A COMPARISION OF SPINAL LOADS WHILE LIFTING IN CONFINED VERTICAL SPACE

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Background: Lifting in confined vertical space is observed across several industries, including airline baggage handling, mining, construction, maintenance, and shipbuilding. However, only a few studies have investigated confined space lifting scenarios with biomechanical methods (Gallagher et al., 1988; Stalhammar et al., 1986), and fewer have quantified biomechanical loads on the intervertebral discs of the lumbar spine while lifting in confined vertical spaces using a biomechanical model (Gallagher et al., 1994; Middelton et al., 2016; Splittstoesser et al., 2007). The objective of this study was to quantify spinal loads for kneeling and sitting lifting styles in confined vertical space. This was accomplished via the replication of the baggage compartment of a narrow-bodied aircraft in a laboratory.

Methods: Ten males performed airline baggage handling tasks for this study. A fully balanced design was implemented, and independent variables included lifting style (3), exertion type (4), bag weight (2), and their interactions. Lifting styles investigated included stooping, kneeling, and cross-legged sitting. In kneeling and sitting exertions, subjects were confined within 1.22 m of vertical space (i.e., the vertical constraint within a narrow-bodied airplane). However, stooping conditions were performed as a control condition in unconfined vertical space. Exertion type included loading bags from the floor to a low and high vertical heights or unloading bags from low and high vertical heights to the floor. Subjects lifted bags weighing either 14.5 kg (industry average) or 22.7 kg (95^{th} percentile in U.S.) (Lu et al., 2018). Dependent measures included the peak torso flexion for each lift and peak spinal loads in compression, anterior/posterior (A/P) shear, and lateral shear derived from an electromyography (EMG)-driven spine model (Dufour et al., 2013; Hwang et al., 2016a, b). These spinal loads were compared to documented tolerance limits for spinal loading (Gallagher and Marras, 2012; Waters et al., 1993).

Results and Discussion**:** Stooping, kneeling, and sitting all posed significant risk of injury to the lumbar spine via excessive compressive and A/P shear loading. Statistically significant differences attributable to lift style (stooping, kneeling, sitting) were not observed for peak compressive or lateral shear, but kneeling decreased anterior/posterior (A/P) shear spinal loads relative to stooping (p=0.02). Collectively, kneeling presented the least risk for injury to the low back when lifting in confined spaces because the torso remained more upright, subsequently reducing shear forces on the lumbar spine. However, future studies should also aim to assess the biomechanical risks associated with confined lifting scenarios to other regions of the body in which musculoskeletal disorders might be of concern (i.e., shoulders, knees). Though experimental conditions specific to baggage handling were examined, it is expected that the results of this investigation are applicable across all industries in which lifting in confined vertical spaces is observed.

Conclusion: Baggage handling tasks performed in confined vertical space pose significant biomechanical risk to the lumbar spine in compression and A/P shear. From a low back loading perspective, kneeling lifting styles should be preferred to sitting when lifting in a confined vertical because of the ability to keep a more upright torso.

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