technique training. Physiotherapists are seen as experts in this area, and promote this perception. Further, we profess that treatment of symptoms without attempting to prevent recurrence is unsatisfactory management. Thus lifting technique training is often provided for patients with low back pain. However, this position of influence also carries responsibility. If we are teaching people an incorrect technique, we are, at the very least, wasting health care resources and, at worst, increasing their risk of injury.

The evidence used to evaluate which is the correct lifting technique has been categorised into biomechanical, physiological, psychophysical, psychological, performance and clinical criteria (Straker 1997). Whilst the evidence for the validity of each of these criteria is less than totally convincing, there is some evidence to suggest they are valid criteria (see Straker 1997 for a detailed review).

Evidence that psychophysically determined loads are related to injury risk comes from two large epidemiological studies. A study by Snook et al (1975) found that the 25 per cent of jobs with task demands acceptable to fewer than 75 per cent of the workers accounted for 50 per cent of the low back injuries. Similarly, Herrin et al (1986) found injury incidence and severity was weakly correlated with psychophysical acceptability.

Direct evidence that psychological measures such as discomfort and perceived exertion are related to injury is scant. Discomfort and exertion have been found to be related to biomechanical loading and physiological stress (Bonney et al 1990, Bousenna et al 1982; Cafarelli et al 1977, Ekblom and Goldbarg 1971) thus providing indirect evidence of their validity as a risk measure.

Psychophysical and psychological measures are widely used by researchers, suggesting face validity.
Further discussion on the validity of these criteria can be found in Straker (1997). However, as indicated in a recent review of research on lifting techniques (Straker 1999a, 1999b and 1999c), there is little evidence available comparing squat and stoop lifting on psychophysical and psychological criteria.

Whilst psychophysical criteria of MAW is a widely used risk indicator in manual handling risk assessment, only one study could be found which compared squat and stoop lifting. Garg and Saxena (1979) found six young male subjects selected a MAW for stoop lifting 12 per cent greater than for squat lifting. Their unreplicated results therefore suggest that squat lifting is less safe than stoop lifting. Their unreplicated results therefore suggest that squat lifting is less safe than stoop lifting.

Similarly, there is little reported evidence for psychological criteria such as perceived exertion, discomfort and preference. The four reports found suggest squat lifting may result in higher perceived exertion and discomfort (Hagen and Harms-Ringdahl 1994, Hagen et al 1993, Kumar 1984, Wiker and Stultz 1992). Again, the available evidence does not support the widely promoted view of squat being the correct technique. As well as being limited in number, much of the available research has used male subjects, making generalisation to females more tenuous. Therefore, the aim of the present study was to compare squat and stoop lifting in a group of females, using psychophysical and psychological criteria.

Method

Study design A within-subjects cross over design was used to allow subjects to determine their MAW, rating of exertion, discomfort and preference for squat and stoop lifting when lifting a box from floor to knuckle height.

Subjects Nineteen female physiotherapy students were recruited through personal contact and campus notices. Volunteers were excluded if they had experienced back pain in the previous 12 months, had a chronic disease which may have affected their lifting capacity, were unwell or were outside the 5th and 95th percentiles for height and weight. One volunteer was excluded due to a history of low back
pain and one subject withdrew due to severe knee pain during squat lifting 5.9kg (she had successfully completed stoop lifting testing with 8.5kg).

The remaining sample of 17 had a mean (SD) age of 20.5 (2.1) years, height of 166.14 (7.25) cm and weight of 59.3 (6.2) kg.

**Variables** The independent variable was the style of lifting, with two levels: squat and stoop. Squat lifting was defined as starting with feet in stride stance close to the diagonally opposite box corners, bending at the knees to reach the box and lifting it by knee and hip extension (see Figure 1). Stoop lifting was defined as starting with feet shoulder width apart in parallel stance and knees extended, bending at the hips to reach the box and lifting it by hip and lumbar spine extension (see Figure 2).

The dependent variables were the MAW, RPE, discomfort and preference.

Maximum acceptable weight was the weight of the box at the end of the subject performing the floor to knuckle height box lifting task five times per minute for 20 minutes. Subjects adjusted the box weight by adding or removing lead shot. Following established psychophysical methodology (Snook and Ciriello 1991), subjects were instructed to determine a suitable load that they perceived they could lift working as hard as they could without straining, becoming unusually tired, overheated, weakened or out of breath for an 8h day (Straker et al 1996).

Borg's (1985) 6-20 rating of perceived exertion scale was used for subjects to rate their whole body exertion. Subjects were asked whether they experienced discomfort during testing and, using a follow-up questionnaire, were asked about post-testing muscle/joint soreness. The questionnaire also asked subjects which lift they preferred and which they would choose in a similar situation in the future. Specific questions are listed in the Appendix.

**Materials** The plastic crate used was 360mm long and wide and 290mm deep, with integral cut-out handles 250mm from the bottom. The box weighed between 1.8kg and 2.6kg depending on the random presence of an additional weight beneath a false bottom. Up to 25kg of lead shot was available for subjects to add to the box.

**Procedure** Subjects performed a 3min warm-up involving jogging on the spot with arm swinging followed by stretches for lower limb and trunk muscles. Following random allocation to a lifting technique and demonstration of that technique, subjects practised the technique. Subjects then performed the lifting task for 20 minutes, adjusting the box weight as they desired and rating their exertion every four minutes. Subjects returned one week later to perform the other lifting technique.

**Ethical considerations** Risk of injury during testing was minimised by use of warm-up, exclusion of susceptible subjects, psychophysical protocol and a maximum weight of less than 55kg (Worksafe Australia 1990). Ethical approval for the study was obtained from the Human Ethics Research Committee of Curtin University of Technology.

**Data analysis** Paired t-tests were used to test for differences between lifting techniques for MAW and RPE measures, using a critical alpha probability of 0.05.
Results

Maximum acceptable weight  Figure 3a shows the trend for squat lifting MAW [7.0 (2.2) kg] to be less than stoop lifting MAW [8.5 (2.4) kg]. A paired t-test confirmed the apparent difference ($t_{(16)} = 3.03, p = 0.008$). Thirteen of the 17 subjects selected a larger MAW for stoop lifting.

Rating of perceived exertion  Figure 3b shows an opposite trend with mean (SD) squat lifting RPE 15.2 (1.5) appearing to be greater than stoop lifting RPE 13.3 (1.5). A paired t-test confirmed the apparent difference ($t_{(16)} = 3.86, p = 0.001$). Twelve of the 17 subjects rated RPE lower for stoop lifting.

Discomfort  All 17 subjects reported discomfort after squat lifting, with quadriceps soreness lasting 2-7 days being the main complaint. Twelve subjects reported discomfort following stoop lifting, mainly in back extensor and hip extensor muscle groups. The severity and duration of discomfort was less following stoop lift. Aside from the subject who was withdrawn, no subjects reported discomfort during testing.

Preference  Thirteen subjects stated a preference for stoop lifting, citing less severe after-effects and less effort during lifting, as reasons for their preference. Four subjects preferred the squat lift, citing previous training, reduced muscle soreness and less effort as reasons.

When asked which technique they would use if faced with a similar lifting situation, seven stated stoop, four stated squat, five stated an intermediate semi-squat and one stated a mixture of stoop and squat.

Discussion

The results of the present study support the hypothesis that squat lifting has a lower MAW than stoop lifting for a floor to knuckle height lift. Whilst the link between risk and psychophysical acceptability has little substantive evidence, it is widely accepted (Straker 1997). If the link does exist, then these results suggest the squat lifting technique presents a higher risk of injury than stoop lifting. These results also confirm the pattern found in young males (Garg and Saxena 1979).

The RPE results of the present study support the hypothesis that squat lifting involves more perceived exertion than stoop lifting for a floor to knuckle height MAW lift. These results are somewhat surprising, as subjects were instructed to work at their maximum acceptable level, and adjusted the weight of the box to be less for squat lifting. Thus, even though subjects partly compensated for squat lifting by reducing box weight by, on average, 20 per cent, squat lifting was still rated as more demanding.

Previous research on perceived exertion provided inconsistent evidence. The Kumar (1984) study on young males and females lifting a 10kg load found squat lifting rated as more tiresome than stoop lifting. Similarly, Wiker and Stultz (1992) found male and female subjects reported more perceived strain in squat lifting than stoop lifting. In contrast, Hagen et al (1993) found male subjects reported similar whole body RPE for squat and stoop lifting. The subjects in the latter study were lifting at maximum short term capacity (more than 20kg at around 20 times per minute), which may account for the lack of difference.

Hagen et al (1993) also asked subjects to rate low back and thigh RPE using Borg's 1-10 scale (1985) and found a trend for thigh RPE to be higher for squat lifting and back RPE to be higher for stoop lifting. Another study by this group (Hagen and Harms-Ringdahl 1994) found similar differences in thigh and back RPE. They suggested the thigh RPE was affected by quadriceps fatigue and discomfort in squat lifting and hamstrings discomfort and fatigue in stoop lifting, as indicated by the results of the present study.

Ratings of perceived exertion are thought to be important indicators of injury risk, presumably via local and general fatigue mechanisms (Straker 1997). If RPE is a useful risk indicator, then squat lifting may present a higher overall risk of injury than stoop lifting. However, the implications from the research by Hagen and colleagues is that the back may be at higher risk in stoop lifting.

The hypothesis that squat lifting results in more discomfort than stoop lifting is supported by the present study. Whilst these results provide the first evidence, the hypotheses has been suggested previously (Hagen and Harms-Ringdahl 1994).
Discomfort is potentially useful as a risk indicator in noting muscle soreness following fatigue or connective tissue discomfort with strain or microtrauma. Thus the present results suggest squat lifting may be a lower risk for injury to low back and hamstring structures and a greater risk for injury to knee and quadriceps structures.

The results of the present study support the hypothesis that squat lifting is not the technique preferred by novice lifters. This concurs with earlier research which has found novice and expert lifters do not prefer a squat technique (Authier et al 1996). The perception of effort during the task and discomfort following the task appeared to be the important determinants of preference in the present study and these may be important for workers also.

As the subjects in the present study were all physiotherapy students, the authors expected them to state a preference for what the physiotherapy profession, and the Western community generally, widely believe is the correct technique, ie squat. This preconception by subjects was acknowledged by them. For example, Subject 4 stated that she was careful not to lift too much weight using the stoop technique (in fact she lifted 12.3kg with stoop and only 6.6kg with squat). Similarly, when Subject 15 was told how much she lifted with each technique, she stated that she was surprised, as she thought she was lifting less with the stoop technique. Thus the results are even more convincing, as they go against what the subjects expected.

Whilst some subjects stated a preference for a semi-squat technique, this was not one of the options given, so more subjects may have selected this intermediate technique if they thought it was available. Further research on semi-squat technique is required.

It was observed during this study that the squat lift was difficult to teach, even to subjects with highly developed anatomy, biomechanics and movement awareness. It is therefore not surprising that attempts to teach workers to lift using a squat technique have been largely unsuccessful (St Vincent et al 1989).

The conclusions drawn from this study need to acknowledge that only one task was assessed using young, healthy and physically active females and no account was taken of biomechanical, physiological or performance criteria. Clearly, further research across broader task, subject and criteria domains is needed. Additional research is required to provide better evidence for the validity of psychophysical and psychological criteria, as well as biomechanical and physiological criteria.

Conclusion

Overall, the results of the present study provide limited evidence to support the use of stoop rather than squat lifting technique for lifting a medium sized box from floor to knuckle height.

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References


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Appendix

Post Testing Questionnaire

Did you experience any muscle or joint soreness/problems following either of the lifting sessions?

If yes to Q1, Please advise which muscle groups and joints were affected by each lift, and the approximate duration of the symptoms.

If you were faced with a similar situation involving repetitive submaximal lifting from floor to knuckle height, which lifting technique would you use?

Which of the lifting techniques did you prefer from the testing sessions, and why?