Generation of Angular Momentum in Triple Toe-loops in Figure Skating

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Summary

This study investigated the mechanisms of angular momentum generation during the takeoff phase of the triple toe-loop. The findings demonstrated that the lower limbs play a crucial role in generating angular momentum, with the toe-pick leg contributing the most. For the upper limbs, the trail arm showed a greater contribution compared to the lead arm, resembling the characteristics observed with rotation movements on the ground. These findings could provide new insight into coaches to teach the triple toe-loop.

Introduction

Figure skating jumps involve six distinct types of takeoff mechanisms, which are critical determinants of competitive performance. Among these, the toe-loop is considered the least technically challenging takeoff method and serves as a foundation for mastering higher-difficulty jump, such as triple jumps. Previous studies have primarily focused on the Axel jump, revealing that increasing rotational speed is more critical than extending flight duration to achieve greater rotation in the air. Rotational speed is determined by the moment of inertia during flight phase and the angular momentum about the vertical axis (L) generated during the takeoff phase[1,2]. Consequently, understanding the mechanisms of L generation could provide insights for coaching. However, the mechanisms of L generation during the takeoff phase for jumps except the Axel remain insufficiently clarified. Therefore, the purpose of this study was to investigate the L generated during the takeoff phase of triple toe-loop and to elucidate its generation mechanisms.

Methods

The triple toe-loop performed by 10 National and International level competitive women skaters(age: 20.5±2.7 years, height: 1.56±0.03m, mass: 53.2±3.5kg, mean±SD) were recorded using a three-dimensional motion capture system (200Hz; Vicon Motion Systems, Ltd., Oxford, UK). L was calculated using a 14-segment model. Furthermore, L was normalized by skater's height and mass. A paired t-tests were used to examine the statistical difference in each segment L. Statistical significance was set at $p<0.05$.

Results and Discussion

Most of the L was generated by the lower limbs, with the toe-pick leg during the glide phase($80.1\pm10.1\times10^{-3}s^{-1}$) contributing the most. In terms of the upper limbs, the trail arm ($44.9\pm8.0\times10^{-3}s^{-1}$) contributed more significantly than the lead arm ($31.8\pm9.1\times10^{-3}s^{-1}$, $p<0.05$). In rotation movements at the ballet and gymnastics, arm and upper torso actions contribute to L generation, with the trail arm's movement across the chest playing a primary role[3,4]. This study revealed that the mechanism of L generation in the lower limbs differs from off-ice movement, whereas the role of the upper limbs exhibited similar tendencies to those.

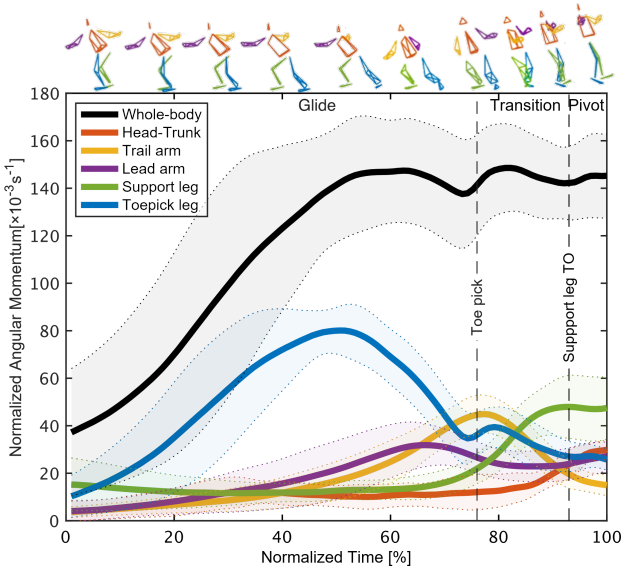

Figure 1:Segmental L of the body during the takeoff phase.

Conclusions

This study revealed that the lower limbs primarily contribute to the generation of L about the vertical axis during the takeoff phase of the triple toe-loop, with the toe-pick leg during the glide phase being the most significant contributor. Additionally, when it comes to the upper limbs, the trail arm contributed significantly more than the lead arm. These findings provide a foundation for understanding the mechanisms of L generation during takeoff and offer valuable insights for coaching figure skating jumps.

References

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