Concurrent validity of kinematics-based method to calculate angular momentum during shot put

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Summary

This study evaluated the validity of a kinematics-based method (L_K) for calculating angular momentum by comparing it with the cumulative integral of ground reaction force (GRF) moment and free moment (L_G) during shot put. Five trained shot putters performed maximal-effort throws, with motion data captured at 500 Hz and GRFs at 1500 Hz. Significant ICCs (0.900–0.982) confirmed L_K's validity during most of the motion, though discrepancies arose in the initial phase (ICCs: 0.407–0.906). Bland-Altman plots showed most data within 95% agreement limits. The findings indicate that the kinematics-based method is enough valid but may involve errors due to limitations in estimating inertia and body posture effects, especially in the early phase of motion.

Introduction

Angular momentum is a critical parameter for evaluating rotational motion during sports activities. While angular momentum about center of mass (COM) can be derived from kinematic variables, the validity of kinematics-based methods for calculating angular momentum remains unclear. The aim of this study was to clarify the validity of a kinematics-based method for calculating angular momentum by comparing it with the cumulative integral of the GRF moment and free moment during shot put motion.

Methods

Five well-trained shot putters (four males and one female) participated in this study. Each participant performed five maximal-effort throws. 3D coordinates of the body and the shot were captured using a 24-camera optical motion capture system (Mac3D System, Motion Analysis Corp., USA) at 500 Hz. GRFs, the center of pressure (COP), and free moments of the COP were recorded using six force plates (TF-90100, Tec Gihan, Japan) synchronized with the motion capture system at 1500 Hz. Kinematics-based angular momentum (L_K) about the vertical axis of the athlete-shot system's COM (COM_S) was calculated from the coordinate data using Dapena's method (Dapena, 1978). The cumulative integral of the GRF moment about the vertical axis and the free moment throughout the shot put motion was calculated to serve as the reference angular momentum (L_G). Intra-class correlation coefficients (ICCs) were calculated to assess the validity of L_K compared to L_G. Differences between L_K and L_G were further analyzed using Bland-Altman plots. Statistical significance was set at $p < 0.01$.

Results and Discussion

Figure 1 illustrates changes in L_G and L_K for five trials, with one representative trial per participant shown. Significant ICCs were observed during 35–86%, 90% and 98–99% of the normalized time of the shot put motion (ICCs: 0.900–0.982). However, ICCs were not significant during 0–34%, 87–89% and 100% (ICCs: 0.407–0.906). Figure 2 shows the Bland-Altman plot of L_G and L_K, and data points were mostly plotted within 95% limits of agreements except for the low value of the L_G and L_K. These results indicate that the kinematics-based method (L_K) is almost valid when L_G is used as the reference. However, discrepancies were identified especially in the initial phase of the shot put motion, suggesting potential limitations of the methods. This discrepancy is considered to be due to the following factors in each method: L_G cannot calculate the initial value; L_K estimates the moment of inertia and is affected by the posture of each body segment of the body.

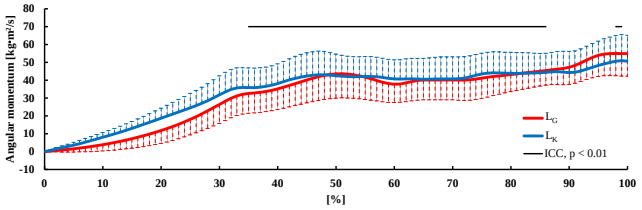

Figure 1 Comparison between L_G and L_K with ICC between the methods.

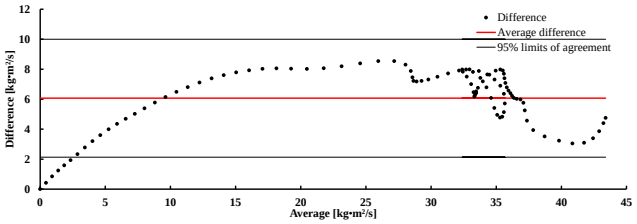

Figure 2 Bland-Altman plot for L_G and L_K

Conclusions

Kinematics-based angular momentum calculation method has enough validity, but it is clear that it potentially has errors due to the calculation procedure.

References

[1] Dapena J. (1978). *J. Biomech.* **11**: 251-256.