Background

Lifting is one of the primary causes of musculoskeletal injuries in today’s industry. Relevant whole body kinetics include pre-lift preparatory postural adjustments as well as handling behaviours and post-lift corrective responses\(^1\). Experimental evidence suggests that the coupling provided through different handle designs changes the nature of a lift, and thereby modifies lifting behaviours, soft tissue loading, and the risk of lower back injuries\(^2\). The objective of this experiment was to implement a system analysis paradigm to the postural kinetics of a bimanual lifting task, with the goal of discriminating lifting behaviours by coupling type and risk for chronic soft tissue injury.

Methods

Thirty five healthy subjects (21.4 ± 3.4 years old, 174.8 ± 9.4 cm, 24F) were recruited and randomly assigned to GOOD (n = 12), FAIR (n = 11), and POOR (n = 12) coupling types. Participants lifted a load of 10 kg bimanually, with handles modified to satisfy NIOSH definitions for each coupling type\(^3\) (Figure 1). Two force platforms (Figure 2) were used to collect force and moment data at a sampling frequency of 200 Hz. Signals from the stance force plate were converted using a force-plate calibration matrix, and were used to calculate the antero-posterior center of pressure (CoPx) displacement values for each individual. Load platform signals were processed through a dual pass filter for artifact removal, and were then used to identify the temporal parameters of grasp and lift onset. The onsets were used as the central and upper bounds of the CoPx data that defined the lifting period.

Postural behavior of each participant was characterized using a third order nonparametric system identification. The input, \(U(s)\), was the normalized affordance distance in the form of a step function, and the output, \(Y(s)\), was the calculated CoPx displacement for each lift. Matlab’s System Identification toolbox was used to identify the corresponding transfer functions in the form of:

\[
H(s) = \frac{a_0}{s^3 + b_2s^2 + b_1s + b_0}
\]

An averaged transfer function was calculated for each coupling group (Figure 3) and the calculated mean coefficients (Table 1) were compared to analyze the lifting strategies.

Results

The three coupling types prompted three distinct lifting behaviors. POOR coupling involved more postural deflection thus having the highest CoPx reach. GOOD coupling had the lowest CoPx reach indicating the hands on approach when lifting. FAIR coupling was a combination of GOOD and POOR, where the lift started off with high postural deflection and transitioned into hand control halfway through the lift.

Discussion

Our results seem to suggest that GOOD coupling encourages individuals to minimize COPx displacement, possibly moving their hands more than their body when performing a bimanual lift, whereas POOR coupling leads to more postural deflection during a lift. Nonparametric system analysis allows us to perform more comprehensive kinetic postural analysis on lifting tasks, due to its dynamic temporal component, and thus can be used as a sensitive tool to identify and promote safer lifting techniques in the industry.

References