PRINCIPAL COMPONENT ANALYSIS OF LIFTING WAVEFORMS

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INTRODUCTION

In a previous investigation [3] we demonstrated the utility of a Principal Component Analysis (PCA) to discriminate between a group of healthy workers; 50 of whom remained healthy (CON) and 56 of whom developed low back pain (LBP) over a two-year assessment period [2]. This discrimination was done on the kinematic and kinetic waveforms associated with individual lifting patterns of a 15kg load performed when all worker were healthy. The purpose of this study is to determine if the PCA approach is robust enough to discriminate the clinical status of the workers when a confounding factor of load is introduced.

METHODS

One kinematic (box velocity) and five kinetic (S1, L1, and T1 extension moments; trunk compression; trunk shear) waveforms describing the 2D motion of the trunk and box of 106 healthy male workers performing sagittal lifts of 5kg, 15kg, and 25kg box loads were analyzed. PCA [1] was applied to matrices consisting of each of the 6-waveform variables from both groups. All waveform data was transformed into principal components (PC)s using an eigenvector analysis of the covariance matrix. By orthonormalizing the covariance matrix (S), the eigenvector matrix (U) is determined. The eigenvalues are extracted by taking the diagonal components of Equation 1.

Equation 1: Calculation of Eigenvalues

$$\underset{p\times p}{L} = \underset{p\times p}{U'} \times \underset{p\times p}{S} \times \underset{p\times p}{U}, \text{ where } \underset{p\times p}{L} = \text{diagonal eigenvalues matrix}$$

The number of PCs retained for comparison (k) was determined using parallel analysis (Jackson, 1991). PC scores were calculated by projecting the original data points (X) into the new coordinate space defined by the k PCs (Equation 2).

Equation 2: Calculation of Principal Component Scores

$$\underset{n\times p}{Z} = \underset{n\times p}{X} \times \underset{p\times p}{U'}, \text{ where } \underset{n\times p}{Z} = \text{the matrix of PCscores}$$

The k PC scores for each variable were used as the dependent measures in a two-way MANOVA in order to determine if there were any significant group differences.

RESULTS AND DISCUSSION

The MANOVA results (Table 1) revealed that the PCA was insensitive to confounding load effects as the same clinical status effects that were identified from our previous study [3] were identified again (Figure 1). Furthermore, significant load differences for the first PC of every kinetic variable (Figure 1) indicates that magnitude effects account for the greatest amount of variation in the waveform data sets.

Table 1: MANOVA results for group differences and interaction for the PC scores of each waveform variable.

Effect	*F*	*P*	η_p^2
Clinical Status	3.006	0.001	0.147
Load	54.527	0.001	0.758
Clinical Status * Load	0.519	0.990	0.029

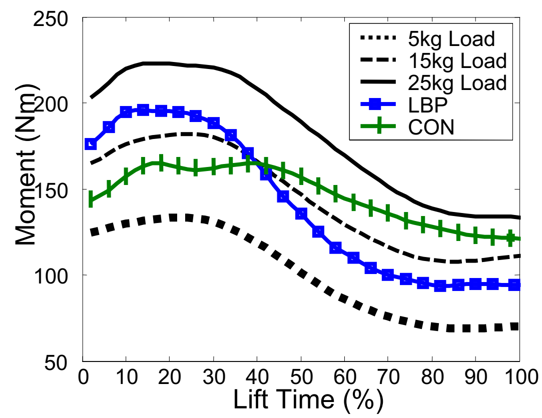

Figure 1: A significant load effect is illustrated with the three lines –, ---, and ··· representing the mean of the trunk extension moment waveforms for each load. Two more lines (+ and □) were plotted to illustrate a clinical status effect based on waveforms that illustrate the PC score and PC coefficient relationship. The differences in load represent a magnitude effect while the differences in extension moment between the CON and LBP group show a change in the trunk loading pattern throughout the lift.

CONCLUSIONS

The PCA technique was able to identify important biomechanical differences between the groups, and was insensitive to confounding load effects. This research has been able to relate differences in lifting technique prior to the development of LBP, and has identified that these differences are not load dependent.

REFERENCES

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