AN OBJECTIVE SET OF GUIDELINES FOR PUSHING AND PULLING

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SUMMARY

Current guidelines related to pushing and pulling commonly used by practitioners were developed using *subjective* methods and may underestimate risk to the lower back and shoulders. This document describes the development of a new set of *objective* guidelines and how to implement them moving forward to help reduce the risk of workplace injury to the low back and shoulders.

BACKGROUND

Occupationally-related low back disorders (LBD) and shoulder musculoskeletal disorders are a leading cause of lost work days and are a costly occupational safety and health problem facing industry today. In the United States, treatment of low back pain costs over $50 billion annually in direct costs alone, while the direct cost of treating shoulder injury is over $7 billion (Meislin et al. 2005; Davis et al 2012).

As employers have recognized the risks associated with lifting, they have shifted the manual materials handling burden to interventions involving pushing and pulling (such as overhead hoists, carts, and articulating arms). However, pushing and pulling is also associated with its own risk of injury to the low back and shoulders as well.

Guidelines presented to practitioners have the potential to aid in workplace design and reduce the risk of low back and shoulder injuries. However, the only current pushing and pulling guidelines were developed *subjectively*, relying on the assumption that an individual's perception of maximum acceptable external forces corresponds to biomechanical risk to the low back and shoulders (Snook and Ciriello 1991). Prior literature shows this assumption is incorrect (Jorgensen et al. 1999; Davis et al. 2000; Le et al. 2012). ***Thus, objectively determined guidelines are necessary for pushing and pulling.***

This study used biomechanical information collected from 62 human subjects in a laboratory to develop pushing and pulling guidelines for practitioners. This was achieved via establishing a relationship between the biomechanical loads induced onto the spine and hand forces generated by the participants. Risk limits were determined by investigating which hand forces or turning torques led to spinal loads over risk thresholds (Gallagher and Marras 2012; NIOSH 1981). Loads on the spine were predicted using a unique biomechanical model that is validated for pushing and pulling, dynamic, and accurately accounts for the way each person recruits their muscles to complete a task (Granata and Marras 1993; Hwang et al. 2016; Knapik and Marras 2009).

Subjects performed activities including 1 Handed Pulling, 2 Handed Pulling, and 2 Handed Pushing. They performed exertions at three different handle heights (32 in, 40 in, 48 in) and performed both straight and turning push/pull exertions.

RECOMMENDATIONS FOR WORKPLACE DESIGN

The results of this study suggest that the following be considered related to pushing and pulling.

- Higher handle heights (up to 48 in.) are generally preferable for all pushing and pulling exertions.
- Turning push/pull exertions should be avoided where possible because these exertions subjected participants to higher biomechanical loads than straight exertions.
- Two handed turning exertions (such as moving a cart) are recommended over one handed turning exertions (such as moving a pallet jack).
- The widely-accepted *subjectively* determined limits for hand force during pushing and pulling (Snook and Ciriello 1991) are not protective enough of injury risk. The objective, biomechanically-determined risk limits derived from our study **are up to 30% lower than the limits reported previously.**

GUIDELINES FOR OCCUPATIONAL PUSHING AND PULLING

- The *objectively* determined guidelines are presented in tables below. These limits and are expected to be protective of both the low back and shoulders.
- Note that the pushing and pulling guidelines proposed within this investigation ***did not differ based on gender.***

Using the Guidelines

It will be necessary to enter several pieces of information about the push/pull task being tested into the online web interface in order to estimate biomechanical risk. This includes simple *characteristics* about the exertion such as the **action being performed** (1 Handed Pull, 2 Handed Pull, 2 Handed Push) and the **exertion type** (a straight push or pull or a turn). Practitioners will also need to *measure* **maximum push/pull force** required to move the object and the **hand height** from the ground (in inches).

Measuring Maximum Push/Pull Forces

Hand forces and torques can easily be measured in the field using a dynamometer (Figure 1a). For pushing, the practitioner should be able to push right on the handle(s) of the object being pushed. For pulling, the practitioner may choose to attach a rope to the handles and use the dynamometer's 'hook' attachment. Examples are shown in Figure 1.

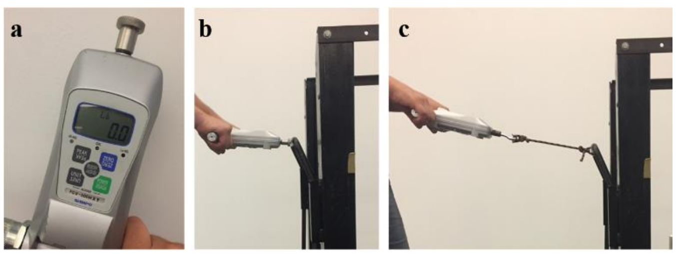

Figure 1. Measurement of pushing and pulling forces using (a) a dynamometer for (b) pushing and (c) pulling.

The practitioner should place the hand dynamometer (or rope) where a workers' hand would usually make contact with the object that is to be moved. After placing the hand dynamometer in the correct location, the practitioner should record the ***maximum*** **forces** required to move (push, pull, turn) an object (in pounds). This maximum force is the best indicator of the risk associated with performing a particular job. Most of the time, this will be the hand force or turning torque required to initiate movement of the object from a standstill. However, it is important to note that some occupational exposures such as pushing or pulling a cart up a ramp might require higher pushing and pulling forces than initiating motion.

In an occupational environment, the direction that pushing and pulling forces are applied by workers is largely dependent on the handle height or weight of the object being pushed or pulled. However, when collecting data regarding pushing and pulling in order to apply the guidelines set forth herein, practitioners should record forces applied *horizontally relative to the ground*. This recommendation mirrors recommendations set forth by preexisting pushing and pulling guidelines and will ensure greater consistency in measurement.

Measuring Hand Height

Practitioners should measure the *vertical* height of the hands from the floor. The measure should be taken where the worker's hands would normally be on the handle. The guidelines accommodate hand heights of 32" to 48."

Measuring Hand Distance

In turning exertions, it will also be necessary to record a measure of the **distance of the hands** from the center of rotation (in inches). This measure is detailed further in Figure 2 below. For one-handed pulls with items such as a pallet jack, this will be the distance from the center of the object to the hands. Likewise, for two-handed push/pull turns, this will be the distance between the hands if the hands are centered on the object being turned.

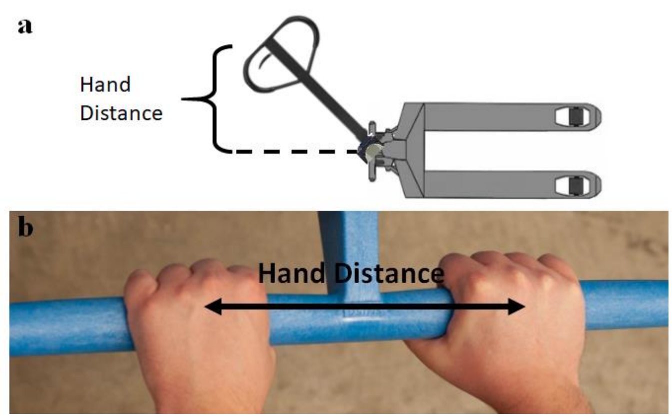

Figure 2. Calculation hand distance in (a) one-handed push/pull turns such as with a pallet jack and (b) two-handed push/pull turns as with a four-wheeled cart.

Interpreting Risk

After entering all of the necessary information, the web interface will calculate the risk associated with performing that particular type of exertion and assign it a risk level of either green, yellow, or red (Figure 3).

Green. The exertion is safe for at least 80% of the working population. This exertion may be viewed as acceptable.

Yellow. The exertion is safe for 50-80% of the working population. It is *recommended* that changes to the task be made to make it safer for more people.

Red. The exertion is safe for less than 50% of the working population. It is *strongly recommended* that changes to the task be made to make it safer for more people.

Figure 3. Risk levels as outputs to the online push/pull guidelines and their meaning to the practitioner.

GUIDELINES FOR STRAIGHT PUSHING AND PULLING (LIMITS IN LBS.)

Action	Hand Height (inches)	Most Protective (Green)	Moderate (Yellow)	Least Protective (Red)
		80+% population protected	*50-80% population protected*	*<50% population protected*
1 Hand Pull	**32 inches**	38 lbs. or less	39-46 lbs.	47 lbs. or more
	33 inches	40 lbs. or less	41-48 lbs.	49 lbs. or more
	34 inches	41 lbs. or less	42-49 lbs.	50 lbs. or more
	35 inches	42 lbs. or less	43-50 lbs.	51 lbs. or more
	36 inches	43 lbs. or less	44-51 lbs.	52 lbs. or more
	37 inches	43 lbs. or less	44-52 lbs.	53 lbs. or more
	38 inches	44 lbs. or less	45-52 lbs.	53 lbs. or more
	39 inches	44 lbs. or less	45-52 lbs.	53 lbs. or more
	40 inches	44 lbs. or less	45-52 lbs.	53 lbs. or more
	41 inches	44 lbs. or less	45-53 lbs.	54 lbs. or more
	42 inches	44 lbs. or less	45-53 lbs.	54 lbs. or more
	43 inches	44 lbs. or less	45-53 lbs.	54 lbs. or more
	44 inches	44 lbs. or less	45-53 lbs.	54 lbs. or more
	45 inches	44 lbs. or less	45-53 lbs.	54 lbs. or more
	46 inches	43 lbs. or less	44-53 lbs.	54 lbs. or more
	47 inches	43 lbs. or less	44-52 lbs.	53 lbs. or more
	48 inches	42 lbs. or less	43-52 lbs.	53 lbs. or more
2 Hand Pull	**32 inches**	41 lbs. or less	42-57 lbs.	58 lbs. or more
	33 inches	44 lbs. or less	45-60 lbs.	61 lbs. or more
	34 inches	47 lbs. or less	48-63 lbs.	64 lbs. or more
	35 inches	50 lbs. or less	51-65 lbs.	66 lbs. or more
	36 inches	52 lbs. or less	53-68 lbs.	69 lbs. or more
	37 inches	55 lbs. or less	56-70 lbs.	71 lbs. or more
	38 inches	58 lbs. or less	59-72 lbs.	73 lbs. or more
	39 inches	60 lbs. or less	61-73 lbs.	74 lbs. or more
	40 inches	62 lbs. or less	63-74 lbs.	75 lbs. or more
	41 inches	64 lbs. or less	65-76 lbs.	77 lbs. or more
	42 inches	66 lbs. or less	67-77 lbs.	78 lbs. or more
	43 inches	67 lbs. or less	68-79 lbs.	80 lbs. or more
	44 inches	69 lbs. or less	70-80 lbs.	81 lbs. or more
	45 inches	70 lbs. or less	71-81 lbs.	82 lbs. or more
	46 inches	71 lbs. or less	72-82 lbs.	83 lbs. or more
	47 inches	72 lbs. or less	73-83 lbs.	84 lbs. or more
	48 inches	73 lbs. or less	74-83 lbs.	84 lbs. or more
2 Hand Push	**32 inches**	48 lbs. or less	49-61 lbs.	62 lbs. or more
	33 inches	50 lbs. or less	51-62 lbs.	63 lbs. or more
	34 inches	50 lbs. or less	51-63 lbs.	64 lbs. or more
	35 inches	51 lbs. or less	52-63 lbs.	64 lbs. or more
	36 inches	52 lbs. or less	53-63 lbs.	64 lbs. or more
	37 inches	53 lbs. or less	54-63 lbs.	64 lbs. or more
	38 inches	53 lbs. or less	54-63 lbs.	64 lbs. or more
	39 inches	54 lbs. or less	55-63 lbs.	64 lbs. or more
	40 inches	54 lbs. or less	55-64 lbs.	65 lbs. or more
	41 inches	56 lbs. or less	57-66 lbs.	67 lbs. or more
	42 inches	58 lbs. or less	59-68 lbs.	69 lbs. or more
	43 inches	60 lbs. or less	61-71 lbs.	72 lbs. or more
	44 inches	62 lbs. or less	63-73 lbs.	74 lbs. or more
	45 inches	64 lbs. or less	65-75 lbs.	76 lbs. or more
	46 inches	65 lbs. or less	66-76 lbs.	77 lbs. or more
	47 inches	67 lbs. or less	68-78 lbs.	79 lbs. or more
	48 inches	68 lbs. or less	69-79 lbs.	80 lbs. or more

GUIDELINES FOR TURNING PUSHING AND PULLING (LIMITS IN FT-LBS.*)

Action	Hand Height (inches)	Most Protective (Green) 80+% population protected	Moderate (Yellow) 50-80% population protected	Least Protective (Red) <50% population protected
1 Hand Pull	32 inches	50 ft-lbs. or less	51-64 ft-lbs.	65 ft-lbs. or more
	33 inches	52 ft-lbs. or less	53-65 ft-lbs.	66 ft-lbs. or more
	34 inches	53 ft-lbs. or less	54-67 ft-lbs.	68 ft-lbs. or more
	35 inches	55 ft-lbs. or less	56-68 ft-lbs.	69 ft-lbs. or more
	36 inches	56 ft-lbs. or less	57-70 ft-lbs.	71 ft-lbs. or more
	37 inches	58 ft-lbs. or less	59-71 ft-lbs.	72 ft-lbs. or more
	38 inches	59 ft-lbs. or less	60-73 ft-lbs.	74 ft-lbs. or more
	39 inches	61 ft-lbs. or less	62-74 ft-lbs.	75 ft-lbs. or more
	40 inches	62 ft-lbs. or less	63-76 ft-lbs.	77 ft-lbs. or more
	41 inches	62 ft-lbs. or less	63-76 ft-lbs.	77 ft-lbs. or more
	42 inches	63 ft-lbs. or less	64-76 ft-lbs.	77 ft-lbs. or more
	43 inches	63 ft-lbs. or less	64-77 ft-lbs.	78 ft-lbs. or more
	44 inches	63 ft-lbs. or less	64-77 ft-lbs.	78 ft-lbs. or more
	45 inches	63 ft-lbs. or less	64-77 ft-lbs.	78 ft-lbs. or more
	46 inches	63 ft-lbs. or less	64-78 ft-lbs.	79 ft-lbs. or more
	47 inches	63 ft-lbs. or less	64-78 ft-lbs.	79 ft-lbs. or more
	48 inches	64 ft-lbs. or less	65-79 ft-lbs.	80 ft-lbs. or more
2 Hand Push/Pull	32 inches	60 ft-lbs. or less	61-74 ft-lbs.	75 ft-lbs. or more
	33 inches	62 ft-lbs. or less	63-76 ft-lbs.	77 ft-lbs. or more
	34 inches	64 ft-lbs. or less	65-78 ft-lbs.	79 ft-lbs. or more
	35 inches	65 ft-lbs. or less	66-80 ft-lbs.	81 ft-lbs. or more
	36 inches	67 ft-lbs. or less	68-82 ft-lbs.	83 ft-lbs. or more
	37 inches	69 ft-lbs. or less	70-84 ft-lbs.	85 ft-lbs. or more
	38 inches	70 ft-lbs. or less	71-86 ft-lbs.	87 ft-lbs. or more
	39 inches	72 ft-lbs. or less	73-88 ft-lbs.	89 ft-lbs. or more
	40 inches	73 ft-lbs. or less	74-90 ft-lbs.	91 ft-lbs. or more
	41 inches	74 ft-lbs. or less	75-91 ft-lbs.	92 ft-lbs. or more
	42 inches	75 ft-lbs. or less	76-92 ft-lbs.	93 ft-lbs. or more
	43 inches	76 ft-lbs. or less	77-93 ft-lbs.	94 ft-lbs. or more
	44 inches	77 ft-lbs. or less	78-94 ft-lbs.	95 ft-lbs. or more
	45 inches	78 ft-lbs. or less	79-95 ft-lbs.	96 ft-lbs. or more
	46 inches	78 ft-lbs. or less	79-95 ft-lbs.	96 ft-lbs. or more
	47 inches	79 ft-lbs. or less	80-96 ft-lbs.	97 ft-lbs. or more
	48 inches	80 ft-lbs. or less	81-97 ft-lbs.	98 ft-lbs. or more

* *If using the online web interface, this torque calculation is performed for the user. However, to calculate turning torque, multiply **maximum hand force (in lbs.)** by respective **moment arm (in feet)**. The moment arm will be the distance between the center of the object being turned and the hand dynamometer that is exerting the torque.*

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FOR MORE INFORMATION

More information about our laboratory and our prior work can be found at http://spine.osu.edu.

For questions about this study in particular, please email the corresponding author at weston.101@osu.edu.

More information about the Ohio Bureau of Workers' Compensation (BWC) can be found on their website at http://www.bwc.ohio.gov/Default.aspx.