The Effect of Lift Teams on Kinematics and Muscle Activity of the Upper Extremity and Trunk in Bricklayers

Healthcare practitioners often provide ergonomic guidance when rehabilitating patients after work-related musculoskeletal disorders (MSDs). Additionally, clinicians may be involved with primary prevention when working as ergonomic consultants. In this role, consultants provide ergonomic education, assess exposure to biomechanical risk factors, and suggest interventions to reduce injury risk. Among all occupational injury-prevention services provided by physical therapists, instruction in proper lifting technique is likely the most common.

Patients in the clinic or workplace are generally taught a squat or straddle lift as an option to the stoop lift. Although lift training can change behavior, there is no evidence that one lifting technique is best. Additionally, instruction in lifting techniques is generally limited to single lift scenarios, and these techniques are usually not applicable to more complex work tasks, such as lifting heavier items or lifting in teams.

Lifting-related MSDs affect all sectors of the working population and are especially prevalent in construction workers. In construction, overexertion while lifting accounts for over 40% of MSDs with days away from work. Of all construction trade workers, masons (bricklayers and cement masons) have one of the highest rates of back injuries and illnesses with days away from work. Although 75% of bricklayers report low back symptoms, shoulder and wrist symptoms are also prevalent in this trade. Therefore, bricklayers repre...
sent an important population for primary and secondary prevention programs.

Bricklayers handle heavier materials than bricks, such as concrete blocks weighing from 16 to 34 kg. In a typical work day, bricklayers lift hundreds of blocks, approximately over 4000 kg of material. A number of interventions have been proposed to aid in reducing the risk associated with repetitive lifting of heavy block. These solutions include lighter-weight blocks, adjustable-height scaffolding to keep lifting between knee and chest height, and use of lift teams when handling heavy block.

It seems intuitive that lift teams could more safely handle heavier concrete blocks than a bricklayer working alone. Heavier concrete block is used to construct the exterior of large buildings such as big-box stores or elementary schools. Yet, laboratory studies suggest that lifting an object with a partner may increase spinal loads compared to lifting alone. Bricklayers do not consistently support the use of lift teams, with anecdotal evidence suggesting that it may be easier or more productive to work alone. Use of lift teams remains an infrequently used strategy, with only 24% of contractors making use of such teams. Thus, it is unclear if lift teams are a desirable workplace intervention.

The purpose of this study was to evaluate the effect of lift teams on trunk and upper extremity kinematics and muscle activity among bricklayers. A secondary purpose of the study was to evaluate the interaction of lifting height with these outcome variables.

METHODS

Subjects

Eighteen male bricklayers constructed walls with 12-inch (30.5-cm) concrete blocks alone (1 person) and in 2-person lift teams. This block is among the heaviest a bricklayer will individually handle in the United States. Participants in this task-simulation study were third- or fourth-year apprentice-level bricklayers, recruited from a regional apprenticeship training center (International Masonry Institute, Seattle, WA). Third- and fourth-year apprentices are working full time and fully skilled in their trade. Volunteers were eligible for participation if they were currently employed as a bricklayer and at least 21 years of age. Exclusion criteria included any MSD of the upper extremity or spine diagnosed by a healthcare professional during the previous 6 months; previous surgery for any upper extremity, cervical, or lumbar MSD; or a history of rheumatoid arthritis. Exclusion criteria were assessed by self-report on a demographic questionnaire. The Institutional Review Board at Eastern Washington University approved the study, and participants provided written consent. Participants were compensated monetarily for participating in the study.

Motion Capture

Shoulder and trunk motions during wall construction were measured with a 3-D motion-capture system (VICON 624c M2 cameras and Workstation Version 4.6 software; OMG plc, Oxford, UK) and analyzed with Visual3D Version 3.25 software (C-Motion, Inc, Germantown, MD). The nontrowel hand (ie, the non–trowel-holding hand) during concrete blocks on the wall using just their non–trowel-holding hand during wall construction. Some participants were able to position concrete blocks on the wall using just their non–trowel-holding hand during wall construction. The nontrowel hand is also the arm used to lift concrete blocks during team lifting.

Tracking markers were placed on the surface of the block that faced away from the subject as the subject set the block onto the wall. The tracking markers made an individual coordinate system for each block. One of the block’s tracking markers was placed at the center of the block face, at the bisection of 2 lines drawn to adjacent corners of the block. The center of mass of each block was tracked by forming a virtual marker positioned in the center of the block. The virtual center-of-mass marker was created in Visual3D software at a distance halfway into the block, starting from the center marker and moving in a direction orthogonal to the block face surface. Events of interest were the start of a lift, defined as when the bricklayer lifted the block off the supply stack, and the end of the lift, defined as when the block’s velocity reached zero as it was placed on the wall. The placement of 1 block for each row of the wall construction was chosen. This block was typically in the middle of the row and was the one least visually compromised by wall construction, building materials, or lifting partner.

Subjects wore black spandex shirts with holes cut into the fabric so the markers could be attached directly to skin and be visible to the 8-camera setup around the room. The pelvis and trunk marker set was adapted from a previously published marker set. Reflective marker spheres (14 mm) were placed using double-sided tape and Quick Drying Adherent Spray (Mueller Sports Medicine, Inc, Prairie du Sac, WI) to identify pelvis, trunk, and shoulder segment dimensions (FIGURE 1). The pelvis segment was defined by markers placed on the most superior part of the pelvis at the iliac crests and the greater trochanters of the femur. The trunk-segment dimensions were defined by the iliac crest markers, as well as markers on the superior aspect of the acromioclavicular joints. A rigid, thermoplastic shell to track pelvis position was affixed over the sacrum by Velcro (Velcro USA Inc, Manchester, NH) sewn into elastic baseball pants and held in place with a leather belt. Five markers were used to define a coordinate system to track motion of the trunk segment. They were placed on the superior aspect of the sternum, the spinous processes of the T1 vertebra, lateral to the T8 vertebra, and lateral to both sides of the erector spinae at approximately the T4 level. The shoulder-segment dimensions and marker setup were adapted from prior work.
The shoulder-segment dimensions were defined proximally, at a position 6 cm inferior to the acromioclavicular marker (negative vertical displacement relative to the trunk’s coordinate system), and distally, by markers placed on the most caudal point of the medial and lateral epicondyles of the humerus. A shell with 4 tracking markers affixed to its surface was attached to the arm via a Coban wrap (3M Health Care, St Paul, MN) on the lateral surface of the arm to track the 3-D position of the arm segment in space.

Prior to collecting data, a standing calibration collection was recorded to determine joint center locations with respect to each segment. Video data from the cameras were sampled at a rate of 60 Hz. Marker trajectories were low-pass filtered at 3 Hz with a recursive fourth-order Butterworth filter. Trunk motion was expressed as a comparison of the trunk segment in reference to the pelvis segment. Shoulder angles were determined as segment rotations between the coordinate system of the upper arm segment in reference to the trunk segment. This was accomplished with Euler angle calculations resolved in the sagittal plane (flexion motion about the x-axis), then the frontal plane (abduction motion about the y-axis), and then the transverse plane (rotation motion about the z-axis), assuming rigid-body analysis. This resolution of Euler angles is consistent with recommendations for determining shoulder motion by the International Shoulder Group of the International Society of Biomechanics.

Electromyography
Surface electromyography (EMG) was used to measure bilateral activity of the lumbar erector spinae (L3 level, paraspinals), upper trapezius, and flexor digitorum superficialis (flexor forearm) using standard locations. These anatomical regions are known sites of MSDs among bricklayers. The electrodes had dual 1 × 10-mm, bipolar, silver-silver chloride surfaces; an interelectrode distance of 10 mm; and on-site preamplification with a gain of 1000. They were attached to an EMG data logger (Myomonitor IV EMG System; Delsys Inc, Boston, MA), with a sampling frequency of 1000 Hz and a bandwidth of 20 to 450 Hz, placed in a fanny pack, and worn by the participant.

Surface EMG from all muscles was normalized to percent of root-mean-square amplitude during submaximal reference contractions (reference voluntary electrical activation). For normalization of the lumbar paraspinals, participants stood with knees extended and held a concrete block with their elbows extended and lumbar spine flexed until the top of the block was level with their knees. For normalization of the upper trapezius, participants abducted their shoulders to 90° in slight horizontal adduction while holding a 2-kg weight. For normalization of the flexor forearm muscles, participants were instructed to grip a digital hand dynamometer (GripTrack; JTECH Medical, Salt Lake City, UT) to 9.1 kg of force, as observed on the digital display, with their arm in a standard position. For all participants, the handle of the dynamometer was maintained at grip position 2 (the position second closest to the fixed handle).

Participants held reference voluntary electrical activations for 15 seconds, and the middle 10 seconds was used for analysis. Each normalizing contraction was repeated 3 times, with the mean value used for percent reference voluntary electrical activation. The coefficient of variation was calculated to ensure that a mean value could be used for the normalization contraction. Participants rested for 2 minutes between all exertions. Resting EMG amplitude was recorded and subtracted from the amplitudes obtained during normalizing contractions and tasks.

Experimental Procedure
A bricklayer apprenticeship instructor constructed 2 vertical concrete-block piers, approximately 2 m high and 7 blocks apart, out of 12-inch block (0.3 × 0.3 × 0.4 m) to act as boundaries for wall length and height. Three sections of re-
FIGURE 2

FIGURE 3. Wall construction at row 6 using a lift team.

bar (Ø5, 1.6-cm diameter, 1.3-m length) were placed vertically in holes drilled in the floor. Study participants constructed walls 6 rows high using 12-inch whole and half blocks in a staggered pattern (running bond), which is a conventional construction method (FIGURE 2). The odd rows of the wall consisted of 6 whole blocks, and the even rows consisted of 5 whole and 2 half blocks. Thus, each wall was constructed with 33 whole blocks and 6 half blocks. Whole blocks weighed approximately 21 kg and were manufactured by a single supplier.

A 0.8-m-high mortar board was placed behind the bricklayer, and a stack of blocks was placed on both sides of the mortar board. The mortar was made of SPEC MIX (SPEC MIX, Inc, Eagan, MN) and dehydrated lime mixed with water. An experienced masonry laborer maintained an adequate supply of mortar and kept the supply stack of blocks at a constant height of 0.9 m.

After the instrumentation was applied and data logging was initiated, participants constructed 2 concrete-block walls, beginning from the left pier using the 1-person method (FIGURE 2) and in a 2-person lift team (FIGURE 3). The 1-person wall-construction method consisted of 4 primary subtasks: (1) “line block” positioning, (2) mortar application, (3) block placement, and (4) finishing. The line block is a string with wooden blocks on either end used to maintain level rows. At the beginning of the first row, the line block was positioned between the 2 piers. Next, mortar was applied to the floor with a trowel. The block-placement task consisted of picking up a block from the supply stack with 1 or 2 hands and positioning it on the row. Most bricklayers handle heavy concrete blocks with 2 hands, simultaneously holding on to their trowel in their dominant hand. The finishing task consisted of scraping off excess mortar or tapping on a block to maintain a level row/wall. Subsequent rows followed the same pattern of the 4 subtasks (ONLINE VIDEO).

The 4 primary tasks were similar for the lift team, with a few exceptions. Both bricklayers positioned the line block and applied mortar. For the block-placement subtask, each bricklayer used 1 hand to lift the block off of the supply stack and place it on the wall. Subjects used their nondominant hand to help lift the block and their dominant hand to hold their trowel. After the block was placed on the wall, the subject performed the finishing task while the other bricklayer applied mortar to the next block to be placed (ONLINE VIDEO). The bricklayers were instructed to perform the task at their normal work pace, using a lifting technique of their choice. Construction duration was timed, and subjects rested 20 minutes before starting the second wall. Subjects were not instructed to use any specific lifting technique, such as squat or stoop, while constructing the walls. The wall order was counterbalanced among participants to prevent an order effect.

A single block lift was analyzed with motion capture during the building of rows 1, 3, and 6, after the instrumentation was applied for preplanned comparisons at rows 1, 3, and 6. All data collection started when the subject first laid mortar to begin a row and ended when the last whole block was positioned on the respective row.

Statistical Analysis

Prior to the main analyses, all variables were checked for out-of-range values, assumptions of normality, and outliers. It was decided a priori to consider kinematic and EMG values with z scores greater than 2.58 (P = .01, 2-tailed) as outliers. Outliers were recoded to a value of 1 unit greater than (or less than) the next most extreme value.48 After recoding the outliers, all data could be considered normally distributed.

Descriptive statistics were calculated for the kinematic and EMG variables. Differences between the construction methods for all outcome measures were evaluated with 2-way repeated-measures analyses of variance. Separate models were run for each outcome variable. Construction method was a within-subject factor, with 2 fixed levels (1 person alone and 2-person lift team). Row was also a within-subject factor, with 3 fixed levels (1, 3, and 6). The interaction between method and row was a fixed factor, and subjects were random. Although main effects and interaction were evaluated, simple effects were the primary comparisons of interest. The Mauchly test was used to test the sphericity assumption, and a Greenhouse-Geisser epsilon estimate was used for violations. The familywise alpha level was .05, and a Bonferroni adjustment was used for preplanned comparisons of methods at rows 1, 3, and 6. All analyses were conducted with SPSS Version 19.0 (SPSS Inc, Chicago, IL).
RESULTS

The study participants (N = 18) had a mean ± SD age of 29.5 ± 7.1 years, height of 1.8 ± 0.06 m, and weight of 84.9 ± 14.3 kg. The mean ± SD years of employment for the third- and fourth-year apprentices was 4.5 ± 6.6, because many had bricklaying experience before entering apprenticeship training. Due to data logger malfunction, kinematic data are reported on 18 bricklayers and EMG data are reported on 17 bricklayers. The mean construction time was 25.3 minutes for the 1-person method and 15.8 minutes for lift teams (paired t test, P < .001).

TABLE 1 summarizes trunk and shoulder kinematic data. For trunk flexion, there was a significant main effect of wall-construction method (P = .008) and a main effect of row (P < .001), but no interaction between the method and row height (P = .209). In contrast, trunk sidebending exhibited main effects for construction method and row height, and an interaction effect between the factors (P < .011). Trunk rotation also showed a significant main effect of method (P < .001), where lift teams demonstrated more motion than the 1-person lift at every row (P < .028).

TABLE 2 shows that study participants demonstrated significantly less lumbar muscle activity on the nondominant side when constructing the wall in a lift team (main effect, P = .019), but there was no statistically significant difference between methods for the dominant-side paraspinals (main effect, P = .013; Bonferroni-corrected a = .008). Also, there was no main effect of row height for lumbar muscles on the nondominant side (P = .118) or dominant side (P = .807). Differences were not statistically significant in the preplanned comparisons (row 1 versus row 6, P = .014; row 3 versus row 6, P = .018; Bonferroni-corrected a = .008).

For peak shoulder flexion kinematics, there were significant main effects of both method type and row height (P < .004), with a significant interaction present between these factors (P = .017) (TABLE 1). Analysis of shoulder abduction during peak flexion revealed main effects for lift method and row height (P < .006), with no interaction between the lifting method and row height (P = .555). There were significant simple effects for differences in row height within each method (P < .001), but only row 3 compared to row 6 for lift teams was statistically significant (P < .001).

Working in lift teams resulted in significantly less upper trapezius activity on the dominant side (main effect of method, P = .027) and significantly greater activity on the nondominant side (P = .033) (TABLE 2). In general, more upper trapezius exertion was necessary when

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**TABLE 1**

<table>
<thead>
<tr>
<th>Variable/Height</th>
<th>1 Person</th>
<th>Lift Team</th>
<th>P Value</th>
<th>Preplanned comparison significantly different between rows 1 and 3.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk flexion, deg</td>
<td>Row 1</td>
<td>82 ± 13§</td>
<td>77 ± 10*</td>
<td>.007</td>
</tr>
<tr>
<td></td>
<td>Row 3</td>
<td>58 ± 15§</td>
<td>75 ± 13*</td>
<td>.598</td>
</tr>
<tr>
<td></td>
<td>Row 6</td>
<td>32 ± 12§</td>
<td>25 ± 11§</td>
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<td>P value§</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk sidebending, deg</td>
<td>Row 1</td>
<td>10 ± 5</td>
<td>17 ± 4</td>
<td>.215</td>
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<tr>
<td></td>
<td>Row 3</td>
<td>13 ± 4</td>
<td>13 ± 4</td>
<td>.999</td>
</tr>
<tr>
<td></td>
<td>Row 6</td>
<td>13 ± 5</td>
<td>21 ± 7</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>P value§</td>
<td>989</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk rotation, deg</td>
<td>Row 1</td>
<td>18 ± 7</td>
<td>25 ± 9</td>
<td>.013</td>
</tr>
<tr>
<td></td>
<td>Row 3</td>
<td>18 ± 7</td>
<td>24 ± 7</td>
<td>.014</td>
</tr>
<tr>
<td></td>
<td>Row 6</td>
<td>18 ± 7</td>
<td>24 ± 10</td>
<td>.028</td>
</tr>
<tr>
<td>P value§</td>
<td>955</td>
<td>.941</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder flexion, deg</td>
<td>Row 1</td>
<td>97 ± 18§</td>
<td>94 ± 15</td>
<td>.390</td>
</tr>
<tr>
<td></td>
<td>Row 3</td>
<td>72 ± 21§</td>
<td>57 ± 15</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td>Row 6</td>
<td>107 ± 13§</td>
<td>105 ± 14§</td>
<td>.698</td>
</tr>
<tr>
<td>P value§</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder abduction, deg</td>
<td>Row 1</td>
<td>30 ± 15§</td>
<td>39 ± 13§</td>
<td>.007</td>
</tr>
<tr>
<td></td>
<td>Row 3</td>
<td>36 ± 15§</td>
<td>37 ± 16§</td>
<td>.685</td>
</tr>
<tr>
<td></td>
<td>Row 6</td>
<td>44 ± 5§</td>
<td>54 ± 11§</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>P value§</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block moment arm, m**</td>
<td>Row 1</td>
<td>0.7 ± 0.2§</td>
<td>1.0 ± 0.2§</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Row 3</td>
<td>0.6 ± 0.1§</td>
<td>0.7 ± 0.1§</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Row 6</td>
<td>0.5 ± 0.1§</td>
<td>0.7 ± 0.1§</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>P value§</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Values are mean ± SD (n = 18) unless otherwise indicated.

†Simple effect of construction method.

‡Preplanned comparison significantly different between rows 1 and 3.

§Preplanned comparison significantly different between rows 1 and 6.

¶Preplanned comparison significantly different between rows 3 and 6.

&Simple effect of row.

#Greenhouse-Geisser correction.

**Block moment arm is the horizontal distance from the center of mass of the pelvis to the center of mass of the block in the sagittal plane.
TABLE 2  

Electromyographic Amplitudes for the Lumbar Erector Spinae, Upper Trapezius, and Flexor Forearm While Laying Block Individually and in a Lift Team*  

<table>
<thead>
<tr>
<th>Variable/Height</th>
<th>1 Person</th>
<th>Lift Team</th>
<th>P Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar erector spinae, dominant side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row 1</td>
<td>94±53</td>
<td>79±41</td>
<td>.061</td>
</tr>
<tr>
<td>Row 3</td>
<td>90±40</td>
<td>79±28</td>
<td>.008</td>
</tr>
<tr>
<td>Row 6</td>
<td>83±25</td>
<td>84±26</td>
<td>.868</td>
</tr>
<tr>
<td>P value‡</td>
<td>.366</td>
<td>.636</td>
<td></td>
</tr>
<tr>
<td>Lumbar erector spinae, nondominant side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row 1</td>
<td>104±64</td>
<td>75±24</td>
<td>.026</td>
</tr>
<tr>
<td>Row 3</td>
<td>113±74</td>
<td>81±34</td>
<td>.031</td>
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<tr>
<td>Row 6</td>
<td>122±74</td>
<td>100±50</td>
<td>.104</td>
</tr>
<tr>
<td>P value‡</td>
<td>.580</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>Upper trapezius, dominant side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row 1</td>
<td>47±18</td>
<td>39±19</td>
<td>.004</td>
</tr>
<tr>
<td>Row 3</td>
<td>50±20</td>
<td>38±19</td>
<td>.002</td>
</tr>
<tr>
<td>Row 6</td>
<td>86±31</td>
<td>77±28</td>
<td>.477</td>
</tr>
<tr>
<td>P value‡</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
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<tr>
<td>Upper trapezius, nondominant side</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Row 1</td>
<td>54±21</td>
<td>55±27</td>
<td>.983</td>
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<td>Row 3</td>
<td>65±32</td>
<td>55±22</td>
<td>.072</td>
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<td>Row 6</td>
<td>100±48</td>
<td>128±60</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>P value‡</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Flexor forearm, dominant side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row 1</td>
<td>159±59</td>
<td>140±52</td>
<td>.028</td>
</tr>
<tr>
<td>Row 3</td>
<td>153±64</td>
<td>130±54</td>
<td>.021</td>
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<tr>
<td>Row 6</td>
<td>145±48</td>
<td>135±50</td>
<td>.210</td>
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<tr>
<td>P value‡</td>
<td>.241</td>
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<td>Flexor forearm, nondominant side</td>
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<tr>
<td>Row 1</td>
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<td>152±90</td>
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<td>Row 6</td>
<td>135±65</td>
<td>163±61</td>
<td>.007</td>
</tr>
<tr>
<td>P value‡</td>
<td>.059</td>
<td>.392</td>
<td></td>
</tr>
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</table>

*Values are mean ± SD % reference voluntary electrical activation (n = 17) unless otherwise indicated.  
†Simple effect of construction method.  
‡Preplanned comparison significantly different between rows 1 and 6.  
§Preplanned comparison significantly different between rows 3 and 6.  
¶Preplanned comparison significantly different between rows 1 and 3.

working at higher rows, regardless of construction method or side (main effect of row, P<.001). Work at row 6 required significantly more exertion than at row 1 or 3 for both the dominant and nondominant upper trapezius (preplanned comparisons, P<.001), whereas no significant difference was noted between rows 1 and 3. Lifting in teams also resulted in significantly lower flexor forearm activity on the dominant side (main effect, P = .040) and nondominant side (main effect, P = .024) (TABLE 2). The pattern for the flexor forearm was similar to that of the upper trapezius. Less exertion was required by lift teams at rows 1 and 3 on the dominant side, and greater exertion at row 6 on the nondominant side.

Finally, the lifting method had an impact on the relative sagittal plane moment arm (ie, position of the block relative to position of the pelvis) (TABLE 1). There was a main effect of lift method and row (P<.001), but no significant interaction (P = .099). Lift-team participants kept the block farther away from their pelvis than those lifting alone at every row height (P<.002). Also, both methods showed a simple effect of row height, with the block held closer to the pelvis at higher rows within each method of wall construction (P<.001).

DISCUSSION

Lift teams may be a beneficial intervention for reducing exposure to biomechanical risk factors when bricklayers work at heights between the knees and waist (approximately at row 3). However, the results of the current study also suggest that lift teams shift their exposure to biomechanical risk factors from one anatomical region to another, depending on the height of the lift.

Less trunk flexion was needed while working in lift teams at rows 1 and 6, but the 5° to 7° reductions may be insufficient to reduce risk alone. Additionally, paraspinal activity was lower bilaterally, although statistically significant only at row 3 on the dominant side. Although sharing the load with a partner lessens the block-weight magnitude, overall physical demands are not proportionally reduced, partly because of the increased moment arm of the block’s weight vector. Lift teams also required significantly more sidebending at row 6 and more trunk rotation at all rows, although not significantly (Bonferroni correction). Because trunk flexion, trunk rotation, and lifting are known risk factors for low back disorders, it is unclear whether lift teams are biomechanically advantageous for the low back.

Lift teams required less muscle activity of the dominant-side upper trapezius...
while working at all rows, although this
was only statistically significant at rows 1
and 3. This result was expected, because
the dominant side was only used to hold
the trowel or stabilize the block during
positioning on the wall (FIGURE 3). Non-
dominant upper trapezius activity was
similar at these rows, regardless of lift-
ing method. Also, shoulder flexion was
significantly lower for lift teams working
at row 3. The combined effect of reduced
muscle activity and less flexion suggests
that lift teams may be beneficial for the
shoulder at lower rows.

However, lift teams are not recom-
mended for the shoulder when lifting to
row 6. Significantly more upper trape-
zius activity occurred on the lifting side,
a finding comparable to that of other studies.4
Also, regardless of lifting method, peak shoulder flexion at row 6 was in a range known to reduce the sub-
acromial space.5,6,11,70 Bricklayers working
in teams may be more susceptible to impingement due to the simultane-
ous decrease in subacromial space5,6,78
and increase in rotator cuff exertion62
and intramuscular pressure57 associated
with lifting at this height. Work with
the hands at or above shoulder level is
associated with MSDs of the upper ex-
tremity,5,79,80,81 with a dose-response rela-
tionship reported.80

The flexor forearm pattern was simi-
lar to the upper trapezius for lift teams,
with generally less exertion found on the
dominant side and more exertion on the
nondominant side. However, only muscle
activity at row 6 was statistically greater
with lift teams. Work-related rotator
cuff syndrome is associated with forceful
hand exertions, such as pinching, while
working with the arms elevated.89

It is considered good ergonomic prac-
tice to handle materials between knee
and waist height,96 and lift teams appear
to be most effective here. Compared to
the 1-person method, lift teams had sub-
stantially less shoulder flexion at row 3
and experienced less muscle activity in
the nondominant paraspinals and bilat-
eral upper trapezius. Also, muscle activity
of the dominant flexor forearm muscles
was lower. However, more exertion was
required of the nondominant flexor fore-
arm, again suggesting shifted exposure.

Other studies have evaluated the effect
of team lifting on spinal variables.72,73,53
Using a sample of untrained volunteers,
Marras and colleagues54 evaluated spinal
loading during specific team-lifting con-
ditions. They found that team lifting was
beneficial only when performing the task
in the sagittal plane (that is, when the
lifters were facing each other). Because
cement block is not handled this way in
the field, it is difficult to compare the cur-
rent study findings to others. Lift teams
in Marras et al’s study54 lifted twice the
weight they lifted individually. In con-
trast, bricklayers in the field will either
lift the same block weight alone or in lift
teams.

The results from this study add to the
literature suggesting that there is no sin-
gle “proper lifting technique” for reduc-
ing the risk of musculoskeletal injury.6
It is unrealistic to expect a bricklayer to
use a squat lift hundreds of times a day
at the worksite. Energy requirements are
greater with the squat lift,67,68 there is in-
creased force on the knee,14,32 and a posi-
tive association exists between squatting
and knee MSDs.58 Therefore, physical
therapists and other practitioners should
determine specific lifting parameters for
each worker.

Healthcare practitioners who treat
injured workers must be aware of their
productivity expectations. Bricklay-
ers working alone typically lift over 160
standard-sized concrete blocks per day,
and fewer when lifting 12-inch block
alone. Lift teams are expected to handle
approximately 20 to 40 more blocks per
day than individual bricklayers and may
be more productive over an entire work
week. In the current study, lift teams built
the wall more quickly than those working
alone, but not twice as fast. Although in-
creased productivity may be a beneficial
side effect of lift teams, the faster work
pace could cause greater fatigue and
more cumulative exposure to lifting.74

In addition to productivity issues, cli-
icians should be aware that lift teams
are considered a personal control, which
is the least effective type of ergonomic
intervention.56 Engineering controls are
better options for reducing exposure
to heavy lifting and include interven-
tions such as adjustable-height scaffold-
ing,18,43,61 light-weight concrete block,2,57
and mechanical lifting devices,62 among
others.14,46 These interventions aim to
minimize spinal forces and encourage
manual material handling between knee
and chest height.59 Teams could also lift
using both hands instead of 1 hand.75,44
However, many construction environ-
ments have limited space, which pre-
cedes the use of 2-handed lift-team
techniques.

A possible limitation of the current
study was that spinal compression, mo-
ments, and shear forces were not estimat-
ed in the low back or shoulder during
the wall-building tasks. Previous investiga-
tors have used force plates to help estimate
spinal compression during individual60
and team-lifting situations.57,44 However,
subjects in these laboratory studies were
constrained to lifting while standing on
a force plate.63 Bricklayers in field situa-
tions do not remain in 1 spot during lift-
ing, and typically step while retrieving or
placing blocks. To keep the task as realis-
tic as possible, we allowed the bricklayers
to perform unconstrained lifts.

Previous investigators have used large
samples of muscles around the trunk to
estimate spinal compressive forces and
shear forces during lifting.12,34,44,45 Due
to time limitations, we conducted EMG of
muscles in the top 3 anatomical sites for
injury among bricklayers.44 Our narrow
sample of trunk EMG prohibited mean-
ingful estimates of shear and compres-
sive forces, and it is likely that exertion
of other muscle groups, such as the su-
praspinatus, occurs during lifting. How-
ever, surface EMG of the upper trapezius
is commonly used as a proxy for rotator
cuff activity.77

The bricklayers participating in this
study were asked to build the wall using
their choice of lifting technique (squat, stoop, or combination lifts). Therefore, the kinematic and EMG data were likely to be more variable than previous studies in which subjects were instructed to use a specific lifting method.\textsuperscript{22,34,44} However, greater variance in the current study may be offset because experienced bricklayers participated. Experienced workers have a different, and possibly safer, lifting method than novices such as graduate students.\textsuperscript{23,45} Keir and MacDonell\textsuperscript{45} reported that experienced patient handlers had less lumbar paraspinous exertion but higher upper trapezius exertion than novice handlers. Likewise, Marras and colleagues\textsuperscript{46} found that spinal loading was greater for inexperienced lifters when performing the same lifting task as experienced lifters. Indeed, Barrett and Dennis\textsuperscript{3} reported that using study participants with “limited skill and experience in lifting,” that is, college students, was a serious limitation of lift-team studies.

CONCLUSION

LIFT TEAMS MAY BE A BENEFICIAL INTERVENTION TO REDUCE EXPOSURE TO BIOMECHANICAL RISK FACTORS WHEN BRICKLAYERS WORK AT HEIGHTS BETWEEN THE KNEES AND WAIST (APPROXIMATELY AT ROW 3). MUSCLE EXERTION WAS LOWER OR COMPARABLE TO 1-PERSON LIFTING IN THE LOW BACK AND UPPER TRAPEZIUS. LIFT TEAMS MAY ALSO HELP TO REDUCE TRUNK FLEXION AND LUMBAR ERCTOR SPINAE EXERTION BELOW ROW 3, WHERE A GREATER POSSIBILITY OF LOW BACK INJURY OCCURS. HOWEVER, AT WORK HEIGHTS AROUND SHOULDER LEVEL, SIGNIFICANTLY GREATER EXERTION OCCURS IN THE LIMB USED FOR LIFTING, AS WELL AS GREATER SHOULDER ABDUCTION AND BLOCK MOMENT ARM. THEREFORE, LIFT TEAMS ARE NOT RECOMMENDED FOR BRICKLAYERS WORKING AT HEIGHTS ABOVE SHOULDER LEVEL.

Like many ergonomic interventions, lift teams are not a panacea. Clinicians should be aware that lift-team effectiveness is dependent on working height and that exposure may be shifted from one anatomical region to another. When instructing patients in lifting techniques, physical therapists and other clinicians should consider parameters such as working height, material size, and other interventions to reduce exposure to heavy lifting.

KEY POINTS

FINDINGS: Lift teams can be used by bricklayers to help reduce exertion of the lumbar erector spinae and peak trunk flexion when placing concrete block at ground level. Lift teams also reduce muscle activity of the lumbar erector spinae and upper trapezius when working between knee and waist height. Lift teams are not recommended for use at higher working heights because upper trapezius exertion is high.

IMPLICATIONS: Working in lift teams may be beneficial at certain work heights, but exposure to biomechanical risk factors may shift from one anatomical region to another when working with a partner.

CAUTION: Results of this study are not necessarily generalizable to other team-lifting situations.

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