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Elbow joint variability for different hand positions of the round off in gymnastics

Roman Farana [a,*], Gareth Irwin [a,b], Daniel Jandacka [a], Jaroslav Uchytil [a], David R. Mullineaux [c]

[a] Human Motion Diagnostic Center, University of Ostrava, Czech Republic
[b] Sport Biomechanics Research Group, Cardiff School of Sport, Cardiff Metropolitan University, UK
[c] School of Sport and Exercise Science, University of Lincoln, UK

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ABSTRACT

The aim of the present study was to conduct within-gymnast analyses of biological movement variability in impact forces, elbow joint kinematics and kinetics of expert gymnasts in the execution of the round-off with different hand positions. Six international level female gymnasts performed 10 trials of the round-off from a hurdle step to a back-handspring using two hand potions: parallel and T-shape. Two force plates were used to determine ground reaction forces. Eight infrared cameras were employed to collect the kinematic data automatically. Within gymnast variability was calculated using biological coefficient of variation (BCV) discretely for ground reaction force, kinematic and kinetic measures. Variability of the continuous data was quantified using coefficient of multiple correlations (CMC). Group BCV and CMC were calculated and *T*-test with effect size statistics determined differences between the variability of the two techniques examined in this study. The major observation was a higher level of biological variability in the elbow joint abduction angle and adduction moment of force in the T-shaped hand position. This finding may lead to a reduced repetitive abduction stress and thus protect the elbow joint from overload. Knowledge of the differences in biological variability can inform clinicians and practitioners with effective skill selection.

* Corresponding author at: Human Motion Diagnostic Center, University of Ostrava, 701 03 Moravska Ostrava, Czech Republic. Tel.: +420 597 09 2593.
E-mail address: Roman.Farana@osu.cz (R. Farana).

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1. Introduction

Research based evidence has shown that movement variability plays an important role in many sport skills including running (Queen, Gross, & Liu, 2006), sprinting (Bradshaw, Maulder, & Keogh, 2007; Salo & Grimshaw, 1998), athletic jumping (Wilson, Simpson, van Emmerik, & Hamill, 2008), baseball pitching (Fleisig, Chu, Weber, & Andrews, 2009) and gymnastics (Gittoes, Irwin, Mullineaux, & Kerwin, 2011; Irwin & Kerwin, 2007). Biological variability is an established component of human motor performance, as such, when a performer replicates the same movement, even when the goal remains constant, the exhibited kinematics and kinetics will vary between trials (Miller, Chang, Baird, van Emmerik, & Hamill, 2010; Preatoni et al., 2013).

The traditional motor learning perspective suggests that a reduction in movement variability will aid in the development of a skilled performance (Wilson et al., 2008). From a dynamical systems perspective high movement variability in the localized joint and segmental movement strategies are beneficial to the task outcomes (Gittoes et al., 2011; Newell, 1986), and has been considered to be an essential element to normal, healthy function, thus offering flexibility in adapting to perturbations (Hamill, van Emmerik, Heiderscheit, & Li, 1999). From an injury perspective movement variability is a positive feature because it helps minimize chronic injury potential (Heiderscheit, Hamill, & van Emmerik, 2002). It is postulated that movement variability during running attenuates impact shocks when runners are subjected to large forces and demonstrates a potential relationship between variability and overuse injury (Hamill et al., 1999; Heiderscheit et al., 2002). These authors suggested that movement variability might provide a broader distribution of stresses among different tissues, potentially reducing the cumulative load on internal structures of the body. Wilson et al. (2008) observed a U-shape relationship between movement variability and skill level whilst examining intermediate and expert triple jumpers, whereby in the final stages of developing a skill, variability is accessed that brings flexibility to the system allowing it to cope with perturbations (Wilson et al., 2008).

In gymnastics, when the same skill is performed a number of times it may be expected that gymnasts are attempting to use the same technique (Hiley, Zuevsky, & Yeadon, 2013). However, movement variability occurs when the same action is repeated and even the elite athlete is not able to perform identical motor patterns (Preatoni, Ferrario, Donà, Hamill, & Rodano, 2010). Gittoes et al. (2011) investigated movement variability in whole-body and multi-joint kinematic control strategies of expert gymnasts in the execution of fundamental backward rotating dismount skills from balance beam. The authors suggest that a self-selected multi-joint kinematic strategy is used in the impact phase for customization of the joint loading adjustments in executing the fundamental dismount skills. Hiley et al. (2013) investigated movement variability in the important aspects of high bar swinging technique. They found that the more elite gymnasts have less variability in the more mechanically important aspects of technique (e.g., the instants of maximum hip and shoulder extension and flexion as the gymnast passed through the lower part of the longswing), and more variability in some of the less mechanically important aspects. These studies are focused on movement variability of whole body coordinated movements. However, there is a lack of evidence relating to movement variability of weight-bearing limb kinematics and kinetics during fundamental gymnastics skills.

Daly, Rich, Klein, and Bass (1999) demonstrated that gymnastics' training can be associated with on average more than 100 impacts per training session on the upper extremities. Weight-bearing impacts onto the hands and the repetitive compressive forces can lead to both acute and chronic injuries to the upper extremities (Davidson, Mahar, Chalmers, & Wilson, 2005). Lindner and Caine (1990) identified the floor exercise as the most hazardous gymnastics event and most injuries happened with skills that are basic or moderately difficult and well-established. In artistic gymnastics the round-off (RO) (Fig. 1a) is a fundamental gymnastics skill and a key movement in the development of elite female gymnasts, owing to its association with learning more complex skills (Farana, Jandacka, Uchytil, Zahradnik, & Irwin, 2014). Two common techniques are used to perform the RO, the parallel hand position (Fig. 1b) and the T-shape hand position (Fig. 1c).

Farana et al. (2014) observed that different hand positions during RO in female gymnastics significantly influenced elbow loading during the second contact hand. These authors stated that the T-shape position of the hands reduces peak vertical, anterior–posterior, and resultant contact forces