

## ELBOW AND WRIST JOINT LOADING DURING THE ROUND-OFF SKILLS IN MALE GYMNASTICS: A CASE STUDY

Roman Farana<sup>1</sup>, Petra Janeczkova<sup>1</sup>, Jaroslav Uchtyl<sup>1</sup>, Daniel Jandacka<sup>1</sup>, David Zahradnik<sup>1</sup> and Gareth Irwin<sup>1,2</sup>

Department of Human Movement Studies, University of Ostrava, Czech Republic<sup>1</sup>; Cardiff School of Sport, Cardiff Metropolitan University, Cardiff, UK<sup>2</sup>

Elbow and wrist injuries are a major concern in elite male gymnastics. The aim of the current study was to investigate key elbow and wrist joint injury risk factors (internal and external kinetics) during different round-off techniques in male artistic gymnastics. One international level male gymnast performed 15 trials of a round-off from a hurdle step to back handspring with three different hand positions (parallel (5), T-shape (5) and reverse (5)). Synchronized kinematic and kinetic data were collected for each trial. Effect-size statistics determined differences between each hand position. In conclusion the T-shape technique demonstrated reduced vertical, anterior-posterior and resultant ground reaction forces. Differences in elbow and wrist joint kinetics indicated that the T-shape technique may prevent elbow and wrist joint from overload and reduces potential of injuries.

**KEY WORDS:** kinetics, upper limbs, injury prevention.

**INTRODUCTION:** Gymnastics is a unique sport due to the fact that the upper limbs are used for weight-bearing activities (Webb & Rettig, 2008). Elbow and wrist lesions are a potential career ending injuries in gymnastics (Chan et al., 1991; DiFiori et al., 2002), and present a real concern for coaches, scientist and clinicians (Farana et al., 2014). In gymnastics the round-off (RO) is one of the fundamental skills and is defined as the primary way for gymnasts to change from forward-rotating to backward-rotating movements. In the more fundamental skills of gymnastics, the high frequency of performance repetition may have a significant influence on injury potential (Lindner & Caine, 1990). During ISBS 2012 gymnastics applied session Cossens (2012) hypothesized that the T-shape hand position during the hand contact phase of the round-off may be used to reduce the weight-bearing load. Farana et al. (2014) examined injury risk and technique selection associated with the choice of hand placement in RO skills in female gymnastics. These authors found that the T-shape hand position reduced vertical, horizontal and resultant ground reaction forces (GRF) and decreased elbow joint moments indicating a safer technique for the RO skill. Building on previous research by Farana et al. (2014) the aim of the current study was to investigate key elbow and wrist joint injury risk factors including impact forces, elbow and wrist joint kinetics during different round-off techniques in male artistic gymnastics.

**METHODS:** An international level active male gymnast from the Czech Republic participated in the current study. Gymnast age, height and mass were 18 years, 1.68 m and 68 kg. The gymnast performed 15 successful trials of a RO from a hurdle step to back handspring with three different hand positions (parallel (5), T-shape (5) and reverse (5)) (Figure 1). All trials were performed with maximal effort, in random order and were separated by a rest period of 1 min.

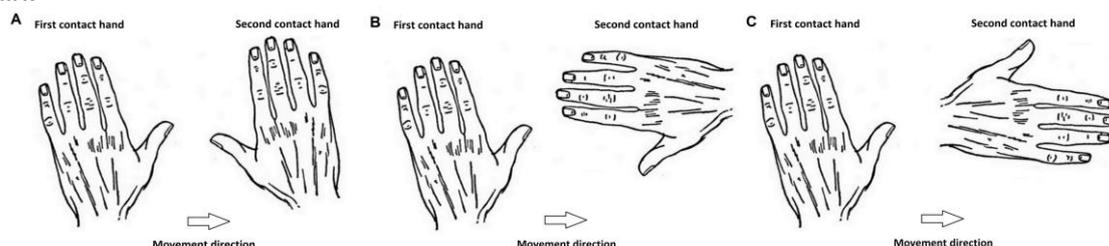


Figure 1: Round-off hand positions (A) Parallel, (B) T-shape and (C) Reverse.

Synchronized kinematic (3D-automated motion analysis system; 240 Hz) and kinetic (force plate; 1200 Hz) data were collected for each trial. Based on C-motion Company (C-motion, Rockville, MD, USA) recommendation, retroreflective markers and clusters were attached to the gymnasts' upper limbs and trunk (Figure 2). Two photocells were used to control hurdle step velocity. The hurdle step velocity was standardized at a range of 3.3–3.7 m/s (Farana et al., 2014). All procedures were in accordance with the guidelines of the Ethics Committee of the University of Ostrava.



**Figure 2: Figure reflective markers attached to gymnast body.**

Raw data were processed using the Visual 3D software (C-motion, Rockville, MD, USA). The local coordinate systems were defined using a standing calibration trial in handstand position (Farana et al., 2014). All analysis focused on the contact phase of the second hand during the RO skills. Key injury risk variables included peak vertical GRF (VGRF), anterior-posterior GRF (APGRF), resultant GRF (RGRF), elbow joint internal adduction moment of force and elbow and wrist joint vertical reaction force. The coordinate data were low-pass filtered using the fourth-order Butterworth filter with a 12 Hz cut off frequency. All force plate data were low-pass filtered using the fourth-order Butterworth filter with a 50 Hz cut off frequency. Effect-size (ES) statistics determined differences between each hand position. ESs were calculated and interpreted as <0.2 trivial, 0.21–0.6 small, 0.61–1.2 moderate, 1.21–2.0 large and >2.0 very large (Hopkins, 2002).

**RESULTS:** Means, standard deviations and effect size values for GRFs and elbow joint kinetics for all techniques of RO skills are displayed in Table 1. The highest magnitude of VGRF, APGRF and RGRF were observed in the reverse technique (Table 1).

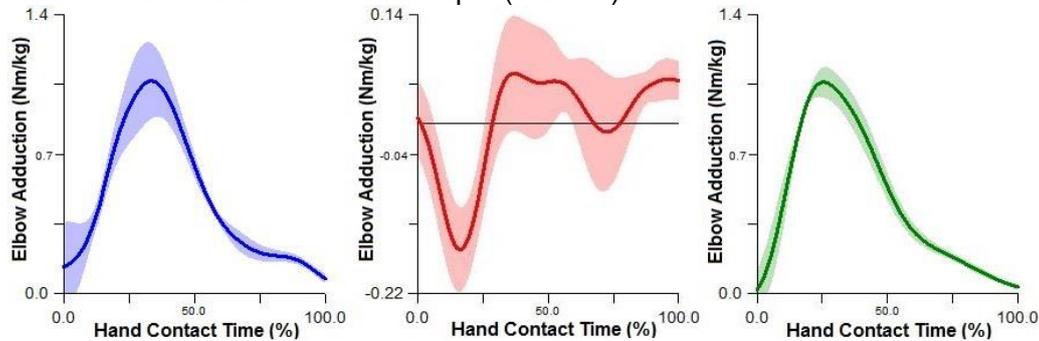
**Table 1**  
**Ground reaction forces and elbow joint kinetics of the second contact hand during round off with three different hand positions.**

Variable	Parallel technique	T-shape Technique	Reverse technique	ES (PxT)	ES (PxR)	ES (TxR)
Peak VGRF (BW)	1.48 ± 0.07	1.36 ± 0.11	1.49 ± 0.05	1.3	0.2	1.5
Peak APGRF (BW)	-0.42 ± 0.03	-0.31 ± 0.03	-0.52 ± 0.06	3.7	2.1	4.4
Peak RGRF (BW)	1.54 ± 0.07	1.39 ± 0.12	1.55 ± 0.07	1.5	0.1	1.6
Elbow adduction moment (Nm/kg)	1.11 ± 0.12	0.10 ± 0.03	1.06 ± 0.05	11.5	0.5	23.3
Elbow vertical RF (N/kg)	-10.39 ± 0.73	-6.63 ± 0.60	-11.33 ± 0.21	5.6	1.8	10.5
Wrist vertical RF (N/kg)	-12.65 ± 0.30	-10.48 ± 0.46	-13.30 ± 0.33	5.6	2.1	7.4

Notes: VGRF, vertical ground reaction force; APGRF, anterior-posterior ground reaction force; RGRF, resultant ground reaction force; BW, body weight; RF, reaction force; Nm/kg, Newton meter per kilogram; N/kg, Newton per kilogram; ES, effect size.

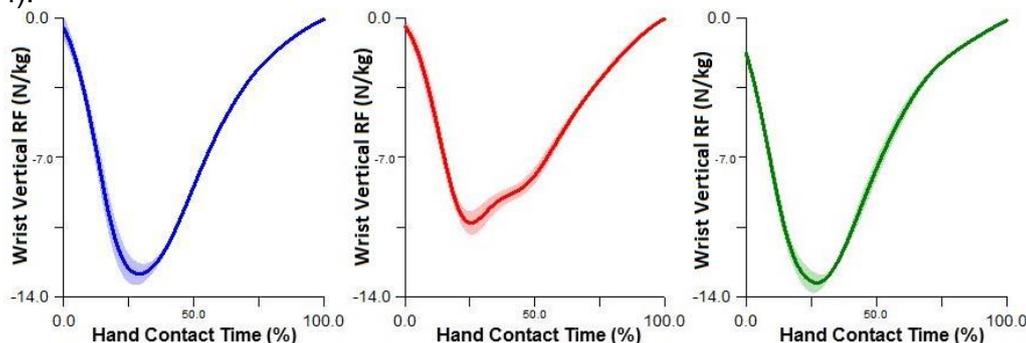
As for elbow joint internal adduction moment very large ESs were observed between parallel and T-shape technique (ES = 11.5, very large), and between T-shape and reverse technique

(ES = 23.3, very large). The highest magnitude of elbow internal adduction moment was observed in the parallel technique (Figure 3 and Table 1). Elbow joint vertical reaction force displayed large to very large ESs between parallel and T-shape technique (ES = 5.6, very large), between parallel and reverse technique (ES = 1.8, large), and between T-shape and reverse technique (ES = 10.5, very large). The highest magnitude of elbow joint reaction force was observed in the reverse technique (Table 1).



**Figure 3: Elbow joint internal adduction moment of force profiles of the second contact hand in parallel (blue), T-shape (red) and reverse (green) techniques.**

Wrist joint vertical reaction force displayed large to very large ESs between parallel and T-shape technique (ES = 5.6, very large), between parallel and reverse technique (ES = 2.1, large), and between T-shape and reverse technique (ES = 7.4, very large). The highest magnitude of wrist joint reaction force was observed in the reverse technique (Table 1 and Figure 4).



**Figure 4: Wrist joint vertical reaction force profiles of the second contact hand in parallel (blue), T-shape (red) and reverse (green) techniques.**

**DISCUSSION:** The current study provided basic insights into how impact forces and elbow and wrist joint kinetics are associated with different hand positions during ground contact of the second hand during RO skills. Previously, Farana et al. (2014) highlighted that, T-shape hand positions reduces peak VGRF, peak APGRF, and peak RGRF of the second contact hand. In the current study, peak VGRF, peak APGRF, and peak RGRF of the second hand were higher in the parallel and reverse techniques compared with the T-shape technique (Table 1). From an injury prospective these observations concur with the comments of Whiting and Zernicke (2008) who stated that peak forces are among the most fundamental injury risk factors. Previous study highlighted an important role of a forearm rotation on the elbow joint loading during the RO in female gymnast (Farana et al., 2014). In the current study very large effect sizes were found for peak internal adduction moment in the round-off with parallel and reverse hand position compared with the T-shape hand position (Figure 3). These findings are in accordance with Farana et al. (2014) research who found significantly lower magnitudes of internal adduction moment in the T-shape technique compared with parallel hand position. Evidence from previous research has identified that repetitive abduction stress placed on the elbow joint can lead to chronic elbow injuries (Hume, Reid, &

Edwards, 2006). Moreover, higher magnitudes of elbow joint vertical reaction force were observed in the parallel and reverse technique compared with the T-shape technique (Table 1). These compression forces and sizeable adduction moments placed on the elbow joint may be responsible for chronic injuries, a finding that concurs with previous research by Koh, Grabiner and Weiker (1992). In the current study, higher magnitudes of wrist joint axial force were found in the reverse and parallel techniques compared with the T-shape technique (Figure 4). It has been highlighted that these compressive loads are transmitted through the carpals to the radius and ulna, with the radius accepting approximately 80% of the load (DiFiori et al., 2002). Evidence from previous research has identified that repetitive loads placed on the wrist joint can lead to distal radius stress injury (DiFiori et al., 2002). These initial findings provide a foundation to investigate this area further, with a larger sample, different performance levels and stages of learning to examine other factors that may influence the occurrence of injury.

**CONCLUSION:** The key conclusions of the current study are that the T-shape technique reduces vertical, anterior-posterior and resultant ground reaction forces. Differences in elbow joint internal adduction moment, elbow and wrist joint compression force indicated that the T-shape technique may prevent elbow and wrist joint from overload and reduces potential of injuries.

#### REFERENCES:

- Cossens, P. (2012). Injury prevention in artistic gymnastics: A guide for coaches and directions for research. In E. J. Bradshaw, A. Burnett, & P. A. Hume (Eds.), *XXX International Symposium of Biomechanics in Sports* (pp. 69–70). Melbourne, Australia: Australian Catholic University.
- Chan, M. D., Aldridge, M. J., Maffulli, N., & Davies, a. M. (1991). Chronic stress injuries of the elbow in young gymnasts. *The British Journal of Radiology*, 64, 1113–1118.
- DiFiori, J. P., Puffer, J. C., Aish, B., & Dorey, F. (2002). Wrist pain, distal radial physeal injury, and ulnar variance in young gymnasts: does a relationship exist? *The American Journal of Sports Medicine*, 30, 879–885.
- Farana, R., Jandacka, D., Uchtyl, J., Zahradnik, D., & Irwin, G. (2014). Musculoskeletal loading during the round-off in female gymnastics: the effect of hand position. *Sports Biomechanics*, 13, 123–134.
- Hopkins, W.G. (2002). *New View of Statistics: Effect of magnitudes*. Retrieved 5. 12. 2014 from the World Wide Web: [http://www.sportsci.org/resource/stats/effect\\_mag.html](http://www.sportsci.org/resource/stats/effect_mag.html)
- Hume, P. A., Reid, D., & Edwards, T. (2006). Epicondylar injury in sport. *Sport Medicine*, 36, 151–170.
- Koh, T. J., Grabiner, M. D., & Weiker, G. G. (1992). Technique and ground reaction forces in the back handspring. *The American Journal of Sports Medicine*, 20, 61–66.
- Lindner, K. J., & Caine, D. J. (1990). Injury patterns of female competitive club gymnasts. *Canadian Journal of Sport Sciences*, 15, 254–261.
- Webb, B., & Rettig, L. (2008). Gymnastic wrist injuries. *Current Sports Medicine Reports*, 7, 289–295.
- Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of musculoskeletal injury* (2nd ed.). Champaign, IL: Human Kinetics.

#### Acknowledgement

The authors would like to thank Phil Cossens for his inspiration at the start of this research. The authors also thanks to the gymnast who participated in the study.