PROACTIVE BALANCE CONTROL: KINEMATIC ANALYSIS OF A REACH TASK

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INTRODUCTION

Feed-forward or proactive balance control mechanisms represent a neurological control strategy which involves activation of the balance system in anticipation of a perturbing force(s). A conventional method to study this is with voluntarily initiated, commonly experienced internal perturbations such as reaching tasks. While numerous studies have addressed various aspects of proactive balance control, these studies have typically utilized a forward reaching task which introduces a sagittal plane perturbation. Few studies have employed non-sagittal plane perturbations, or considered the implications of such in describing the associated balance control mechanisms. Thus, the purpose of this research was to examine the peak center of pressure excursion distance (COP) and maximum trunk lean angles in sagittal and frontal planes in a maximum arm's length reach task, and to determine if these were influenced by the subject's gender. Insight into the balance control mechanisms of healthy human adults may be of particular relevance in the treatment of populations such as the elderly and those with compromised balance due to injury or disease.

METHODS

Twenty healthy volunteers (10 males, 23.7±3.23 years, 76.3±14.2kg, 172.7±8.93cm and 10 females (21.7±3.62 years, 61.1±6.57 kg, 164.4±6.84cm) from the University of Toledo campus with no prior history of limb or low back injury, were recruited for the study. The participants were moderately active and physically fit. Individuals with a history of any condition that may have compromised balance were excluded from participating in this study. All subjects provided written informed consent, as approved by the Human Subjects Research Review Committee at The University of Toledo.

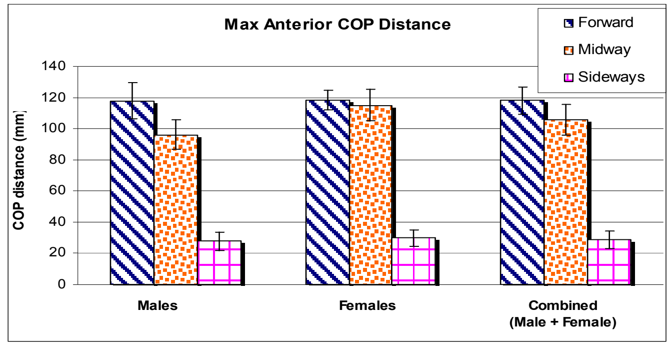

Figure 1 Max. ACOP excursion in males, females & group

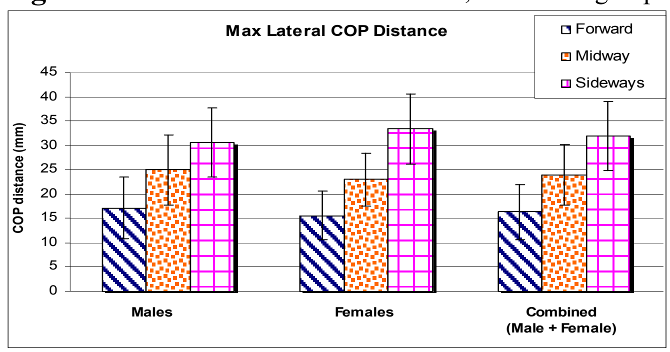

Figure 2 Max. LCOP excursion in males, females & group

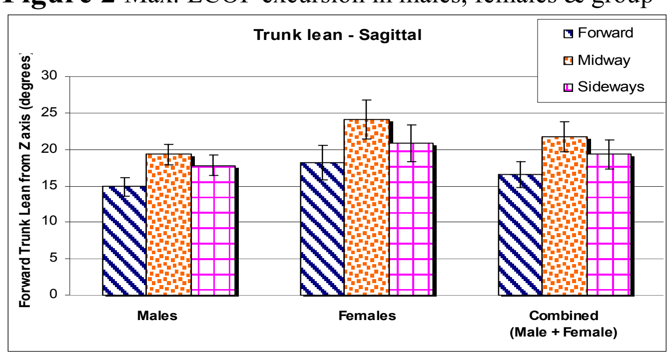

Figure 3 Max. sagittal trunk lean in males, females & group

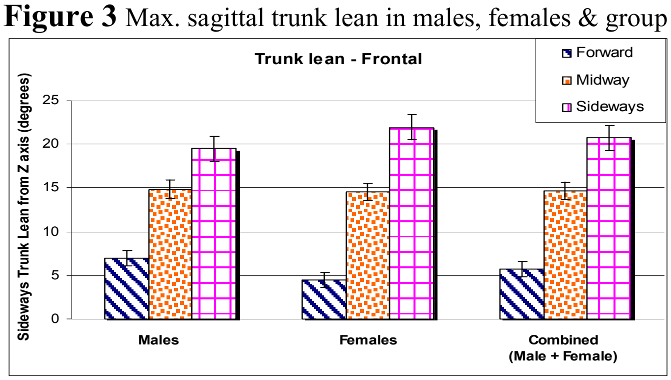

Figure 4 Max. frontal trunk lean in males, females & group

Participants were asked to stand barefoot on a force platform (AMTI, Newton, MA), and, upon an auditory cue, reach for targets kept at their previously measured maximum arm's length distance, in three different reach directions - forward, midway, sideways. There were fifteen randomized trials for each participant, including five in each of the three directions.

Kinematic assessment of the subject's movement was done via a 3D Motion Analysis system (Motion Analysis Inc., CA). Thirty three reflective markers were used to create a kinematic model. Video data was collected at 60Hz while force data was collected at 960Hz. KinTrak 6.2.3 software (Motion Analysis Inc., CA) was used to measure the dependent variables for each trial, which were then averaged across trials and subjects.

Multiple two way repeated measures ANOVA were performed using SPSS 14.0. A priori significance level was set at $p \leq 0.05$, and Tukey post-hoc test performed for pair wise comparisons, to study the effects of reach direction and gender on COP distances and trunk lean angles.

RESULTS AND DISCUSSION

Upon statistical analysis, both sagittal plane COP, i.e. ACOP ($F_{1,18} = 135.40$, $p < 0.001$, $\eta^2 = 0.88$, $1\text{-}\beta > 0.99$) and frontal plane i.e. LCOP ($F_{1,18} = 4.24$, $p < 0.022$, $\eta^2 = 0.19$, $1\text{-}\beta = 0.7$) demonstrated significant main effects. No significant gender differences were found. Maximum trunk angle leans, in both planes also showed significant main effects - sagittal plane, ($F_{2,36} = 7.176$, $p = 0.002$, $\eta^2 = 0.285$, $1\text{-}\beta = 0.912$), and frontal plane, ($F_{2,36} = 84.619$, $p < 0.001$, $\eta^2 = 0.825$, $1\text{-}\beta > 0.99$). However, there was considerable inter-subject variability.

In observing sagittal plane trunk lean, the greatest amount occurred in the midway reach 21.7 ± 6.9^0, followed by sideway reach 19.3 ± 6.5^0 and lastly forward reach 16.5 ± 6^0 (Figure 3). And, as was expected, trunk angle in the frontal plane (Figure 4), was the greatest in the sideway reach task 20.7 ± 4.6^0. We found that females appeared to have greater trunk lean in both planes for all three directions, though differences were not statistically significant ($p=0.133$). An interesting observation was the oppositely directed COP shift at the beginning of every task across all participants, which has been reported in several other studies (1,2). The posterior displacement of the COP appears to be an anticipatory adjustment that is intended to create a distance between the COP and the center of mass location, which defines the moment arm for sagittal plane rotation of the body. The ability of the plantarflexors to create a sagittal plane stabilizing torque allows for greater COP motion in the A-P direction than in the M-L direction. Greater trunk lean angles among females suggest a relationship between anthropometric factors and both COP displacement and amount of trunk lean. Further research is needed to gain insight into these important relationships.

CONCLUSIONS

Collectively, the results of this study generate far more questions than they answer. However, they provide support for the theory that, when faced with a movement that challenges balance, the CNS proactively employs strategies that appear to be intended to minimize the destabilizing effects of this challenge. And, that the characteristics of these strategies are influenced by the nature of the destabilizing challenge. Balance control mechanisms are highly dynamic and complex phenomenon and hence, they should be examined by taking into consideration the cognitive as well as the perceptual nature of a particular task, along with the vestibular, vision and somatosensory aspects.

REFERENCES

1. Kaminski T.R, et al. *Exp Brain Res* **136,** 439-446 2001.
2. Tyler A, et al. *Gait and Posture* **20**,126-133 2004.