Applied Ergonomics 45 (2014) 234–238

Contents lists available at SciVerse ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Technical note

Influence of snow shovel shaft configuration on lumbosacral biomechanics during a load-lifting task

Ryan T. Lewinson [a,d,e,*], Gholamreza Rouhi [a,b,c], D. Gordon E. Robertson [a]

[a] School of Human Kinetics, Faculty of Health Sciences, University of Ottawa, Ottawa, ON, Canada
[b] Department of Mechanical Engineering, Faculty of Engineering, University of Ottawa, Ottawa, ON, Canada
[c] Faculty of Biomedical Engineering, Amirkabir University of Technology, Tehran, Iran
[d] Human Performance Laboratory, Faculty of Kinesiology, University of Calgary, 2500 University Drive N.W., Calgary, AB T2N 1N4, Canada
[e] Biomedical Engineering, Schulich School of Engineering, University of Calgary, Calgary, AB, Canada

ARTICLE INFO

Article history:
Received 6 January 2011
Accepted 4 April 2013

Keywords:
Ergonomics
Joint loading
Low back pain
L5/S1
Spine

ABSTRACT

Lower-back injury from snow shovelling may be related to excessive joint loading. Bent-shaft snow shovels are commonly available for purchase; however, their influence on lower back-joint loading is currently not known. Therefore, the purpose of this study was to compare L5/S1 extension angular impulses between a bent-shaft and a standard straight-shaft snow shovel. Eight healthy subjects participated in this study. Each completed a simulated snow-lifting task in a biomechanics laboratory with each shovel design. A standard motion analysis procedure was used to determine L5/S1 angular impulses during each trial, as well as peak L5/S1 extension moments and peak upper body flexion angle. Paired-samples *t*-tests ($\alpha = 0.05$) were used to compare variables between shovel designs. Correlation was used to determine the relationship between peak flexion and peak moments. Results of this study show that the bent-shaft snow shovel reduced L5/S1 extension angular impulses by 16.5% ($p = 0.022$), decreased peak moments by 11.8% ($p = 0.044$), and peak flexion by 13.0% ($p = 0.002$) compared to the straight-shaft shovel. Peak L5/S1 extension moment magnitude was correlated with peak upper body flexion angle ($r = 0.70$). Based on these results, it is concluded that the bent-shaft snow shovel can likely reduce lower-back joint loading during snow shovelling, and thus may have a role in snow shovelling injury prevention.

1. Introduction

Nearly 12,000 individuals are treated in U.S. emergency departments each year for snow shovelling-related injuries (Watson et al., 2011). The most common anatomical region for shovelling-related injury is the lower-back. Specifically, a retrospective study has shown that lower-back injuries account for 34.3% of all snow shovelling injuries, and in most cases, the injury is due to musculoskeletal overexertion, affecting soft tissues (Watson et al., 2011). Mechanically, this overexertion may be represented as increased joint loading in the lower-back. Therefore, biomechanical design of an ergonomic shovel that can decrease these joint loads may have implications for low-back injury prevention.

Perhaps the most common ergonomic snow shovel that is available for purchase is the bent-shaft shovel, which includes a downward bend in the shovel shaft. Despite the retail of bent-shaft shovels, no scientific evidence exists to support its use in terms of reducing mechanical loading at the lower-back. McGorry et al. (2003) studied bent-shaft shovels from a kinematic perspective, and found that a bent-shaft shovel significantly reduced upper body flexion when compared to the more common straight-shaft shovel. Huang and Paquet (2002) reported similar results. It has been speculated that the decrease in upper body flexion associated with bent-shaft shovel use would also decrease lumbar joint moments (McGorry et al., 2003); however, to the best of our knowledge, no study to date has tested this hypothesis.

Although peak joint moments provide an instantaneous indication of the mechanical loads that occur at a joint, they do not provide cumulative load information. For overuse injuries, such as low-back pain, a measure of cumulative loading such as angular impulse (integral of moments with respect to time) may provide more relevant information (Schipplein et al., 1990; Stefanyshyn

* Corresponding author. Human Performance Laboratory, Faculty of Kinesiology, University of Calgary, 2500 University Drive N.W., Calgary, AB T2N 1N4, Canada. Tel.: +1 403 220 2170.
E-mail address: lewinson@ucalgary.ca (R.T. Lewinson).

0003-6870/$ – see front matter © 2013 Elsevier Ltd and The Ergonomics Society. All rights reserved.
http://dx.doi.org/10.1016/j.apergo.2013.04.004

et al., 2006). Therefore, the purpose of this study was to determine if a bent-shaft shovel influences angular impulses about the L5/S1 joint during a shovelling task. It was hypothesized that L5/S1 extension angular impulses would be decreased with bent-shaft shovel use compared to a straight-shaft snow shovel.

2. Methods

2.1. Subjects

Eight healthy, injury-free subjects (5 male, 3 female, mean (SD) age of 29.4 (1.7) years, height of 1.77 (0.09) m, mass of 73.5 (12.1) kg) participated in the study. All subjects had previous experience in shovelling snow, and two had used a bent-shaft shovel previously, though not regularly. All subjects held the shovel handle with their right hand, and placed their left hand further down the shaft. Subjects gave written informed consent prior to testing. Ethics approval was obtained from the University of Ottawa Research Grant and Ethics committee prior to subject recruitment.

2.2. Shovel designs

Fig. 1 shows a schematic representation of the two shovels tested in this study. When held vertically, the straight-shaft shovel was 6.5 cm taller than the bent-shaft shovel.

2.3. Procedure

Retroreflective markers were placed on each subject's feet, shanks, thighs, pelvis and torso using a modified version of Vicon's Plug-in-Gait marker set, with additional medial markers at the ankle, knee and hip. Subjects positioned themselves with each foot on a separate Kistler force platform (Kistler AG, Winterthur, Switzerland), and were then asked to shovel a 3 kg sand bag at a self-selected speed. As they shovelled, seven Vicon MX13 cameras (Vicon, Centennial, Colorado) recorded the 3D positions of each marker at a sampling rate of 200 Hz, while each force platform simultaneously sampled ground-reaction force data at a frequency of 2000 Hz.

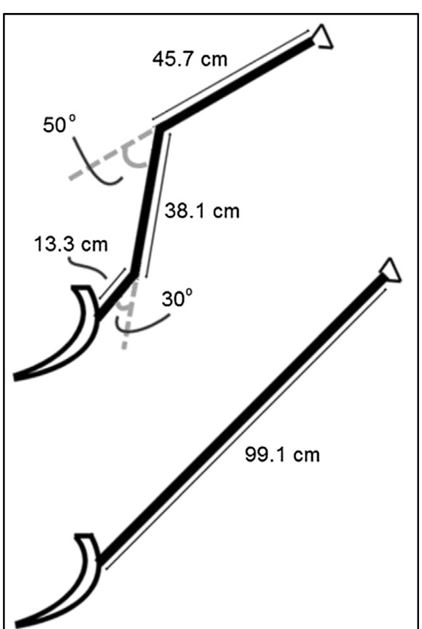

Fig. 1. Schematic showing dimensions of the bent-shaft and straight-shaft snow shovels tested in this study. The mass of the bent-shaft shovel was 1.8 kg; the mass of the straight-shaft shovel was 1.9 kg.

Subjects completed 5 trials with each shovel design in a randomly assigned order, and were provided with a 1 min break between each trial to prevent fatigue. Subjects were asked to shovel at a similar speed in each trial, and use the same hand positioning throughout. Trials began when subjects initiated trunk flexion towards the floor to accept the load, and trials ended once the shaft segment between both hands was parallel with the ground. The load was then dispatched to the left by rotating the shovel about its longitudinal axis, instead of excessive load throwing common to snow shovelling. Thus, this study made an attempt to isolate only the primary lifting movement associated with snow shovelling. A neutral trial was also collected from each subject where the subject stood in the anatomical position.

2.4. Data processing

Marker and ground-reaction force data were imported into Visual3D (C-Motion Inc., Germantown, Maryland) and were smoothed using low-pass filters with cut-off frequencies of 10 Hz (Arjmand et al., 2010). An 8-segment link-segment model comprising two feet, two shanks, two thighs, a pelvis and torso was created based on the neutral trial (Fig. 2). Based on the marker set, ankle, knee, hip and L5/S1 joint centres were defined (Kingma et al., 1996; Robertson et al., 2004). Segment lengths were then defined as the distance from the distal joint centre (or floor in the case of the foot segment) to the proximal joint centre. Using these lengths, the location of the segment centres-of-mass were estimated using established anthropometric guidelines (Dempster, 1955; Clauser et al., 1969; Hanavan, 1964). These anthropometric data, in combination with each subject's total body mass, allowed for estimation of individual segment masses and moments of inertia (Dempster, 1955; Clauser et al., 1969; Hanavan, 1964).

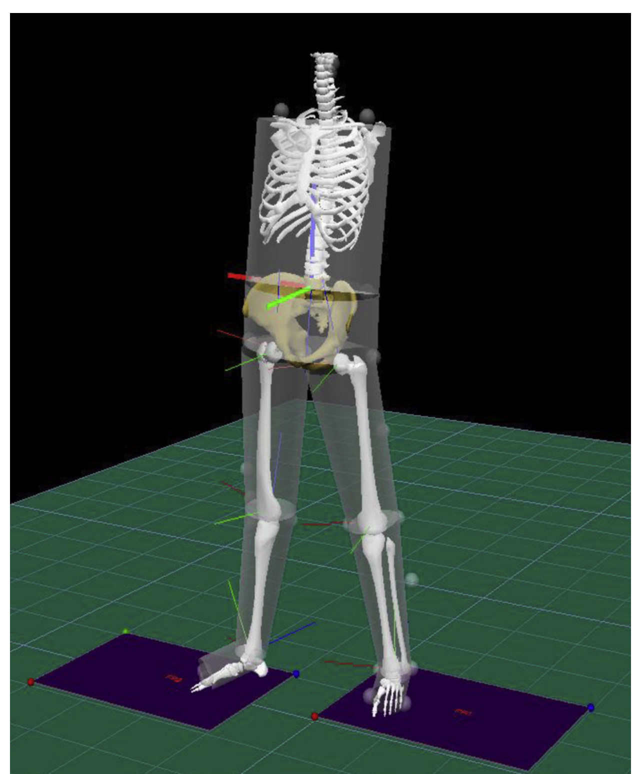

Fig. 2. 8-Segment link-segment model. Rectangles beneath the feet represent the force platform locations. The local joint coordinate systems are also shown.