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Ergonomic evaluation of standard and alternative pallet jack handless

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ABSTRACT

Aim: Transportation of materials using a pallet jack pulled behind the operator is common due to the visual advantages while transporting fully loaded pallets. The objective of this laboratory study was to quantify muscle activity, posture, and low back compressive and shear forces while completing typical pallet jack activities using a standard handle that required one handed pulling of a pallet jack compared to an alternative handle that allowed for two handed pushing.
Methods: Participants ($n = 14$) performed six to ten trials of common pallet jack tasks (straight travel and turning) with each handle. Posture analysis of the trunk and right upper extremity was performed using Motion Analysis (Santa Rosa, CA, USA) and back compressive and shear forces were analyzed using 3D Static Strength Prediction Program (University of Michigan, Ann Arbor, MI). Activity of the upper trapezius (UT), pectoralis major (PM), flexor digitorum superficialis (FDS) and extensor digitorum (ED) muscles were recorded (Telemyo 2400 T, Noraxon, Scottsdale, Arizona) and normalized to percent reference voluntary contraction values. All outcomes were compared using the paired *t*-test.
Results: Peak and mean muscle activity of the PM ($p < 0.001$) and ED ($p < 0.01$) were significantly higher using the alternative push handle during all three tasks. There were larger compressive forces at L4/L5 ($p < 0.08$) and L5/S1 ($p < 0.002$) using the alternative handle, and greater shear forces using the standard handle at both L4/L5 ($p < 0.0001$) and L5/S1 ($p < 0.000$).
Discussion: The standard handle outperformed the alternative handle with regard to muscle activity. The alternative handle had significantly greater compressive forces at L5/S1 due to the pushing nature of the hand-handle interface, yet the standard handle increased shear forces at both L4/L5 and L5/S1 levels in the low back.
Conclusion: In this analysis, there was not a clear benefit to using either handle in terms of trunk strength capacity and varied benefits and drawbacks to each handle when comparing compressive and shear forces in the low back. However, given favorable subjective reports described in a prior publication, and the increased reliance on dynamic versus passive force production, facilitating a workers' ability to push a pallet jack while travelling with large loads is worth further investigation.

1. Introduction

A common task in manual material handling (MMH) jobs includes manual transportation of products or materials on a pallet jack to eliminate workers exposure to carrying heavy loads. However, use of pallet jacks poses a risk of injury since they require pushing and pulling forces to maneuver them (Hoozemans et al., 1998). Pushing and pulling activities increase the incidence of self-report shoulder and low back complaints (Hoozemans et al., 2002a, 2002b, 2014). On average between 9 and 18% of low-back injuries are associated with pushing or pulling tasks (Hoozemans et al., 1998). Although, according to the Bureau of Labor Statistics (2009), there were only 2710 lost time injuries from pallet jack use, operators using pallet jacks to move product are typically also responsible for loading and unloading product from the pallet. The lifting and lowering further increases biomechanical exposure placing workers at increased risk for shoulder, distal upper extremity and back injuries (Hoozemans et al., 1998, 2004). Therefore,

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workers who manually transport products by loading and unloading pallet jacks and then pushing or pulling them are at high risk for costly claims, particularly in the lumbar spine (Dunning et al., 2010). Further, it has been documented that low-back pain is the most physically debilitating musculoskeletal disorder (MSD) with symptoms having the highest correlation with reduced health-related quality of life and increased days of sickness absence (Plouvier et al., 2008). In 2004, lost production time due to back pain among workers 40–65 years costs U.S. employers approximately $7.4 billion per year (Ricci et al., 2006), and in 2005 the average total cost of a lumbar disc injury was $52,041, 600% higher cost than any other body part (Dunning et al., 2010). Thus, the high financial and social cost of work related low back disorders require exposure reduction efforts wherever possible.

When a pallet jack is empty or lightly loaded it can be safely pushed in front of the user. However, when travelling with a fully loaded pallet jack the user must pull it behind them to maintain a clear line of sight and avoid collisions. Pulling a pallet jack results in an awkward shoulder and trunk posture that could pose a substantial physical demand on the body when the pallet is heavily loaded (Harris-Adamson and Lin, 2013). The operator's position includes full extension and internal or external rotation at the glenohumeral joint (depending on a supinated or pronated forearm position), twisting of the trunk, and grasping of a handle that is parallel to the frontal plane of the operator, potentially a less advantageous position for generating maximum force and reducing overall exertion (Kumar 1994; Hoozemans et al., 2004). Critical reviews have found strong evidence to support increased risk of low back disorders associated with bending and twisting activities (Marras, 2000). Punnet et al. (1991) found that approximately 75% of the etiology of low back injuries was due to the effects of non-neutral trunk posture including mild to severe trunk flexion and twisting.

The risk of low back disorders from MMH tasks can be analyzed by quantifying compressive, shear, and torsional forces in the spine (Marras, 2000). Based on tissue tolerance for spinal loading, NIOSH has set maximal spinal loading limits including 3400 N of compressive force and 500 N of anterior/posterior (A/P) shear force (NIOSH, 1981; McGill, 2002). Although these thresholds exist, the evidence has been equivocal on whether pushing or pulling imposes more risk for low-back injury based on compression and shear forces at the lumbar spine. Numerous studies suggest that lumbar spine compressive forces are higher when pulling compared to pushing (Knapik and Marras, 2009; Schibye et al., 2001; Hoozemans et al., 2004; Chow and Dickerson, 2015). Yet, Knapik and Marras (2009) found that pushing imposed 23% more A/P shear force than pulling since spinal tissue tolerances, which are greatly affected by load level, repetition, time of day and posture of the spine, are much lower for shear and torsional forces than compressive ones (Marras, 2000). It has been proposed by Marras (2000) that (A/P) shear force may be more important than compressive force if the magnitude of compressive force is below the threshold that causes tissue damage.

The literature provides information on factors that affect push/pull forces such as wheel specifications and handle height (Lee et al., 1991, 2011; Hoozemans et al., 1998; Al-Eisawi et al., 1999; Chow and Dickerson, 2015). The literature also describes how load weight, load control, and speed of activity influence spinal compressive, lateral shear, and A/P shear forces (Marras et al., 2009). However, research comparing pushing versus pulling pallet jacks is limited. Given the high frequency and cost of low back disorders in MMH tasks, including pallet jack use, finding ways to reduce MMH workers' biomechanical exposure is important. Therefore, the goal of this study was to compare pushing versus pulling when the operator travelled with the load behind thereby allowing a clear line of sight.

In a prior publication we explored the subjective and physiological aspects of pushing versus pulling a pallet jack when the operator travelled with the load behind the user. Results showed that there was no substantial difference in the maximum force production required to maneuver the pallet jack (measured via a force transducer in the stem of the handle), yet the physical demand, quantified by higher oxygen consumption and heart rate levels, was higher while pushing the pallet jack versus pulling it (Harris-Adamson and Lin, 2013). Still, subjective ratings indicated improved comfort for all body regions possibly due to the improved posture of the shoulder and trunk and the ability to share the load with two hands versus one. Therefore, this analysis sought to assess whether pushing versus pulling a pallet jack offered biomechanical advantages as measured by lumbar spine forces, trunk posture, muscle activity and strength capacities.

2. Materials & methods

2.1. Participants

The experimental protocols were approved by the Institutional Review Board of the Liberty Mutual Research Institute for Safety. Men between the ages of 18 and 65 years were recruited for this laboratory study. After giving their informed consent, fourteen people agreed to participate. Study participants had an average age of 43.5 years (SD = 14) with the youngest participant being 22 years of age and the oldest being 59. The average height and weight was 178.7 cm (SD = 6.61) and 85.3 kg (SD = 14.8). Heights ranged between 166.5 cm up to 188 cm and weights ranged between 67 kg and 113 kg. Participants were a sample of convenience and were only excluded if they had any current musculoskeletal disorders, cardiovascular conditions, or other adverse physical conditions that would place them at risk during the experiment.

2.2. Intervention: standard pull versus alternative push handles

The alternative handle was a prototype designed by the authors and collaborating scientists in response to shoulder injuries assessed during fieldwork at material handling plants, yet specifically for research purposes. The design goal was to optimize an operator's efficiency and safety by reducing awkward shoulder, trunk, forearm and wrist posture, potentially reducing biomechanical risk to the lumbar spine and shoulder. Participants performed all tasks with a pallet jack carrying a medium load (295 kg) travelling behind them using two different handles (Li et al., 2008). The standard pallet jack handle was a horizontal handle that allowed for a unilateral grip behind the operator (Fig. 1b). The alternative handle was attached to the pallet jack and allowed bilateral gripping in front of the operator (Fig. 1a). The alternative handle (Harris-Adamson and Lin, 2013) was designed as an optional handle for specific use during long travels when the load was pulled behind the operator. Using Fig. 1a and b as an example, if F is the necessary force required to move the load, when pulling the pallet jack (Fig. 1b) the participant shown would have to apply 40% more hand exertion force (cF given $\Theta = 23^{\circ}$) in order to generate enough horizontal force to pull the load forward. The alternative handle (Fig. 1a) provided greater efficiency by allowing all the participant's push force to be bilaterally directed in the horizontal direction thereby reducing hand exertion force (F/2). The same benefit is appreciated by all participants, albeit slight variations based on the participant's height (affecting Θ and cF) since both the standard and alternative handles were freely adjustable in handle angle (Θ, Fig. 1a and b). The bilateral grip angle was positioned at 15° from vertical in the sagittal plane and 45° from vertical in the

a. Alternative handle. b. Standard handle.

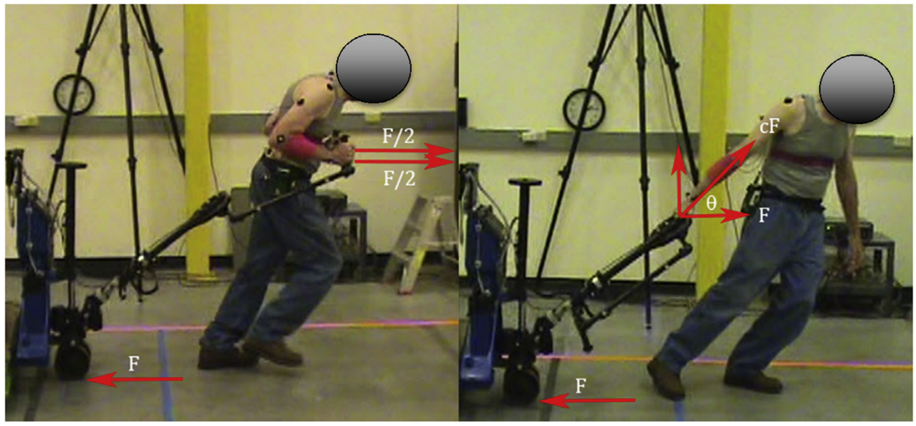


Fig. 1. a & b depict the alternative handle that pushing with bilateral hand exertions and the standard pulling handle that allows for one handed pulling. The diagrams depict the force estimates for each scenario (see Section 2.2 for more detail). a. Alternative handle. b. Standard handle.

frontal plane to maximize grip strength efficiency (Lin et al., 2012). The postures used with each handle were similar across subjects and previously described in detail (Harris-Adamson and Lin, 2013). Although the standard handle allowed for pulling at approximately hip height and the alternative handle accommodated a waist high push force, both handles allowed for a close to neutral wrist position in the sagittal and frontal planes.

2.3. Study design & protocol

This was a laboratory based intervention study of cross over design and has already been described in detail (Harris-Adamson and Lin, 2013). First, participants performed maximum voluntary exertions while pushing and pulling using the alternative and standard handles. Participants then performed 10 trials on a straight 8 m long path. Initial segments (0–80% of maximum velocity) and sustained segments (80–100% of maximum velocity) were recorded and quantified. The second task included a right and a left turn and was repeated for 6 trials. The 10 straight trials and 6 turning tasks (3 in each direction) were repeated for both handles; the order of intervention testing was randomized. Participants rested for up to 20 min between interventions.

Muscle activity was assessed via bipolar surface electrodes placed over the extensor digitorum (ED), flexor digitorum superficialis (FDS), upper trapezius (UT), and pectoralis major (PM) muscles of the right upper extremity using recommended anatomical placement (Perotto, 2005). Data were sampled at 1000 Hz, and telemetrically transmitted (Telemyo 2400 T, Noraxon, Scottsdale, Arizona) to be stored in a computer for data processing and analysis.

A motion tracking system (MotionAnalysis, Santa Rosa, CA, U.S.A.) was used to capture the movement of the reflective markers placed on the pelvis, trunk, upper arms, and forearms of the participants, as well as those markers placed on the handle and extension bar of the pallet jack. The forces between the pallet jack and the handle were measured and synchronized with the kinematic data by a multi-axis transducer (PY6-500, Bertec, Columbus, OH, U.S.A.). The raw 3-D kinematics data and the forces between the pallet jack and the handle collected by the motion tracking system and the transducer were filtered with a 4th order Butterworth zero-lag low pass filter at 8 Hz.

2.4. Data analysis

Raw electromyography data (EMG) was converted to RMS using a 100 ms time constant. Three EMG amplitudes recorded for reference voluntary contractions (RVCs) for each muscle were averaged and used as the reference values. The signal for each muscle during tasks was normalized to percent RVC values and summary measures for each muscle were calculated for the amplitude probability distribution (APDF) (Jonsson, 1982). The APDF described the distribution of EMG signals measured such that 50% of all EMG signals were less than the APDF 50 value (50th percentile), and 90% of all EMG signals measured were less than the APDF 90 value (90th percentile), representing median and peak force production.

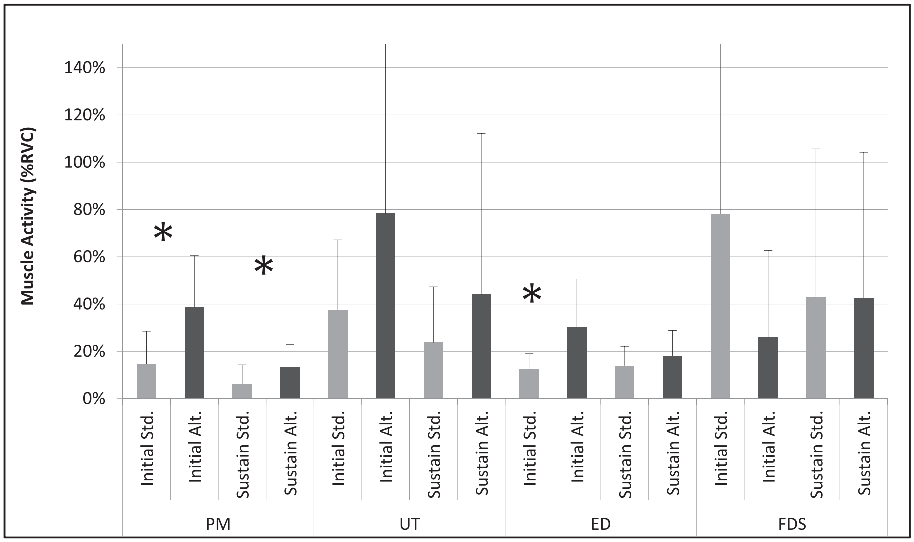
The collected 3-D kinematics data were input to 3D Static Strength Prediction Program (3DSSPP) (University of Michigan, Ann Arbor, MI) for estimating the low back (L4/L5 & L5/S1) compressive, shear (A/P, lateral) and torsional forces when maneuvering the pallet jack using the standard pull versus alternative push handles. Strength capacities of the trunk, shoulder and distal upper extremity were estimated using 3DSSPP and then compared between two handle designs. After being assessed for normality using the Shapiro-Wilks test, all outcome measures were analyzed using the paired *t*-test.

3. Results

The average maximum voluntary pulling (standard handle) and pushing (alternative handle) forces were 435 N (SD = 80) and 439 N (SD = 103), respectively. Among straight segments, the average exertion was 15%–20% capacity for pull and pushing handles, while peak exertion ranged between 72% and 77% capacity.

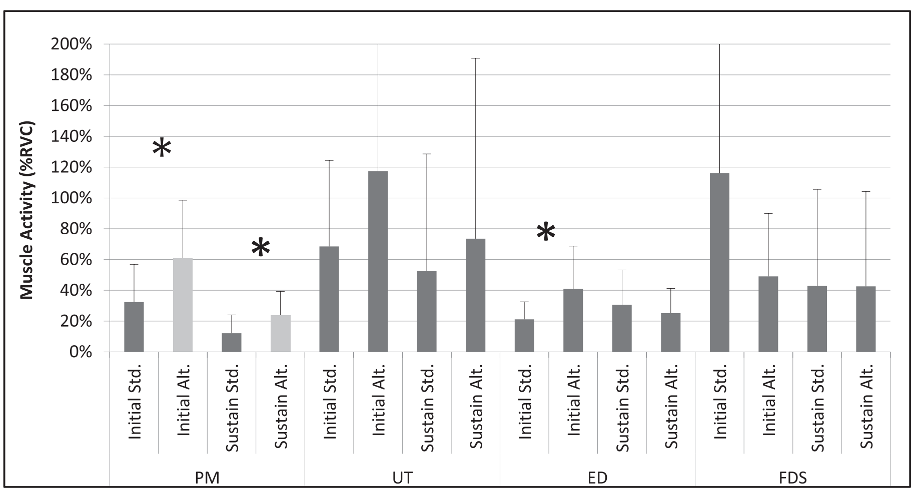
The muscle activity was the same or greater using the alternative handle with occasional increases in muscle activity when using the standard handle (Figs. 2 and 3). Specifically, the mean and peak PM muscle activity was greater while pushing the pallet jack ($p < 0.000$) during all segments. Mean and peak PM activity was lower than 40% and 60% of participants RVC, respectively. There were no significant differences in UT muscle activity when pushing versus pulling during all segments. Peak ED activity was higher while pushing versus pulling during initial ($p < 0.01$) and turning ($p < 0.02$) segments with similar patterns observed for mean ED activity. Activity of the FDS was equal or higher while pulling the pallet jack, though there were no statistically significant differences.

Compressive forces were consistently higher while pushing versus pulling (Fig. 4) and highest during initial segments. Mean compressive forces ranged between 307 N–495 N and peak forces



* significant at p<0.05

Fig. 2. Mean muscle activity (APDF 50) of the pectoralis major (PM), upper trapezius (UT), extensor digitorum (ED), and flexor digitorum superficialis (FDS) during initial and sustained travel segments while using the standard (std.) and alternative (alt.) handles ($N = 14$). *significant at $p < 0.05$.



* significant at p<0.05

Fig. 3. Peak muscle activity (APDF 90) of the pectoralis major (PM), upper trapezius (UT), extensor digitorum (ED), and flexor digitorum superficialis (FDS) during initial and sustained segments while using the standard (std.) and alternative (alt.) handles ($N = 14$). *significant at $p < 0.05$.

ranged between 678 and 712 N while pulling and pushing, respectively. Overall, the magnitude of shear and torsional forces at L5/S1were highest during the initial segment (Fig. 5). The highest mean A/P shear force was 83.7 N while pushing compared to 49.2 N while pulling. Mean lateral shear (111.0 N) and torsional (52.4 N) forces were highest while pulling versus pushing (73.4 N lateral shear; 25.4 N torsion). The pattern of comparative magnitude of forces between pushing and pulling were similar across sustained and turning segments; lateral shear and torsional forces were highest while pulling and the A/P shear forces were highest while pushing.

The elbow and trunk strength required during initial straight, sustained straight and turning segments were acceptable to more than 95% of the population for both handles (Table 1). In the shoulder, initial straight segment strength requirements were acceptable to 89% of the population when pushing and to 97% of the population while pulling ($p < 0.06$). Turning while using the alternative handle was acceptable to only 53% of the population but rose to 63% of the population when pulling the pallet jack by using the standard handle ($p < 0.21$). There was a consistent 5° increase in mean trunk angle while pulling during initial straight ($p < 0.13$), sustained straight ($p < 0.02$) and turning segments ($p < 0.00$).

4. Discussion

Overall, different benefits emerged when comparing pushing to pulling a pallet jack with the load travelling behind the user. The peak push and pull forces (%capacity) measured while using the alternative and standard handles confirmed that there was no difference in the amount of force that was required to maneuver the pallet jack while using each handle. However, pulling the pallet jack outperformed pushing the pallet jack with regard to muscle

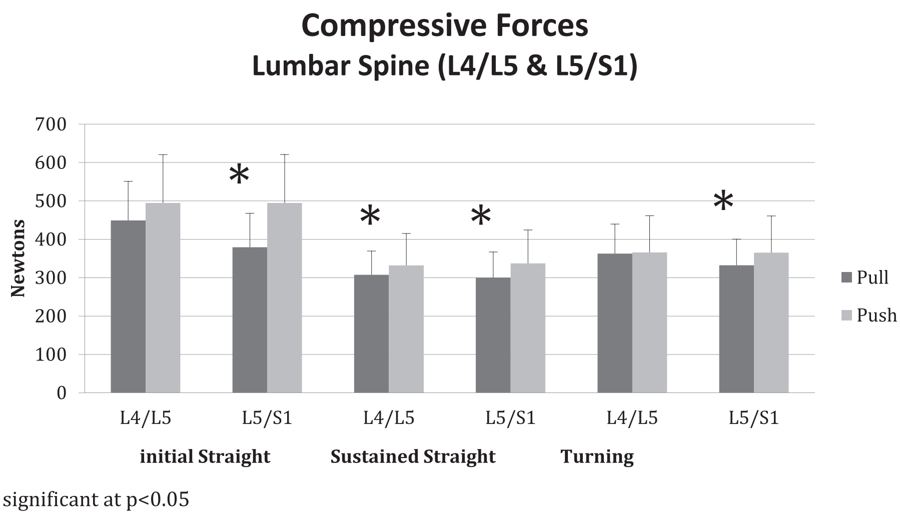


Fig. 4. Compressive Forces at L4/L5 & L5/S1 during initial straight, sustained straight and turning segments while using the standard and alternative handles. *significant at $p < 0.05$.

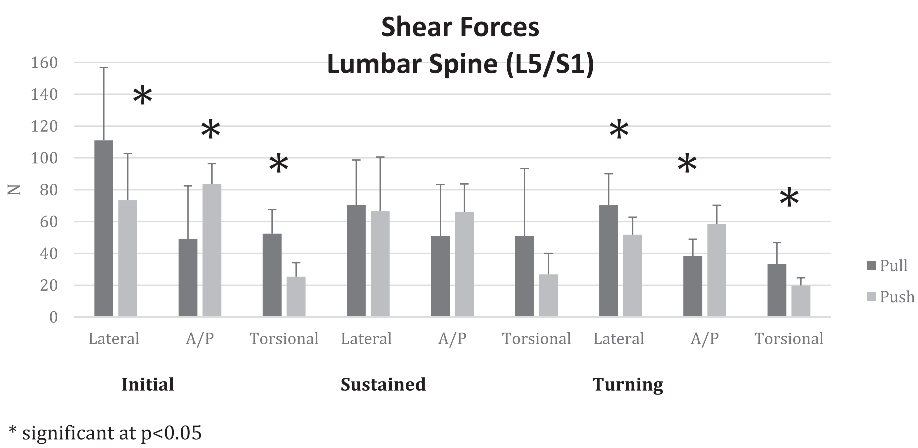


Fig. 5. Dynamic shear forces during initial straight, sustained straight and turning segments while using the standard and alternative handles. *significant at $p < 0.05$.

Table 1
Strength capacity (% of population) and trunk posture (angle) during initial straight, sustained straight and turning segments while using the standard and alternative handles.

Strength capacity	Standard handle				Alternative handle				p value[a]
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Elbow (%)									
Initial	95.9	3.1	89.8	99.1	95.9	5.0	83.3	99.8	p < 0.48
Sustained	99.7	0.2	99.2	99.9	99.6	0.3	99.0	100.0	p < 0.3
Turning	99.1	0.6	97.8	100.0	99.3	0.5	98.3	100.0	p < 0.79
Shoulder (%)									
Initial	88.6	20.3	40.5	99.1	97.4	2.9	88.5	99.2	p < 0.06[a]
Sustained	91.1	15.8	49.8	99.7	98.8	1.6	93.4	99.5	p < 0.04[a]
Turning	62.5	31.2	0.0	99.3	53.1	33.4	0.0	99.0	p < 0.21
Trunk (%)									
Initial	98.0	1.4	93.7	99.0	95.4	3.2	87.5	98.9	p < 0.06[a]
Sustained	98.7	0.6	96.9	99.0	98.2	0.9	96.1	99.0	p < 0.00[a]
Turning	96.7	6.5	74.3	99.0	96.0	6.8	73.0	99.0	p < 0.4
Trunk angle (°)									
Initial	49.8	6.2	40.0	58.2	44.1	10.1	26.0	61.6	p < 0.13
Sustained	39.3	5.1	30.1	49.8	34.7	5.7	23.2	43.7	p < 0.02[a]
Turning	35.0	3.5	29.0	42.7	30.4	4.3	22.0	40.2	p < 0.00[a]

[a] Paired *t*-test.

activity, compressive and A/P shear forces, while pushing was only superior in terms of lateral shear and torsion.

The %RVC was consistently lower when participants used the standard handle to pull the pallet jack. The increase in PM activity using the alternative handle during initial and sustained travel was expected given that the posture required a push force versus a pull force. Although the increase was statistically significant, the median muscle activity, as quantified by the APDF 50, stayed well below 50%RVC (initial) and 20%RVC (sustained) indicating a substantially lower effort than individuals' RVC. Peak muscle activity was also relatively low, the average being below 60%RVC and 40% RVC for initial and sustained travel segments. The relatively low mean and peak muscle activity suggests no disconcerting increase in overall PM muscle activity when pushing using the alternative handle.

The increase in mean and peak (APDF 50 and 90) UT and ED muscle activity while using the alternative handle during initial and sustained travel segments was unexpected and possibly due to the operator actively holding the handle in position, despite our best efforts to eliminate any upward force requirements to support the handle. This design flaw could be improved. It could also indicate that more dynamic muscle activity is required when using the alternative handle, whereas more passive tension of connective tissue contributes to force production when using the standard handle. The statistically significant increase in mean and peak finger flexor muscle activity (FDS) while pulling is important in that the highest mean and peak values of all muscles was observed in the FDS while initiating travel using the standard handle. This may have contributed to the increased hand discomfort reported and described in a prior publication (Harris-Adamson and Lin, 2013).

Consistent with findings from Lett and McGill (2006), our results indicate that pulling produced less compressive and A/P shear forces than pushing. This is in contrast to other literature by Schibye et al. (2001) and Hoozemans et al. (2002a,b) that reported less compressive force during pushing than pulling. It has been reported that optimal handle height for pushing tasks is at the shoulder height which allows the center of mass to be in front of the base of support to assist with forward hinge torque and reduce reliance on muscular activation and overall lower lumbar moments (Lett and McGill, 2006; Hoozemans et al., 2002a,b). In contrast, the optimal handle height while pulling is at waist height (Lett and McGill, 2006), resulting in the lower A/P shear force (Knapik and Marras, 2009) and shear force (Hoozemans et al., 2004). Although neither handle optimized handle height, it is possible that handle height favored pulling since it aligned pull force with the lumbar spine thereby reducing low back spinal extensor muscle activity and resultant compressive loads (Lett and McGill, 2006).

Despite the greater compressive forces while pushing, forces were well below the NIOSH limits of 3400 N set for MMH task (Schibye et al., 2001). Our values for compressive forces are consistent with those from Schibye et al. (2001) who calculated less than 210 N while pushing and pulling waste containers. The A/P shear forces quantified in this study were also well below the suggested limit of 500 N (McGill, 2002). Despite these thresholds, other physical factors such as the frequency and duration of the exertion and personal factors such as comorbidities may influence one's tolerance for lumbar spine compressive and shear forces. In addition, although forces were estimated at the lower lumbar spine in this analysis, Knapik and Marras (2009) found that vertebral segments above L4 had three times more shear force as the lower lumbar levels due to the curvature of the spine. Therefore, it is possible that vertebral levels above L4 experienced shear forces closer to or exceeding the suggested threshold limit value for tissue tolerances.

It is interesting that the biomechanical and physiological evaluation of the alternative handle did not show substantial benefits while the subjective ratings on usability and comfort did (Harris-Adamson and Lin, 2013). One possibility is that the push handle allowed a more neutral spine position favoring engagement of trunk flexors and extensors over lateral flexors and rotators of the spine that were likely engaged when using the standard handle. Higher engagement of global trunk muscles may have provided more stability in the spine, but at a cost of higher compressive force. Collecting data on muscle activity of the trunk muscles may help to corroborate such a theory. The decrease in upper extremity muscle activity while using the standard handle supports the notion that more passive tension is utilized when pulling the pallet jack versus pushing it. When using the standard handle, the full elbow extension, shoulder extension and external rotation places key muscles and some ligaments in lengthened positions thus relying on passive tension of the connective tissues to contribute to overall force production. In contrast, the alternative handle supports neutral shoulder posture and maximizes the length-tension force capability of shoulder and elbow muscles. Elbow and shoulder ligaments are not under tension. Therefore, although dynamic muscle activity is higher using the alternative handle, the joints (shoulder in particular) are in a better position to absorb shock when jolted by bumps or sudden stops versus the standard handle where structures are under tension and in a compromising position. Perhaps this explains why subjectively the alternative handle outperformed the standard handle despite the slightly higher biomechanical and physiological workloads.

It is also important to remember that the expected risk of low back disorders is more complicated than assessing spinal loads since other factors such as psychosocial stress, gender, and personality have also been identified as impacting one's risk for low back disorders (Marras, 2000). It is plausible that the participants' improved comfort while pushing versus pulling (Harris-Adamson and Lin, 2013) is due to some factor other than the physiological and biomechanical factors that we measured. Additionally, although most of the physiological and biomechanical loads were greater when using the alternative handle versus the standard one, all of the loads were reasonably low. Perhaps the improvement in comfort is still worthwhile, particularly if the alternative handle is used for longer bouts of travel. Perhaps future studies should examine the usability, comfort and effectiveness of the handle in a workplace setting over a longer duration of use to fully evaluate its utility as an additional handle.

Some of the constraints of this study include the nature of the laboratory setting and our ability to properly reproduce the various challenges of using pallet jacks in an occupational setting. We did not measure the muscle activity of other larger muscles such as the trunk muscles or leg muscles that may have been more active in the alternative handle causing the higher overall workload previously reported (Harris-Adamson and Lin, 2013). There was increased variance of mean and peak UT and FDS muscle activity across subjects which may indicate that slight differences in how the handles are positioned might have an impact on the magnitude of muscle activity. For example, the amount of forward lean of the body using the alternative handle may shift reliance from the biceps brachii to the upper trapezius muscles, particularly during initiation when force generation requirements are higher. Additionally, having more individuals that were closer to the shortest or tallest adult population statures may have affected the amount of wrist deviation in the frontal plane; thus future designs may require adjustable handles. The small nature of the study also excluded women who are pallet jack users in the field, albeit in much smaller percentages.

5. Conclusion

Pallet jack use is a very common task in MMH jobs and travelling distances with the pallet jack behind the operator is a necessary and common component of using pallet jacks due to the visual advantages that reduce collisions and the efficiency of travel. This project compared a handle that provided an alternative two arm push technique to the one arm pulling technique most commonly used in the workplace. A prior publication presented data on usability, comfort and the physiological demands while using each handle (Harris-Adamson and Lin, 2013) while this paper presents data on spinal loads, muscle activity and strength capacities. Pulling required less muscle activity, less energy expenditure and lower compressive and A/P shear forces. However, pushing resulted in lower lateral shear and torsional forces, lower discomfort ratings, and increased user preference. Given that all of the spinal loads were well below NIOSH threshold limit values and the favorable shoulder position and subjective ratings while using the alternative handle, facilitating MMH workers' ability to push a pallet jack while travelling with large loads is worth further investigation, and could be beneficial as an additional or secondary handle in pallet jack operations.

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