APPLYING PRINCIPAL COMPONENT ANALYSIS TO CHARACTERIZE THE BALANCING ABILITY OF ELITE SYNCHRONIZED ICE SKATERS

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Introduction

The balancing ability allows us to keep our body in a static position or maintain during locomotion. Synchronized skaters' performance emphasizes maintaining the group's precise formation and timing and includes artistic components such as long-lasting spins and lifting elements. It requires exceptional balance training and advanced balancing skills [1].

Principal component analysis (PCA) is a well-established method of studying coordination in clinical biomechanics [2]. In biomechanical interpretation, the most important principal components (PCs) can be regarded as the dominant synergies of the complex motion. Applied on joint angular time series, this provides a means to analyze the importance of individual joints to the whole of motion [3].

The main goal of the present study was to examine the balancing strategy of synchronized skaters compared to an age-matched control group under dynamic circumstances with the help of PCA.

Methods

Twelve female members of the Hungarian Synchronized Ice Skating Team (59.2±5.9 kg, 166.3±4.4 cm) and twelve healthy female age-matched non-skaters as control (61.1±5.5 kg, 171.3±3.5 cm) participated in the study. Balancing ability was examined with dynamic balancing test when subjects are imposed some external perturbations in medio-lateral plane. An optical-based motion capture system (OptiTrack, NaturalPoint, Corvallis, OR, USA) was used to record the subject's movements (f_s=100 Hz). Three set of sudden provocation tests were carried out in bipedal stance, then in single-leg stances for both legs. In between the perturbation tests rotational fatigue session was inserted using a so-called spin-trainer device (EDEA, Milanm Italy). Participants had to perform ten complete rotations in quick succession, standing with their preferred leg on the spin-trainer. Immediately after the spins, the perturbation tests were repeated. PCA was applied to the 3D marker coordinates of the anatomical landmarks (n=39 markers). Our goal with the analysis was to identify the first, dominant principal movement and the less significant (compensatory) principal movements during the balancing test. The PCA was performed with the *PMAnalyzer* software in Matlab [4].

Results and Discussion

As a result of the PCA of the single-leg stances, at least 85% of the total variance was explained by the first five PCs. The first PC was the same for both groups and both stances (rotation of the whole body around the standing leg's hip joint). The relative variance of PC1 was examined with Wilcoxon's signed-rank test to compare the relative variances of the pre-tests with post-test trials ($\alpha = 0.05$). In the case of the control group, PC1's relative variance increased (Fig. 1) after the fatigue sessions significantly ($p = 0.0137$). Regarding the compensatory principal movements (PC2-PC5), the skater group often used the upper body and arms to fulfil the balancing test. On the other hand, the control group applied movements with larger amplitudes with their torso and the elevated legs instead of compensating with the arms.

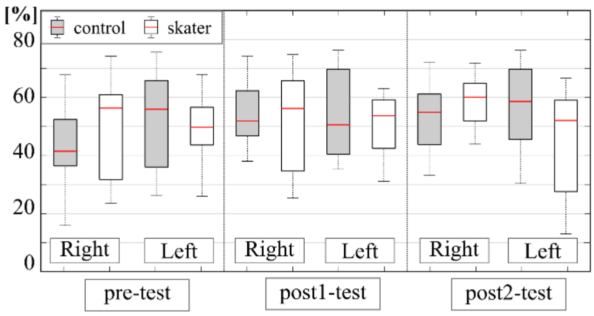

Figure 1: The relative variance of PC1 broken down into the three test sessions.

Considering the success rate of the perturbation tests, skaters were more successful in most of the cases (avg skater: 94%; avg control: 91%). Together with the PCA results, skaters' strategies that require more compensatory movement have proven to be more effective. In general, there are only a few periodic movements among the principal movements (PM1 is seemingly periodic) and there might be some simpler two-phase movements. As a further perspective of the presented method would be a detailed investigation of the PCs' time trial.

References

1. Alpini, D. et al, J Sport Sci for Health, 3(1): 11-17, 2008.
2. Brandon, S. C. E. et al, Journal of Electromyography and Kinesiology, 23(6):1304-1310, 2013.
3. Federolf, P., J of Biom, 49(3): 364-370, 2016.
4. Haid, T. H. et al, Frontiers in Neuroinformatics, 13:24, 2019.

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