ASYMMETRY ANALYSIS OF CROSS ON GYMNASTICS TRAINING AND COMPETITION RINGS

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Based on biomechanics and the principles of training specificity, the purpose of this study was to verify whether the use of a training device is a specific drill to the static cross posture on rings. Six elite Brazilian gymnasts performed the cross on competition and training rings. Variables analysed from digitised video data were right and left shoulder angles in the frontal plane. Larger angles were found when performing the cross on training rings for right (RMSD 3.20°) and left (RMSD 3.27°) shoulders. Less inter-limb asymmetry was also reported for the training rings (1.87%), compared to the competition (2.25%) condition. The training device seems to allow elite gymnasts to reduce shoulder asymmetry and deviations from 90° whilst performing the cross, which can lead to execution penalties in competition.

KEY WORDS: symmetry angle, shoulder, coaching.

INTRODUCTION: The cross is a key posture on rings, which is one event of male artistic gymnastics. It is characterised by maintaining shoulder abduction at 90° in the frontal plane with straight elbows for a minimum of two seconds (FIG, 2013). There are scoring penalties applicable depending on how much deviation from 90° occurs at the shoulder joints whilst the skill is performed (FIG, 2013). Thus, measurement of shoulder angles would increase the understanding of successful performance of this skill.

One training method for developing the cross involves the use of belts attached to the rings, which support gymnasts' forearms to facilitate the training of the skill (Readhead, 1997). This training intends to improve the execution of the cross, reducing the deviations in shoulder angle from 90°, consequently lowering the penalties. However, no shoulder angle data were found regarding the kinematics of this skill in competition or about the drill on training rings. Therefore it is not clear whether the training device contributes to reduce the deviation from the required 90° of shoulder abduction.

Recent research about biomechanical asymmetry can provide information regarding performance and coaching. Information on a participant's asymmetry may inform the coaching – biomechanics interface (Irwin, Bezodis, & Kerwin, 2013) to improve postural stability on rings. Asymmetry scores were used to analyse performance in sprint running (Exell, Irwin, Gittoes, & Kerwin, 2012) and to allow for asymmetry comparisons between athletes over time and between asymmetry and performance (Exell, Gittoes, Irwin, & Kerwin, 2012). In gymnastics, asymmetry has direct implications on performance as penalties can be applied for asymmetrical performance (FIG, 2013). This research aimed to verify whether the use of this training device is a specific drill to the static cross posture and whether it may improve performance on competition rings.

METHODS: Ethical approval was gained from the University's Research Ethics Committee prior to commencement of the study. Six Brazilian senior gymnasts performed three trials of the cross in two conditions: training and competition rings, in a random order. Gymnasts' mean age, mass, stature and years of experience were 21.67 [±3.14] years, 61.53 [±5.66] kg, 1.66 [±0.05] m and 14.17 [±4.02] years, respectively.

The trials were recorded by one digital camera operating at 50 Hz, placed 5 m from gymnasts' frontal plane at the same height as the rings. Data collection occurred in the gymnasts' training gym, with the apparatus that they used to practice.

The videos were digitised and data were filtered with a low-pass Butterworth filter, with appropriate cut-off frequency determined by residual analysis (Winter, 2009). Kinematic data were reconstructed using direct linear transformation in Matlab (Mathworks) (Hedrick, 2008) and imported into Visual 3D (C-Motion). An upper limb model (Rab, Petuskey, & Bagley, 2002) was applied to the data points and the frontal plane angle between trunk and arm segments were considered as shoulder angles. The data analysed comprised the two seconds from the moment that gymnasts reached a static posture.

Percentage differences between left and right values were calculated using the symmetry angle (θ_{SYM}) method (Zifchock, Davis, Higginson, & Royer, 2008):

$$\theta_{SYM} = \frac{(45° - \arctan(Xleft / Xright))}{90} \times 100\% \quad (1)$$

Where θSYM is the symmetry angle; Xleft is the gymnast's mean left shoulder angle (LSHOθ) value and Xright is the gymnast's mean right shoulder angle (RSHOθ) value. The symmetry values were rectified, allowing the magnitude of those values to be more easily compared between conditions. The gymnast's three trials in each condition were averaged, and then RMSD and Asymmetry values were calculated, for each gymnast and condition. Following tests for normality, parametric tests were used to test for significant ($p < 0.05$) differences of group RSHOθ, LSHOθ and Asymmetry in each condition (training versus competition). Mean group RMSD and Asymmetry values were calculated based on six gymnasts' values, rather than shoulder group mean values.

RESULTS: RSHOθ and LSHOθ, RMSD and Asymmetry values are individually shown in Table 1. Shoulder angle values were higher for the training condition for three gymnasts in RSHOθ, five in LSHOθ and in both shoulders for the group mean. Asymmetry values were lower in training condition (more symmetric) for 4 of 6 gymnasts, unaffected in one (gymnast 3), and worse in one (gymnast 6). Statistically significant differences were found between conditions for LSHOθ ($p = 0.017$).

DISCUSSION: Most of the senior gymnasts performed the drill in the training condition with less shoulder angle deviations from the 90° objective that in the competition condition. Differences between conditions were higher for left shoulder angles, which served to reduce asymmetry in the training condition. High similarities between training and competition conditions are required to achieve a replication of the biomechanics of the target skill during training drills (Irwin & Kerwin, 2005; Irwin & Kerwin, 2007; Irwin et al., 2013). Gymnasts shoulder angles were larger for right (RMSD 3.20°) and left (RMSD 3.27°) sides when performing the cross on training rings. Considering the gymnastics regulations, it is desirable to employ training devices that facilitate training performance with less deviation from 90° of shoulder abduction (Readhead, 1997).

Knowledge of shoulder asymmetry in the different conditions can facilitate the understanding and the development of this gymnastic skill (Exell, Irwin, Godden, & Kerwin, 2012), improving performance and developing more complex skill combinations safely and effectively (Readhead, 1997). During the static cross position, asymmetry directly influences performance, due to penalties for asymmetrical posture and the shoulder angle deviating from 90º (FIG, 2013). It is suggested that the use of the training device may be beneficial for improving performance of the cross on rings. However, further research could incorporate other instruments besides video analysis, such as force-instrumented rings, for a comprehensive understanding (Irwin et al., 2013) of the neuromuscular and kinetic demands (Irwin & Kerwin, 2007).

Table 1
Participant mean shoulder angle, symmetry values (%) and RMSD on cross for competition and training conditions

Gymnast	Condition	RSHOθ Mean±SD	LSHOθ Mean±SD	Asymmetry (%)
1	COMP	74.84±1.38	82.89±1.38	3.24
	TRAIN	77.33±1.71	85.29±1.71	3.12
	RMSD	2.49	2.42	-
2	COMP	86.82±2.27	82.08±6.97	1.79
	TRAIN	85.15±2.16	85.33±2.46	0.07
	RMSD	1.68	3.26	-
3	COMP	71.09±1.40	79.23±2.66	3.44
	TRAIN	71.76±3.13	79.19±3.03	3.13
	RMSD	0.67	0.04	-
4	COMP	77.25±2.19	71.94±2.13	2.26
	TRAIN	75.26±0.75	76.71±2.24	0.60
	RMSD	1.98	4.77	-
5	COMP	70.76±2.48	66.34±2.88	2.05
	TRAIN	79.47±3.47	72.97±2.32	2.71
	RMSD	8.71	6.63	-
6	COMP	87.48±1.61	85.57±2.61	0.72
	TRAIN	83.83±1.08	88.05±1.44	1.56
	RMSD	3.65	2.48	-
Group Mean	COMP	78.04±1.71	78.01±3.04	2.25
	TRAIN	78.80±2.41	81.26±2.30*	1.87
	RMSD	3.20	3.27	-

COMP=competition,TRAIN=training. * Statistically significant

Asymmetry was not found to be significantly different between the competition and training conditions. This finding supports the use of the training device as allowing gymnasts to train closer to the desired 90° shoulder abduction angle, without negatively influencing the important consideration of asymmetry.

CONCLUSION: Differences observed for intra limbs and symmetry within each gymnast should be considered as important information source of individual variation in this skill. Most gymnasts performed the cross in the training condition with less deviation from 90° than on competition rings. Based on the individual findings, it should be emphasised that coaches need to consider individual variations when applying results from group data.
The training device with forearm support allowed gymnasts to perform the drill of cross with the shoulders more abducted (closer to 90°), improving specificity between training and the target skill. Moreover, improved limb symmetry was presented with the training device. Future work could investigate coordination and musculoskeletal demand during the cross when performed on training and competition rings. In addition, it would be useful to consider the applicability of the findings of this study to other gymnastic groups, such as junior or novice gymnasts learning the skill.

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