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Comparing the results of five lifting analysis tools

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Abstract

The objective of this study was to compare the results of the *NIOSH, ACGIH TLV, Snook*, *3DSSPP and WA L&I* lifting assessment instruments when applied to a uniform task (lifting and lowering milk cases with capacities of 15 and 23 l). To enable comparisons between the various lifting assessment instruments, the outputs of each method were converted to an exposure index similar to the *NIOSH* Lifting Index. All instruments showed higher exposures associated with lifting the 23 l cases versus the 15 l cases. *The NIOSH*, *ACGIH TLV* and *Snook* methods were similar in their results with respect to the pattern of exposure over various height levels and the differences in exposures associated with lifting 15 and 23 l cases. However, the *WA L&I* and *3DSSPP* predicted substantially lower exposures. The reasons for instrument differences are presented so that practitioners can better select the methods they need and interpret the results appropriately.

Keywords: Lifting analysis; Ergonomics assessment methods; Materials handling

1. Introduction

The prevalence and severity of work-related back injuries is a significant problem; in the State of Washington, self-insured worker's compensation claims data for the period of 1992–2000 shows that 51.5% of compensable closed claims were for back disorders (Safety and Health Assessment and Research for Prevention (SHARP), 2002). Heavy lifting has been identified as a major risk factor for the development of back injuries (Marras et al., 1993; Hildebrandt, 1987). Ergonomists have long sought ways to objectively quantify the exposures associated with heavy lifting in order to more accurately anticipate high risk activities and prescribe appropriate interventions (Dempsey, 1998). Consequently, numerous lifting analysis tools have emerged with each one having different inputs, outputs, and subsequent interpretive capacities. These tools, while advancing the ability to characterize, quantify and predict the exposures, nevertheless retain a degree of uncertainty, incompleteness, and differing attributes that practitioners need to be aware of when using and interpreting results (Fallentin et al., 2001; Janowitz et al., 2005).

Five lifting analysis methods were chosen for comparison: the revised 1991 *National Institute of Occupational Safety and Health lifting equation* (*NIOSH*) (Waters et al., 1993), the American Conference of Governmental Industrial Hygienists *lifting threshold limit values* (*ACGIH TLV*) (ACGIH, 2005), the *Liberty Mutual "Snook" Lifting Tables* (*Snook*)(Snook and Ciriello, 1991), the *University of Michigan 3D static strength prediction program* (*3DSSPP*) (University of Michigan, 2001) and the *Washington State ergonomics rule lifting calculator* (*WA L&I*) (WAC, 2000a, b).

Each of the instruments has unique attributes that make it desirable for this study. The *NIOSH* instrument was selected because it is universally recognized and widely used throughout the world. The *ACGIH TLV* tool is largely based on the *NIOSH* instrument, but is designed to be more expedient than *NIOSH*. It is the most recently developed tool and used mostly within the US. The *Snook*, a psychophysical-based tool, is used by US practitioners to obtain design guidelines. The *3DSSPP* was chosen because

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of its unique low back compression force predictive capabilities. Finally, the *WA L&I*, which is based on the *NIOSH* methodology, was designed for use as a regulatory instrument in Washington state and was designed to identify the highest risk jobs.

The specificity and resolution of inputs (i.e., angles, distances) varies across these tools (Table 1). All methods derive an outcome that attempts to predict the relative safety and/or risk of a lift for given populations, but use different terminology and parameters to do so. All instruments are limited in their capacity to incorporate the degree of acceleration/deceleration, shear forces, ambient temperature extremes, one-handed lifts, the lifting of unstable and odd-shaped objects, or the continuous three-dimensional (3D) forces and moments about the spine into their calculations (Fathallah, 1997).

While the literature is replete with descriptions of individual instruments, quantitative comparisons between the respective methods is less complete (Marklin and Wilzbacher, 1999; Marras et al., 1999; Waters et al., 1998). The aim of our study was to compare the results of the five lifting analyses of a common lifting task in order to clarify the similarities and differences between instruments and provide guidance to ergonomics practitioners.

2. Methods

2.1. Work parameters

A regional grocery store chain requested assistance to assess the potential impact of switching from 23 l cases to 15 l containers in their stocking operations. This opportunity was used to compare five instruments used for assessing musculoskeletal exposures. Baseline data for the analyses were collected by interviewing, observing and videotaping an experienced 95th percentile (for height) male worker while he stocked the dairy cooler with milk shipped in 23 l cases. Anatomical landmarks required for use in *ACGIH TLV*, *Snook* and *WA L&I* were based on the 95th percentile measurements of US males: stature—187.6 cm; shoulder height—156.5 cm; waist height—116.8 cm; knuckle height—82.8 cm; knee height—54.6 cm; mid-shin height—31.5 cm and ankle-to-toe distance—22.5 cm (PeopleSize, 1997; Pheasant, 1996). The subject-specific height (187.6 cm) and weight (83.9 kg) were used to compute the *3DSSPP* results. Lifting frequencies were estimated from typical deliveries to the stock room during an 8 h shift. The same lifting parameters were used as inputs across all the instruments analyzed.

Each 15 l case weighed 17 kg and measured 33 cm wide by 33 cm long by 28 cm tall. Each 23 l case weighed 26 kg and was 33 cm wide by 48 cm long by 28 cm tall. The handles of both of the cases were 25 cm from the bottom of the case. There were thirty 23 l cases and forty-five 15 l cases to a pallet. Both were delivered and stacked three rows wide, five cases high and two rows deep for 23 l cases and three rows deep for 15 l cases. The stacks were pulled off the pallets into the storage area and slid into a storage space on the floor. For purposes of stock rotation, space saving or sorting, some or all of the cases in a stack were redistributed to other stacks up to seven-high. Vertical measurements were taken from the floor. The storage cooler where the de-palletizing took place was a constant 1.7 °C.

Lifting occurred at a rate of 2 min^{-1} for the 23 l cases and 3 min^{-1} for 15 l cases. Both were for durations $\leqslant$2 h. Despite the different rates and number of lifts between the 15 and 23 l cases, lifts at rates of 2 min^{-1} and 3 min^{-1} fell into the same frequency category on all tools, and as a result, the 15 and 23 l cases used the same frequency multipliers.

2.2. Measurements

Consistent values were used in the lifting equations derived from how the subject actually performed the task.

Table 1
Input variables and outcomes of five lifting assessment tools

Input variables	WA L&I	NIOSH	ACGIH TLV	Snook	3DSSPP
Anthropometry	X		X	X	X
Height and weight					X
Joint angles					X
Maximum lift (kg)	41	23	32	Subject based	NA
Frequency	X	X	X	X	
Duration	X	X	X		
Lift origin (H&V)	X	X	X	X	X
Destination (H&V)		X			
Travel distance		X		X	
Coupling		X			
Asymmetry	X	X			X
Outcomes	Lifting limit	Recommended weight limit; lifting index	Threshold limit value	Design goal; % strength capable	L5/S1 compression force (LB); % strength capable, joint moments