Structure of Perturbation-based Balance Training Affects Coordination of Trip Perturbations

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Summary

Thirty-two participants performed a perturbation-based balance training (PBT) on a treadmill in blocked or randomized order. Principal component analysis (PCA) on full-body kinematics was used to extract movement components, i.e., kinematic synergies (kSYNs), of trip perturbations during the perturbed swing phase. The relative variance (rVar) of individual kSYNs was analyzed to assess training effects, i.e., quantifying the kSYNs' contribution to the overall movement. The blocked compared to the random group showed a higher contribution for the knee flexion from swing initiation to the perturbation, highlighting differences in forward foot movement as part of trip preparation. The observed differences in coordination may be attributed to the increased predictability of blocked training schedules.

Introduction

PBT shows tremendous potential for fall prevention by improving reactive recovery mechanisms in response to non-predictable perturbations [1]. However, while trip perturbations have been shown to cause adaptations in the recovery response, there is only limited transferability to different types of perturbations [1]. Research suggests that practice variability and structure, particularly the contextual interference effect (CIE), could improve PBT outcomes [2]. To gain a deeper understanding of possible effects of the CIE, kSYNs can be analyzed. We hypothesized that a blocked vs. randomized PBT schedule would lead to differences in the coordination of the perturbed step.

Methods

Thirty-two participants (26.5 ± 3.2 years; 176.8 ± 10.9 cm; 72.8 ± 14.0 kg) were assigned equally to the blocked or random group. Sixteen cameras (200 Hz, Vicon) captured full-body kinematics. Participants were exposed to three trip perturbations (left-late swing phase (SP), right-early SP and right-late SP) while walking on the treadmill (1.1 m/s) using a self-developed cable-based perturbation mechanism. Each perturbation type was delivered unanticipatedly 10 times with 60-100s of steady-state walking in between, resulting in 30 perturbations over 40min in blocked or random order. After z-normalization and centering, PCA [3] decomposed the perturbed SP of the first right-early (first) and last right-early (last) perturbation into kSYNs. The training-induced changes and group differences were assessed regarding the kSYNs relative variances (rVar) with a 2x2 rmANOVA ($\alpha = .05$).

Results and Discussion

Seven principle components explain 91.9% (>90%) of the variance. No significant interaction was found, but training-related adaptations were observed for rVar in kSYN1, kSYN2, kSYN6 and kSYN7; and group differences in kSYN3 (Figure 1). kSYN1 and kSYN2 account for the greatest variance, characterizing the center of mass (CoM) movement until the perturbation and the subsequent foot touchdown. kSYN3 describes the knee flexion from the onset of the SP until the perturbation. For the blocked group, kSYN3 has a higher contribution than for the random group (sum first-last rVar: 9.43%; 7.85%). Random training may induce uncertainties in perturbation anticipation, leading to a reduced preparation for the trip and differently pronounced early swing movements.

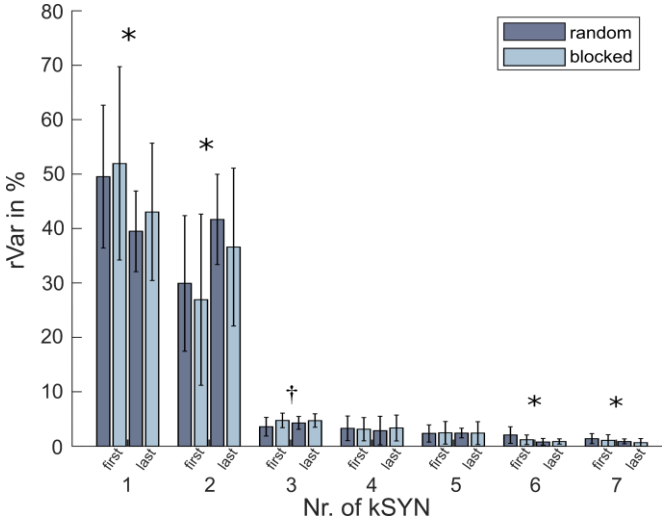

Figure 1: Subject-specific rVar. Bars represent the mean of the group with standard deviation. Significant differences are marked with * (first-last) and † (group).

Conclusions

PBT changes reactive responses to trips, particularly through training the most contributing kSYNs, which are the CoM movement before the perturbation and the recovery foot touchdown. Furthermore, the CIE caused a group difference in the early swing phase, indicating that the trip preparation may depend on the predictability of the trip.

Acknowledgments

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References

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