POSTURAL CONTROL RESPONSE TO STANCE ON A COMPLIANT SURFACE

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INTRODUCTION

Balance training is a common methodology used in rehabilitation and training settings, intended to enhance an individual's ability to maintain stability. Regularly, the use of a compliant surface is included in this training. It is implied that improvements in postural performance during interaction with a dynamic surface will translate to improved posture during stance on solid ground [1]. However, characterization of the postural control strategies used by the individual during interaction with a dynamic surface may serve to provide great insight to the control systems used to maintain posture during stance under any condition.

Center of pressure (COP) is a standard laboratory measure of stability, commonly collected and analyzed for characteristics such as sway range, velocity, and variability. Currently, there is a strong movement in the literature to consider the use of nonlinear statistics as ancillary measures for describing COP data [2].

The purpose of this study was to evaluate the postural sway performance of participants during quiet stance on a compliant surface, measured longitudinally throughout a balance training program. One of the goals of this evaluation includes determination of movement characteristics of postural sway during interaction with a movement responsive surface. Additionally, a nonlinear method of data processing was presented, along with traditional linear statistics, to serve as an effective movement descriptor.

METHODS

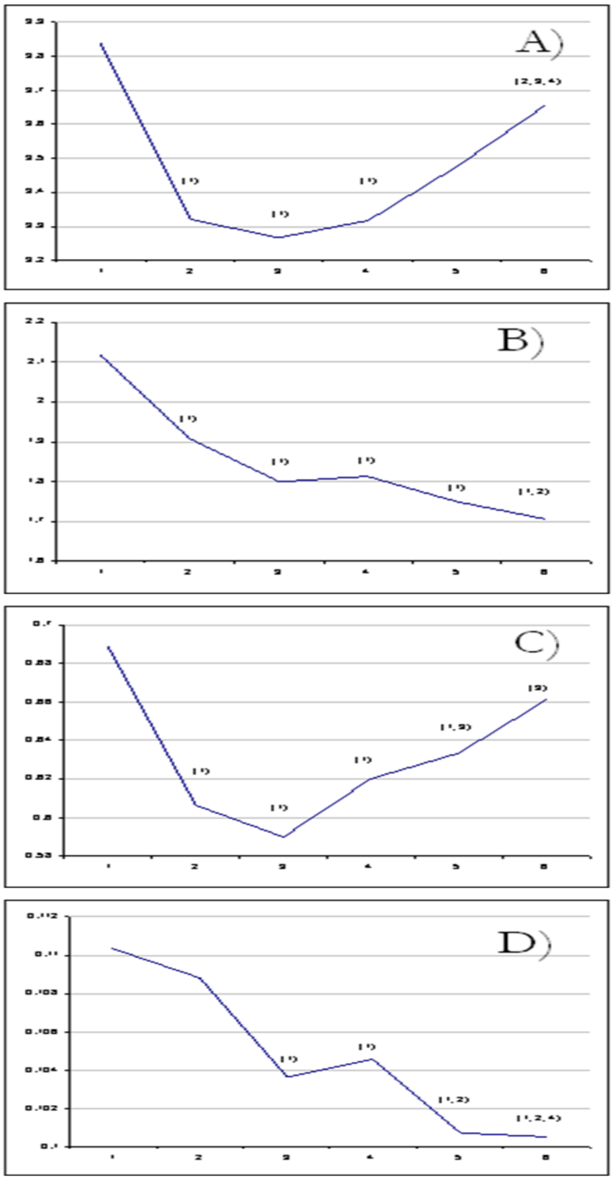
Eighteen healthy, physically active individuals (5 male, 13 female; age (yrs) = 20.24 ± .90; body mass (kg) = 66.05 ± 11.78), engaged in a six week balance training program (18 sessions) designed to target a variety of stance conditions. Each of these sessions lasted approximately 30 minutes and included a single trial of COP data collection followed by a series of eight training exercises (each including four levels of increasing difficulty) designed to maintain a safe but challenging experience during each exercise. COP was measured on a compliant surface, DynaDisc-Plus, placed atop a force plate (Bertec 60cm x 90cm).

Range, velocity, variability, and Lyapunov Exponent were calculated from each COP time series after separation into mediolateral and anterposterior components. Each variable was condensed by averaging the performance of all participants across 3 day groups to represent mean weekly performance. A one way repeated measure MANOVA was used to determine whether changes occurred across the six weeks. Paired t-tests were used *post hoc* to locate where these changes occurred throughout the six weeks. MANOVA and t-tests were performed using SPSS software v.16.0. Alpha level $p < 0.05$ was used for analyses

RESULTS AND DISCUSSION

Results of the repeated measures MANOVA indicate significant differences in each variable (range, variability, velocity, and LyE) across the six weeks of training, similar for both the ML and AP directions. Figure 1 presents the results in the mediolateral direction. In both directions, COP range (ML: $F_{5,85} = 4.065$, $P < 0.002$; AP: $F_{5,85} = 2.825$, $P < 0.021$) and variability (ML: $F_{4.185,71.145} = 4.789$, $P < 0.002$; AP: $F_{5,85} = 2.357$, $P < 0.047$) follow a quadratic trend, showing an initial (first two weeks) reduction followed by a return to pre-test values. This is interpreted as an initial attempt to reduce degrees of freedom, which is subsequently overcome by the added advantage to environmental searching and recognition associated with increased range and variability.

Figure 1: Week-wise analysis of variables in the ML direction;
A) COP Range, B) COP Velocity, C) COP Variability, and D) COP LyE.



Weeks where difference is significant are listed in ( ), p< 0.05

Velocity (ML: $F_{5,85} = 8.366$, $P < 0.000$; AP: $F_{5,85} = 12.806$, $P < 0.000$) and LyE (ML: $F_{5,85} = 6.098$, $P < 0.000$; AP: $F_{3.211,54.593} = 5.886$, $P < 0.001$) follow a linear trend of continued reduction throughout the study. A Huyh-Feldt correction factor was used where Mauchly's test for sphericity indicated a violation of assumptions, as was the case for variability in the ML direction (Mauchly's W = 0.154; $\chi^2 = 28.26$, $P < 0.014$) and LyE in the AP (Mauchly's W = 0.144; $\chi^2 = 29.3$, $P < 0.010$). In both cases, the correction yielded significant results as presented above. Reduced LyE values indicate a more periodic (self-similar) structure within the COP path. It appears that the participants were able to develop a more calculated approach to the maintenance of balance by moving both more slowly and with a more regular movement pattern. It is argued that the slower and more regular movement pattern provides the performer with a strategic control over the behavior of the compliant surface, thus decreasing the complexity of the interaction task and allowing for a more stable postural experience, even in the face of a seemingly erratic environment.

CONCLUSIONS

This research has provided evidence that individuals do respond to balance training with changes in postural sway. Measures of range and variability were shown to decrease during the first two weeks of training, and then subsequently return to week one values. Measures of velocity and LyE were shown to decrease in a linear fashion throughout all six weeks of training. These changes in performance can be explained as a result of changing strategies enacted by the postural control system. At the outset, postural performance exhibits a developing rigidity in all four measured variables. In sum, individuals tend to move less within a smaller range, at a slower rate and with a more consistent pattern of movement. After two weeks of experience within the dynamic environment, training, the motor control system seems to become more relaxed in its control of range and variability. This is thought to occur due to the benefit to the system of increased exploratory movement within the environment, thus maximizing the information gathering capacity from which future movement is planned. At the same time, velocity continues to decrease as movement continues to become more self-similar. These qualities signify the benefit of increased processing time and planning of future movements. Slower movements result in slower response by the environment to those actions. More regular movement patterns elicit responses by the environment that are more predictable, and thus allow greater potential that the subsequently planned movement will be appropriate for the individual within the resulting environment.

REFERENCES

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