Neuromechanical Adaptations for Postural Control: Influence of Upper-body Perturbation Magnitude and Predictability

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Summary

This study examined postural responses to varying perturbation magnitudes and the role of vision in muscle activation. Basketballs induced greater postural displacement and muscle activation than volleyballs and tennis balls in both anticipatory and compensatory phases. Vision significantly affected trunk stabilization, demonstrating its role in balance control. These findings contribute to understanding postural stability mechanisms and may aid in fall prevention strategies.

Introduction

Postural stability during unexpected perturbations relies on both anticipatory and compensatory mechanisms integrating sensory and motor responses [1,2]. While previous research has focused on platform-induced perturbations, the effects of direct upper-body impacts in various conditions remain underexplored. This study examines how different perturbation magnitudes, induced by varying ball types, influence postural adjustments and muscle activation. Further, the role of vision in modulating these responses is assessed.

Methods

Participants stood on dual force plates with arms extended while basketballs (BB), volleyballs (VB), and tennis balls (TB) were dropped onto their palms with elbow straight. Postural adjustments were assessed using center of pressure (COP) measures in anticipatory (COP_Ant) and compensatory (COP_Comp) phases, and the time of maximum COP in compensatory phase (COP_Comp_time). Muscle onset latency and integrated EMG activity were recorded from the Tibialis Anterior (TA), Soleus (SL), Vastus Lateralis (VL), Biceps Femoris (BF), Gluteus Medius (Gmed), Rectus Abdominis (RA), and Erector Spinae (ES). Repeated-measures ANOVA was conducted to assess the effects of ball type and eye condition, followed by post hoc Tukey HSD tests.

Results and Discussion

Ball type significantly affected anticipatory displacement ($F(2,6)=9.49$, $p=0.01$, $\eta^2G=0.38$), with basketballs inducing greater COP displacement than volleyballs ($p=0.02$) and tennis balls ($p=0.02$). Compensatory displacement was also significantly affected ($F(2,6)=16.45$, $p=0.004$, $\eta^2G=0.12$), with basketballs causing greater COP displacement than tennis balls in both eyes-open ($p=0.008$) and eyes-closed conditions ($p=0.001$). However, compensatory displacement time was not significantly different across conditions ($p=0.69$).

For muscle onset latency, a significant effect of eye condition was observed for the RA ($F(1,3)=39.80$, $p=0.008$, $\eta^2G=0.03$), suggesting vision's role in trunk stabilization. No significant differences were found for other muscles. In the anticipatory phase, TA activation was significantly higher for basketballs than for volleyballs ($p=0.002$) and tennis balls ($p<0.001$), indicating increased preparatory control. In the compensatory phase, both ball type ($p=0.03$, $\eta^2G=0.44$) and eye condition ($p=0.01$, $\eta^2G=0.22$) influenced TA activation, demonstrating the role of vision in postural stabilization (Figure 1).

These findings suggest that individuals modulate postural responses based on perturbation magnitude, with greater muscle engagement in response to larger forces. The effect of vision specifically on trunk stabilization highlights the importance of sensory integration in balance recovery.

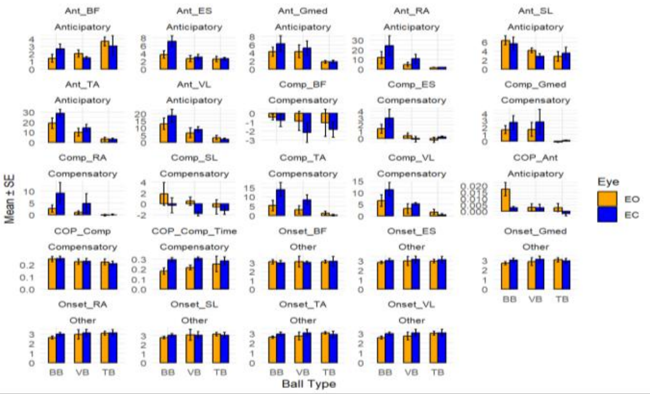

Figure 1: COP and EMG activities across different postural perturbation magnitude and vision conditions

Conclusions

Larger perturbations led to greater anticipatory and compensatory adjustments, while vision significantly influenced trunk muscle activation. These results provide insights into balance control strategies and may inform interventions aimed at improving postural stability in populations at risk of falls.

Acknowledgments

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References

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