INJURY RISK IN TECHNIQUE SELECTION: INFLUENCE OF HAND POSITION IN THE BACK HANDSPRING.

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This study aims to investigate the influence of hand position on the biomechanical risk factors at the wrist during the back handspring in gymnastics. Three national level female gymnasts performed five back handspring trials with “inward”, “parallel” and “outward” hand positions. Synchronised three-dimensional kinematic and kinetic data were collected and inverse dynamics analysis performed to calculate internal wrist joint kinetics. Increased vertical (3.33 ± 0.82 BW) and medio-lateral (1.74 ± 0.42 BW) force at the wrist joint during the outward hand position may lead to increased injury risk and should be discouraged in practice. However, reduced impact forces at the wrist during the inward hand position may lead to reduced wrist stress, thus lower injury potential during the back handspring.

KEY WORDS: biomechanics, gymnastics, injury prevention, wrist.

INTRODUCTION: Gymnastics is a challenging activity in which the upper limb musculoskeletal structure is exposed to high loading (Farana, Jandacka, Uchytil, Zahradník, & Irwin, 2014; Farana, Jandacka, Uchytil, Zahradník & Irwin, 2016). The previous century has seen significant progress within artistic gymnastics where the evolution of coaches' knowledge has prompted modifications in teaching approach and skill selection (McClellan, 2009). Within artistic gymnastics, skill selection is founded upon sports biomechanics (Manning, Irwin, Gittoes & Kerwin, 2011) and coaching knowledge (Irwin, Hanton & Kerwin, 2005). The same elements can be executed with various techniques within the restrictions imposed by the Federation International de Gymnastique (FIG). Coaches therefore face the challenge of determining appropriate techniques for individual gymnasts, reducing injury potential and optimising performance with the aim of making the sport safer, more efficient and effective.

A common feature of gymnastics is the need for the upper extremities to hold the gymnast's full body weight (DiFiori, Caine & Malina, 2006). Singh, Smith, Fields and McKenzie (2008) stated that 42% of all gymnastics injuries were located at the upper extremities and the skills most commonly related to these injuries were forwards and backwards handsprings. Throughout the back handspring, the hands encounter sizable compression impacts and large moments at the joints that can lead to excessive upper limb loading injuries (Koh, Grabiner & Weiker, 1992). Farana *et al.* (2016) investigated technique selection during the round off and found that in the parallel technique the wrist joint of the second contact limb is exposed to higher axial compression load. During upper extremity loading, excessive force has to be dispersed throughout the structure of the wrist (Webb & Rettig, 2008); these loads can contribute to both acute and chronic injuries (Davidson, Mahar, Chalmers & Wilson, 2005). Sands and McNeal (2006) stated that an “inward” hand position throughout a back handspring may decrease wrist hyperextension. The suggestion is that by moving the wrists inwards, flexion at the elbow reduces wrist loading, however this conflicts with the Code of Points skill execution specification and may result in the gymnast's performance being penalised (FIG, 2013). The hand positions during the handspring are defined as follows: inward (wrist flexion and internal rotation), parallel (wrist flexion) and outward (wrist flexion and external rotation) and are all observed within the back handspring. Consequently, there is a requirement to recognise effective skill selection that will enhance performance and reduce the potential of injury onset (Irwin, Hanton & Kerwin, 2005).

The aim of this study is to investigate the influence of hand position on the biomechanical risk factors at the wrist during the back handspring in female artistic gymnastics. The overall purpose was to gain insight into injury risk and offer valuable information for athletes, coaches and clinicians.

METHODS: Participants and Protocol: Three national level female artistic gymnasts were enlisted as participants for this research. Their mean ± *SD* age was 20.60 ± 1.52 years; body mass 57.30 ± 4.44 kg and height 1.64 ± 0.05 m. All participants were free from injury at the time of data collection. The study protocol was verbally explained to each gymnast and informed consent was gained in agreement within the regulations of the Ethics Committee of Cardiff Metropolitan University. Experimental trials operated in the National Indoor Athletics Centre at Cardiff Metropolitan University. Participants performed a self-selected warm-up routine including practice back handspring trials with the three hand positions. Landing mats were used in the performance area ensuring participant safety throughout the skill execution. Two gymnastic floor mats were secured over both force plates in order to imitate the surface of the gymnastics floor; this protocol was successfully used by Farana *et al.* (2016).
Following the practice trials, all gymnasts performed five back handspring trials from a hurdle step round off using each hand position (Figure 1). All trials were completed in a fully randomised order with maximal exertion and were separated by sufficient rest until the gymnast felt they had returned to a resting state. The hand position was controlled by observation from a qualified coach.

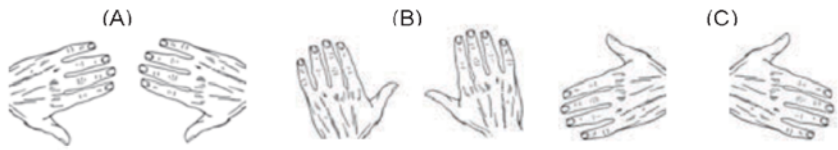

Figure 1. Hand positions: (A) inward (B) parallel (C) outward.

Data Collection and Processing: Force data were collected using two piezo-electric force plates (Kistler, 9287BA, Switzerland) embedded into the ground sampling at 1000 Hz. Three-dimensional kinematic data were collected using an automated motion capture system (Vicon Mx System, Vicon, UK) consisting of 13 opto-electric cameras sampling at 250 Hz. The capture volume was calibrated according to the manufacture's specifications. Global coordinates were defined so the x-axis represented the antero-posterior, the y-axis represented the medio-lateral and the z-axis represented the vertical direction.
Retro-reflective markers (19 mm diameter) were placed bilaterally on the trunk and upper limbs of the gymnast at the subsequent anatomical sites: the acromion process, gleno-humeral joint, lateral and medial epicondyle of the humerus, radial-styloid, ulnar-styloid, head of the second and fifth metacarpal, iliac crest tubercle, inferior-medial angle of the scapula, seventh cervical and tenth thoracic vertebrae, sternum and xiphoid process, in accordance with the C-motion Company guidelines (C-motion, Rockville, MD, USA).

Data Analysis: Data were processed using Visual 3D software (C-Motion, Rockville, MD, USA). Static calibration was conducted in accordance with Farana *et al.* (2014). All analyses centred on the support phase of both left and right hands during the back handspring. The support phase was defined using the Target Pattern Recognition method described by Stanhope, Kepple, McGuire and Roman (1990). The resulting model of the wrist allowed the definition of six degrees of freedom. External kinetic variables included three-dimensional ground reaction force (GRF) and internal kinetic variables included wrist joint forces and moments. All flexion, abduction and internal rotation movement at the wrist was considered positive. The Newton-Euler method for inverse dynamics was used to generate three-dimensional joints at the wrist (Selbie, Hamill & Kepple, 2014). Kinematic data were filtered using a low-pass Butterworth filter with a 12 Hz cut-off frequency. Hanavan's (1964) inertial model was used to gain inertial properties of segments. All GRF data were normalised to body weight (BW) and moment of force data were normalised to body mass (Nm/kg) to permit comparison. A group analysis was used as individual data were similar in nature. A one-way ANOVA and least significant difference post hoc test, examined differences between techniques; alpha level was set at 0.05.

RESULTS:

Means and standard deviations for selected external and internal kinetic variables at the wrist for the three hand positions in the back handspring are shown in Table 1. Significantly lower internal vertical and medio-lateral force was observed at the wrist joint when using the inward hand position in comparison to the outward and parallel hand positions. Significantly larger peak vertical and medio-lateral GRF and internal rotation moments at the wrist were displayed for the outward hand position when compared to the inward hand position. Highest values were observed over all variables when using the outward hand position.

Table 1. Summary of external and internal kinetic variables for inward, parallel and outward hand positions during the back handspring.

Variable	Anatomical Description		
	Inward	Parallel	Outward
Peak vertical GRF (BW)	1.37 ± 0.28[3]	1.47 ± 0.25[3]	1.66 ± 0.13[1 2]
Peak medio-lateral GRF (BW)	0.06 ± 0.04[3]	0.12 ± 0.05	0.17 ± 0.05[1]
Internal vertical force (BW)	0.95 ± 0.45[2 3]	2.36 ±0.49[1 3]	3.33 ± 0.82[1 2]
Internal medio-lateral force (BW)	0.50 ± 0.12[2 3]	0.11 ± 0.05[1 3]	1.74 ± 0.42[1 2]
Internal rotation moment (Nm/kg)	0.39 ± 0.13[2 3]	-0.26 ±0.10[1]	-0.94 ± 0.29[1]

Notes: [1] significantly different to inward, [2]parallel and [3]outward hand positions ($P<0.05$).

DISCUSSION: The aim of this study was to investigate the influence of hand position on the biomechanical injury risk factors at the wrist during the back handspring in female gymnastics. This current study has offered an insight into injury risk at the wrist joint, offering valuable information for athletes, coaches and clinicians. Previous research has stated that peak force is the most significant characteristic in determining injury (Davidson et al., 2005). In the current study, significantly higher peak vertical and medio-lateral ground reaction forces were observed in the outward hand position and significantly lower in the inward hand position. These findings suggest that coaches should discourage the use of the outward hand position and promote the inward hand position in the back handspring to reduce injury risk at the wrist joint. In the current study, significantly higher magnitudes of internal vertical force (3.33 ± 0.82 BW compared to 0.95 ± 0.45 BW and 2.36 ± 0.49 BW) and medio-lateral force (1.74 ± 0.42 BW compared to 0.50 ± 0.12 BW and 0.11 ± 0.05 BW) at the wrist joint were observed in the outward hand position and significantly lower values in the inward and parallel technique respectively. This difference in force indicates that the wrist is experiencing highest wrist stress when the hands are placed outwards. This excessive force paired with hyperextension of the wrist can cause a tearing or rupture of the triangular fibrocartilage wrist complex (Palmer, 1990). It was also identified that hyper-rotation injuries to the wrist or forearm can result in severe lesions of the triangular fibrocartilage complex at the wrist (Palmer, 1990). The current study displayed significantly higher rotational moments at the wrist when using the outward technique when compared to the inward technique (Table 1). This increased internal loading combined with increased internal rotational moment at the wrist indicates that using the outward hand position during the back handspring can be potentially harmful to the wrist joint. A limitation of this study was the small sample size. However, these initial findings provide a foundation to investigate this area further, with differing performance levels, age, gender and learning stages of gymnasts to examine other factors that may influence the injury occurrence.

CONCLUSION: The main conclusions from this study state that when using the outward hand position, the wrist joint is exposed to increase joint kinetics and biophysical loading that may increase injury risk at the wrist. The outward hand position in the back handspring should therefore be discouraged in gymnastics practice. The inward hand position may lower injury risk in the back handspring due to lower external and internal forces occurring at the wrist joint. These implications may offer valuable information for coaches, in terms of technique selection and to aid clinicians in identifying injury risk.

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