

WRIST JOINT LOADING DURING THE ROUND-OFF SKILLS IN FEMALE GYMNASTICS

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The aim of this study was to investigate key injury risk factors including wrist joint kinetics and kinematics in the second contact limb for both parallel and T-shape RO techniques. Seven international level female gymnasts performed 10 trials of round-off from a hurdle step to back handspring with “parallel” and “T” shape hand position. Two force plates were used to determine ground reaction forces. Eight infrared cameras were employed to collect the kinematic data. T-test and effect size statistics established differences. Key findings of the current study are that in the parallel technique the wrist joint is exposing to higher axial compression load. Increased wrist joint dorsiflexion and radial deviation in the T-shape technique may indicate higher risk of wrist injury in gymnastics.

KEY WORDS: biomechanics, gymnastics, round-off, wrist joint, injury prevention.

INTRODUCTION: A unique aspect of artistic gymnastics is the frequent use of the upper extremities to support body weight (DiFiori, Caine, & Malina, 2006). Gymnasts are often involved in activities requiring weight-bearing with their wrist in hyperextension, such as the beam, tumbling, vault, and floor routines. During these activities the wrist is exposed to many different types of stresses including repetitive motion, high impact loading, axial compression, torsional forces, hyperextension, ulnar and radial deviations, and is the most frequently injured site in the upper extremity of female gymnasts followed by the elbow (Webb & Rettig, 2008). The floor exercise is the most frequently associated with wrist pain in female gymnasts (DiFiori, Puffer, Aish, & Dorey, 2002). Previous research by 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. Farana, Jandacka, Uchytíl, Zahradník and Irwin (2014) stated that in the fundamental skills of gymnastics, the high frequency of performance repetition may have a significant influence on injury potential. When gymnasts’ performing high volumes of these skills within a session and across a season the implications for micro traumas become apparent, the load will affect the nature and severity of injury particularly at vulnerable joints such as the elbow and the wrist (Irwin, 2011). In gymnastics the round-off (RO) is one the fundamental skills and a simple and effective way for the gymnast to change from forward-rotating to backward-rotating movements while moving in one direction along a straight line. Research groups from Ostrava and Cardiff have examined injury risk and technique selection associated with the choice of hand placement in RO skills (Farana et al., 2014). These authors highlighted that the T-shape position may prevent overloading of the joint complex and consequently reduce the potential for elbow injury. The aim of this study was to investigate key injury risk factors including wrist joint kinetics and kinematics in the second contact limb for both parallel and T-shape RO techniques. The current research provides an insight to RO technique selection to increase the understanding elbow joint injury risk, which would provide useful insights into technique selection for coaches, athletes and clinicians.

METHODS: Seven international level female gymnasts from the Czech Republic participated in this study. Gymnasts mean \pm SD height was 162.9 ± 3.9 cm; mass 56.7 ± 5.2 kg and age 20.7 ± 1.6 years. Informed consent was obtained in accordance with the guidelines of the Institute’s Ethics and Research Committee. The gymnasts completed their self-selected

warm up and completed a number of practice RO trials in parallel and T-shape techniques (Figure 1). After the warm up and practice, all gymnasts performed 10 trials of RO with a parallel hand position from a hurdle step to a back handspring, and 10 trials of RO with a T-shape hand position from a hurdle step to a back handspring. All trials were performed with maximal effort and in random order and were separated by a rest period of 1 min.

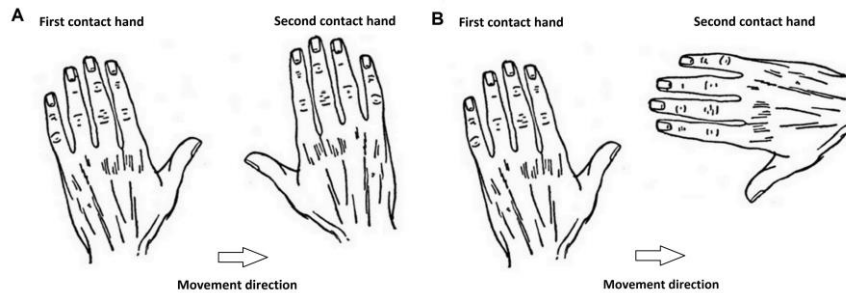


Figure 1: Round-off hand positions (A) Parallel and (B) T-shape technique.

Synchronized kinematic (3D-automated motion analysis system; 247 Hz) and kinetic (force plate; 1235 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). Raw data were processed using the Visual 3D software (C-motion, Rockville, MD, USA). As Figure 2 shows, 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. Kinematic variables included sagittal (+ plantar flexion/- dorsiflexion) and frontal (+ ulnar deviation/- radial deviation) wrist angles and these were calculated using a XYZ order of rotation. Kinetic variables included peak wrist axial force, peak wrist breaking force and loading rates of these forces. 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. Means and standard deviations ($M \pm SD$) were calculated for all measured variables. Statistical significance in variables were quantified using paired t-tests with alpha set to 0.05. Effect sizes (ES) were calculated and interpreted as <0.2 trivial; 0.21-0.5 small; 0.51-0.8 medium and >0.8 large (Cohen, 1988). Statistical analyses were performed using IBM SPSS Statistics 20 and Microsoft Excel software.



Figure 2: Figure reflective markers attached to gymnast body.

RESULTS: Means and standard deviations for wrist joint kinetics and kinematics for both techniques of RO skills are displayed in Table 1. As for wrist joint kinematics significant differences and large ES were found for wrist dorsiflexion (Figure 3 and Table 1) and radial deviation (Table 1). Significant differences and large ESs were found between the hand positions in peak axial force (Figure 3) and loading rate of axial force (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	“P” position	“T” position	ES	Sig.
Peak Axial Compression Force (N/kg)	-14.36 ± 2.27	-12.33 ± 2.71	0.81	0.001
Peak Anterior Shear Force (N/kg)	-3.07 ± 0.30	-2.60 ± 0.30	1.57	0.077
Axial Compression Force Loading Rate (N/kg/s)	-256.63 ± 27.55	-207.83 ± 41.09	1.40	0.000
Anterior Shear Force Loading Rate (N/kg/s)	35.33 ± 10.82	-28.39 ± 7.60	0.74	0.066
Wrist Dorsiflexion Angle (°)	-73.72 ± 2.99	-79.80 ± 3.46	1.89	0.001
Wrist Ulnar/Radial Deviation (°)	1.18 ± 11.53	-22.77 ± 10.48	2.17	0.001

Notes: N/kg, Newton per kilogram; N/kg/s, Newton per kilogram per second; °, degree; ES, effect size.

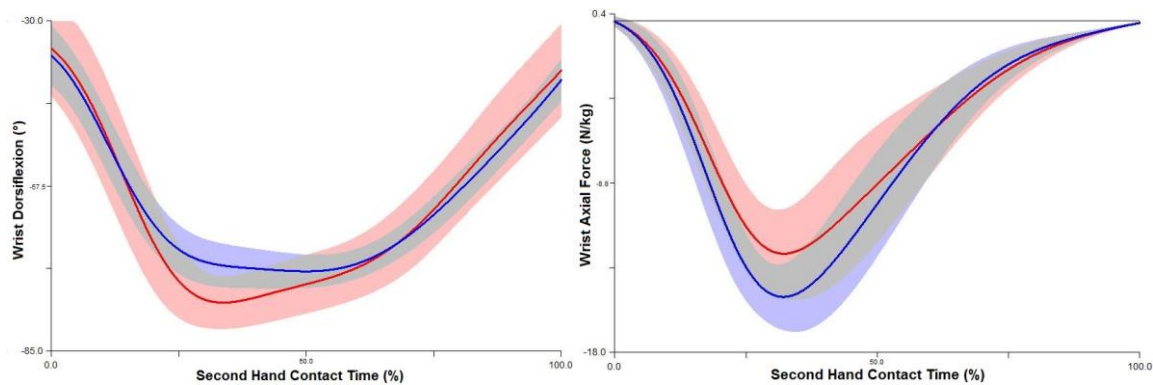


Figure 3: Wrist joint dorsiflexion (left) and axial force (right) profiles of the second contact hand in parallel (blue) and T-shape (red) techniques.

DISCUSSION: The aim of the current study was to investigate key injury risk factors including wrist joint kinetics and kinematics in the second contact limb for both parallel and T-shape RO techniques. This study provided insights into how wrist joint kinematics and kinetics are associated with different hand positions during ground contact of the second hand during RO skills. One of the most common mechanisms of wrist injuries is a compressive force applied to a dorsiflexed (hyperextended) wrist (Webb & Rettig, 2008). In the current study, higher magnitudes of wrist joint axial force and loading rate of this force were found in the parallel compared with the T-shape technique (Figure 3). These findings are in accordance with DiFiori et al. (1996) study who identified axial compression force as wrist joint injury risk factor. From an injury prospective these observations concur with the comments of Davidson, Mahar, Chalmers and Wilson (2005) who stated that peak impact forces are among the fundamental injury risk factors. More specifically, it has been postulated 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). In the current study significantly higher wrist joint dorsiflexion and radial deviation was found in the T-shape technique compared with the parallel technique. Previous study by Weber and Chao (1978) demonstrated that greater than 95° of hyperdorsiflexion load of the wrist in radial deviation places the scaphoid waist at the highest risk for fracture. However, in the current study the wrist dorsiflexion was lower than 80° in both RO techniques. Furthermore, from an injury perspective, the use of very soft mats may exaggerate the amount of dorsiflexion and thus

increase the risk of chronic distal radial injury (DiFiori et al., 2006). Conclusions from this study must be considered with the sample size in mind. This limitation reduces the wider application of these results. However, these initial findings provide a foundation to investigate this area further, with different performance levels, gender and age of gymnasts 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 in the parallel technique the wrist joint is exposing to higher axial compression load. Increased wrist joint axial compression force and loading rate in the parallel technique may indicate higher risk of wrist injury in gymnastics. The implications could help coaches, biomechanists and clinicians.

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