Simulation of symmetrical lifting to determine proper load distribution on the body joints using 3DSSPP software

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Background

Training for safe lifting techniques is used by employers to lower exposure to risk of workplace musculoskeletal injuries. In our previous studies (Abdoli et al., 2017), 266 attendees at two professional conferences were asked to identify and demonstrate their preferred lift technique with demonstration being an ideal floor-to-waist height lift of a 10-kg weighted crate. The results showed that the trained group experience less loading at L5/S1, but higher loading at the knees and ankles.

Objectives

1. To compare the kinematics (joint) of postures of symmetrical lifting techniques.
2. To determine the optimal symmetrical lifting technique that shows reduced moments on all joints.

Methodology

3D Static Strength Posture Prediction software [3DSSPP] was used to model 16 symmetrical postures and a neutral standing position (Figure 1.). Postures were selected based upon the criteria that a person must be able to pick up a box from the ground. Postures were modelled by maintaining a constant knee angle and adjusting trunk angle. A force of 5-kg was applied to each hand to simulate the load applied by lifting a 10-kg box. Male 50th percentile and Female 5th percentile values were chosen for analysis.

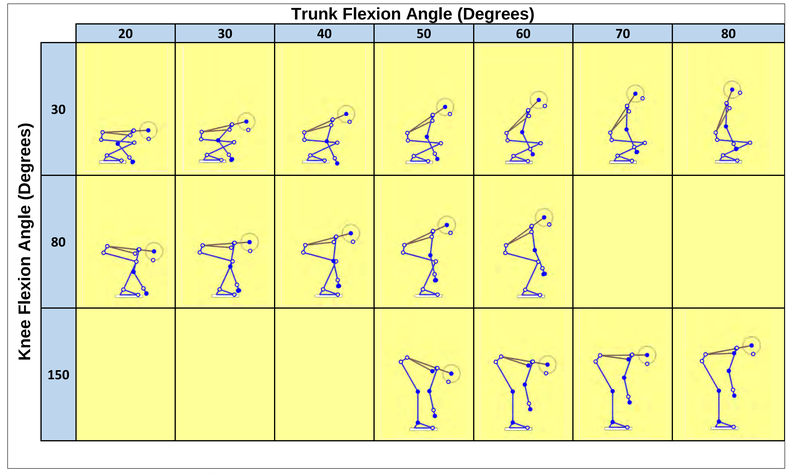

Figure 1. Matrix displaying all postures modelled in 3DSSPP.

Results

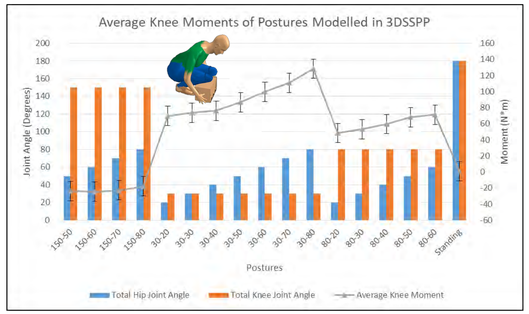

Figure 2. Average knee moments of all population percentiles with standard error bars of postures modelled in 3DSSPP.

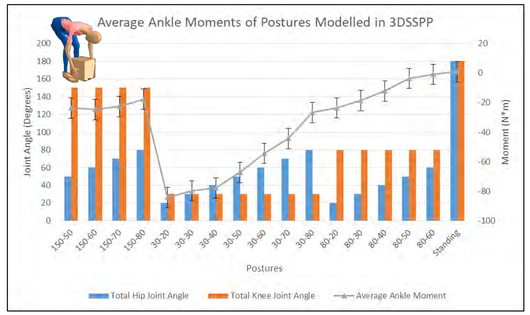

Figure 4. Average ankle moments of all population percentiles with standard error bars of postures modelled in 3DSSPP.

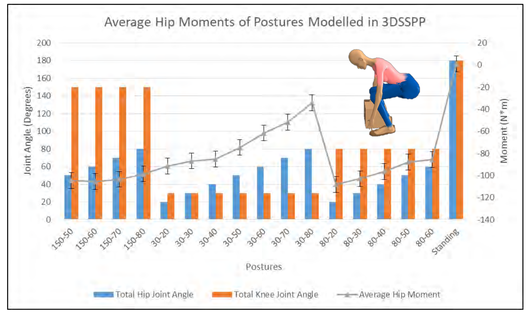

Figure 3. Average hip moments of all population percentiles with standard error bars of postures modelled in 3DSSPP.

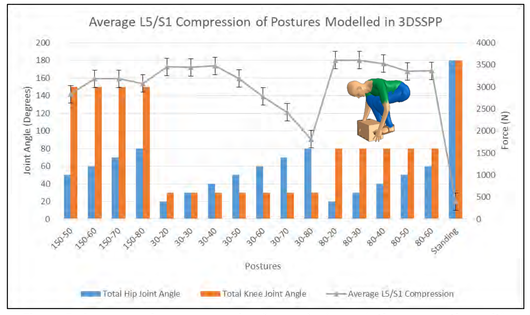

Figure 5. Average spinal compression force of all population percentiles with standard error bars of postures modelled in 3DSSPP.

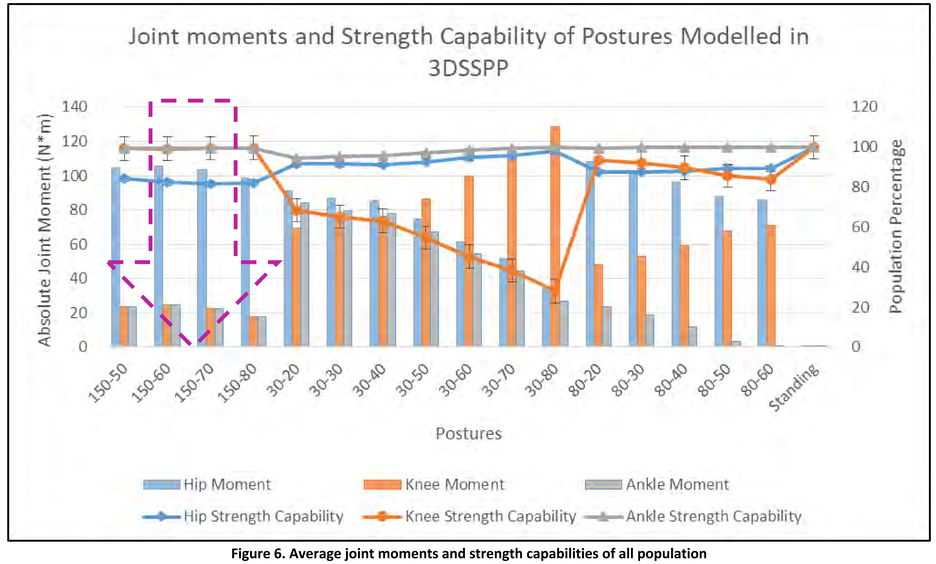

Figure 6. Average joint moments and strength capabilities of all population percentiles with standard error bars of postures modelled in 3DSSPP.

Results and Discussion

Joint moments, spinal compression forces, and population strength capabilities were analyzed from the data collected. Respectively, lowest average joint moments for the knee and hip were observed in the 150-80 (Figure 2.), and 30-80 (Figure 3.) postures. Lowest ankle joint moments varied by population. These were seen in the 80-60 posture for Male 50th percentile population and the 80-50 posture for Female 5th percentile population. When average ankle joint moments were examined, the 80-60 posture produced the lowest moment (Figure 4.). All populations showed the lowest L5/S1 compression forces in the 30-80 posture (Figure 5.). Hip and ankle population strength capabilities were within safe ranges with more than 80% of all populations capable of reproducing the required joint angles (Figure 6.). Knee population strength capabilities showed some areas of concern though with only 29.97% of the Male 50th percentile population and 55.93% of the Female 5th percentile population having the strength required to reproduce the 30-80 posture. Postures with knee angles of 80 and 150 degrees were observed to have the greatest proportion of the population able to reproduce the posture (Figure 6.).

Conclusion

Optimal lifting postures are often thought of as a squat lift or stoop lift similar to the 30 degree knee angle postures modelled with minimizing spinal forces as the main focus of training. However, this analysis presents findings that show some populations may not have the strength capable to produce these postures, and have higher total joint moments when the load is lifted symmetrically in front of the body. Based on the postures modelled, 150 degree knee angle are optimal for this task when the feet are parallel and kept symmetrical close to one another. This is supported by lower total joint moments compared to all other postures and the greater proportion of the populations capable of producing it. The central limitation of this study is that the postures examined are not exhaustive of all the symmetrical postures that can be developed using 3DSSPP. Future research should seek to expand upon the matrix that has been developed. Further expansion of the matrix should seek to include different stances as an additional dimension to accommodate various symmetrical and asymmetrical postures.