KINEMATIC ANALYSIS OF CROSS ON TRAINING AND COMPETITION RINGS: COMPARISON BETWEEN ELITE AND INTERNATIONAL LEVEL GYMNASTS

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Abstract

Auxiliary devices are used to train gymnastics skills. Based on the principles of training specificity, this study aimed to investigate the effectiveness of a training device for the static cross posture on Men's Artistic Gymnastics rings through kinematic analysis. Twelve national team gymnasts were divided into two groups, based on their competitive results: the elite group (age: 21.8±3.2 years) and the international group (age: 19.3±3.3 years) performed the cross three times under both conditions: standard competition rings, and training rings with an auxiliary device. The videos were digitised and analysed with shoulder angles as trunk and arm segments. The variables included the right and the left shoulder angles in the frontal plane, as well as any asymmetry of those angles. Two-way ANOVA (conditions versus groups) and individual t-test statistics were conducted. Both groups performed the cross on training rings with increased abduction at both right ($p<0.001$) and left ($p<0.001$) shoulders and reduced asymmetry ($p=0.01$) than on competition rings. These kinematic improvements would translate into competition-typical score improvements of 0.1 to 0.3 points, and enhanced shoulder joint stability. Hence, the training rings with an auxiliary device effectively replicate skill-specific joint angles, adhering to the kinematics principles of training specificity for the static cross posture on rings, thus benefiting both elite and international-level gymnasts.

Keywords: *Gymnastics; Sport Coaches; Shoulder Angle; video analysis; Symmetry Analysis; Strength Exercise.*

INTRODUCTION

The cross is a key posture on rings in men's artistic gymnastics (MAG). It requires maintaining 90° shoulder abduction with straight elbows for two seconds (FIG, 2018). In competition, penalties (0.1, 0.3 or 0.5 points) apply, depending on how much the angle deviates (up to 15°, 30°, 45° or more) from 90° at the shoulder joints (FIG, 2018). Currently, even minor deviations of 0.1 points can impact

medal contention for international gymnasts. The unstable nature of the rings, comprised of 3-meter cables, adds to the skill's difficulty (FIG, 2018).

To help beginners and developing gymnasts master the cross, coaches often use a drill with belts attached to the rings. These belts support the forearms, reducing the effective mass and torque the gymnasts' shoulders need to handle (Bernasconi et al., 2004; Readhead, 1997).

Studies comparing the competition skill and training drill for cross posture on rings have focused on muscle activity patterns through EMG measurements (Bernasconi et al., 2004; Bernasconi et al., 2006), indicating similar overall muscle activation. However, measuring shoulder angles would provide additional clarity on the drill's effectiveness by revealing whether it helps maintain the required 90° shoulder abduction posture throughout the skill.

The effectiveness of training methods hinges on biomechanical similarity to the target sport, encompassing joint motions and muscle actions across relevant planes (Bompa & Buzzichelli, 2015). Thus, athletes require increasingly specific exercises and training methods to maximize competitive preparedness (Zatsiorsky et al., 2020).

Therefore, it is unclear whether the training device improves the gymnast's proficiency at the cross, particularly in reducing angular deviation from the required 90° shoulder abduction, remains unclear, especially across different competitive levels. For training specificity to be effective, drills need to closely resemble the target skills in terms of joint motions, muscle actions, and movement planes. While upper body strength training progressions are crucial for maximizing technique (Holvoet, 2011), coaches also rely on the principle of training specificity to promote performance-related adaptations (Irwin & Kerwin, 2005). Despite its prevalence in gyms due to its ease of assembly and perceived competition specificity, further research is needed to determine if this drill truly adheres to these principles and provides sufficient overload for skill improvement (Bompa & Buzzichelli, 2015; Zatsiorsky et al., 2020).

The cross posture on rings demands 90° shoulder stability in the frontal plane, but this can paradoxically induce instability due to glenohumeral joint extension (Graichen et al., 2005; Ludewig et al., 2009). Therefore, appropriate physical preparation, especially in shoulder abduction positions, is crucial before practicing this complex skill. Unbalanced shoulder joint strengthening in the cross posture can exacerbate instability and potentially displace the glenohumeral joint (Labriola et al., 2005).

Information about gymnast's limb asymmetry can guide coaches by improving posture stability on rings (Irwin et al., 2013). Kinematic asymmetry in ring skills leads to cables instability and score penalties (FIG, 2018). Minimising kinematic asymmetry is vital for both successful performance and injury prevention, making it a valuable concept for coaches, clinicians and technology perspectives (Exell et al., 2016). Analysing asymmetry scores in the cross posture would be particularly useful for coaches to assess technical correctness and performance levels.

This study investigates whether the training device is a specific drill for the cross posture and whether it improves performance. It also examines the effectiveness of the training device across

different competitive levels. By understanding its effectiveness, coaches can better determine its value for training and developing the cross. Our specific objective is to analyze the left and right frontal plane shoulder angles and asymmetry of gymnasts performing the cross on both training and competition rings. The null hypotheses predict no performance differences due to either a) gymnasts' competitive levels or b) rings type.

METHODS

Twelve Brazilian national team gymnasts were divided into two groups based on their individual rings scores: six elite gymnasts (including one Olympic champion on rings, one top-ranked on rings, three Olympic National Team, and one junior national team member) and six international gymnasts (including senior and junior national teams, participants of World Championships and Word Cup series). The elite gymnasts' group had a mean age of 21.8 ± 3.2 years, height of 1.67 ± 0.06 meters, weight of 63.2 ± 7.7 kg, and 14.2 ± 4.0 years of practice. The international gymnasts' group had a mean age of 19.3 ± 3.3 years, height 1.65 ± 0.04 meters, weight of 64.7 ± 7.2 kg, and 12.5 ± 2.8 years of practice. Ethical approval was obtained from the University of São Paulo Ethics Committee prior to this study (CAAE: 32724014.2.0000.5390).

The gymnasts performed three trials of the MAG cross posture (shown in Figure 1) on both training and competition rings, in a random order, separated by a two-minute rest period per attempt (De Luca, 1997). The training device was placed on the forearm 0.15 m from rings. A platform near the rings allowed them to mount the apparatus independently. Starting from the support position, gymnasts lowered into the cross posture, holding their upper limbs abducted at approximately 90 degrees in the frontal plane for two seconds. A voice alert then signaled them to stop the cross, which was validated by a brevet international judge (FIG, 2018). Trials were recorded using a digital camera operating at 50 Hz with HD resolution, positioned five meters from gymnasts' frontal plane at rings height. The camera view captured the gymnast's entire body and the rings apparatus. Spherical reflective markers (radius 20 mm) were attached to specific locations on the gymnast (Rab et al., 2002) and on the rings frame to improve video calibration accuracy (Figure 2). Data collection occurred in the gymnasts' training gym, with the apparatuses they regularly practice with.

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Figure 1A. Competition rings.

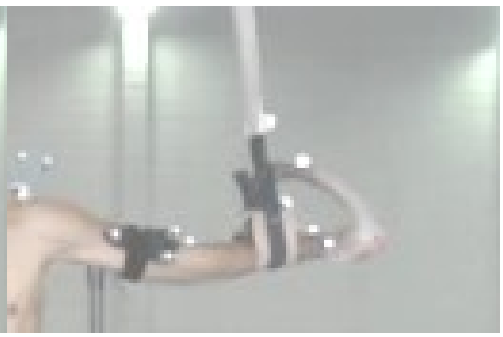

Figure 1B. Training rings.

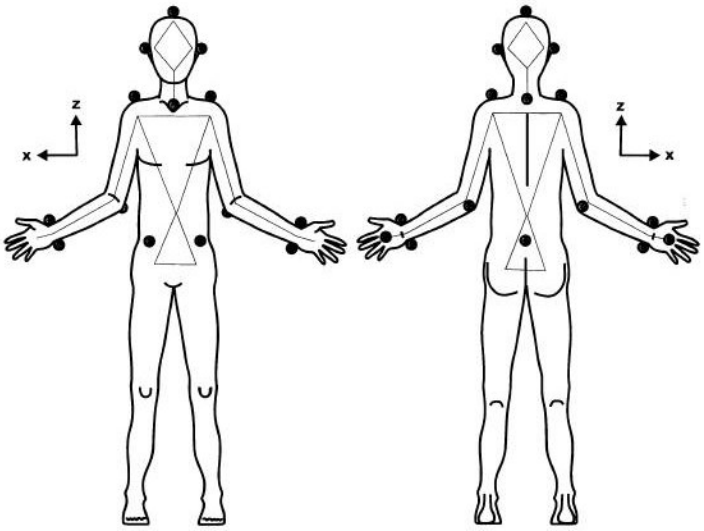

Figure 2. Upper extremity landmarks (Rab et al., 2002).

A single operator digitized all video trials, ensuring consistency. Data were filtered using a low-pass Butterworth filter with a cut-off frequency of 5.3 Hz, as determined optimal through residual analysis (Winter, 2009). Kinematic data were reconstructed using DLT via Matlab with specific routines (Hedrick, 2008). The data were then imported into Visual 3D software (version 5; C-Motion, Rockville, MD, USA). An upper limb model, based on the work of Rab et al. (2002), was applied to the data points. In this model, each segment is defined by a proximal and distal point located at a joint center, along with a third non-collinear point for determining rotational orientation. Shoulder angles were calculated as the angles between the trunk and humerus segments.

Each cross skill attempt was divided into three distinct sections: support, lowering, and static position. This segmentation was achieved through a combined approach of validated computer algorithms and expert visual inspection of the trials, ensuring accuracy.

Data from all trials were time-normalized to account for potential variations in timing and then averaged to obtain representative values for each gymnast. Root Mean Square Difference (RMSD) values were calculated within each data sample across the three trials, and then averaged. Mean group RMSD and Asymmetry values were calculated based on the individual data from the six gymnasts within each group, rather than using shoulder group mean values.

To assess individual-level differences between left and right shoulder angles, asymmetry analysis was conducted using the asymmetry angle (Zifchock et al., 2008):

$$\theta_{SYM} = ((45° - \arctan(Xleft / Xright)))/90 \text{ x } 100\% \quad [1]$$

Where θ_{SYM} 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. To facilitate direct comparison of asymmetry magnitudes

between conditions (training rings vs. competition rings), the asymmetry values were rectified.

Statistical tests were processed using SPSS software version 22.0 (IBM, Armonk, NY, USA). The normality assumption for the data set was verified using the Shapiro–Wilk test. A two-way ANOVA was applied to assess the impact of ring type (competition or training) and group level (elite or international) on discrete variables results (Right and Left shoulder angles and asymmetry). Additionally, a One-way ANOVA was utilized to identify differences within each factor level (effect of rings; effect of group) across discrete variables. Post hoc analysis of achieved power was calculated for the right (0.966), left (0.99) and asymmetry (0.99) using G*Power Version 3.1, (University of Dusseldorf, Germany). Effect sizes were calculated for ANOVAs, measured via partial $\eta^{2,}$ were interpreted as trivial (<0.01); small (0.01–0.06); medium (0.06–0.14), and large (>0.14)(Cohen, 1992).

Results of all trials were averaged, and subsequently, RMSD and Asymmetry values were calculated for each gymnast and condition. Means (M) and standard deviations (SD) were computed for RSHOθ, LSHOθ, RMSD and Asymmetry in each condition (training versus competition). The intraclass correlation coefficient (ICC) was calculated for both conditions, and the typical error of measurement was expressed as coefficients of variation (CV%). Average variability, derived from both measures (ICC and CV), was considered small for an ICC > 0.67 and CV < 10% (Bradshaw et al., 2007). The significance level was set at $p < 0.05$. Mean group RMSD and Asymmetry values were calculated based on the values of the six gymnasts, rather than the group mean values.

RESULTS

The time series for right and left shoulder angles kinematics during three attempts are illustrated in Figure 3 and Figure 4. Right and left shoulder angles, RMSD and Asymmetry values from individuals and group means are shown in Table 1. The values of the ICC calculated from repeated measures were 0.95 for RSHO competition, 0.84 for RSHO training, 0.89 for LSHO competition and 0.84 LSHO training, while CV was lower than 10% for all measures, indicating small variability.

The type of rings affected the right ($F_{18.961}$=424 $p<0.001$, η^2=0.22, power 0.99) and the left ($F_{26.063}$=979 $p<0.001$, η^2=0.28, power 0.99) shoulder angles, as well as asymmetry ($F_{6.870}$=19.0 p=0.01, η^2=0.10, power 0.73). The group level influenced the right ($F_{68.781}$=1541 $p<0.001$, η^2=0.50, power 0.97) and the left ($F_{8.044}$=302 p=0.006, η^2=0.11, power 0.80) shoulder angles, but not asymmetry.

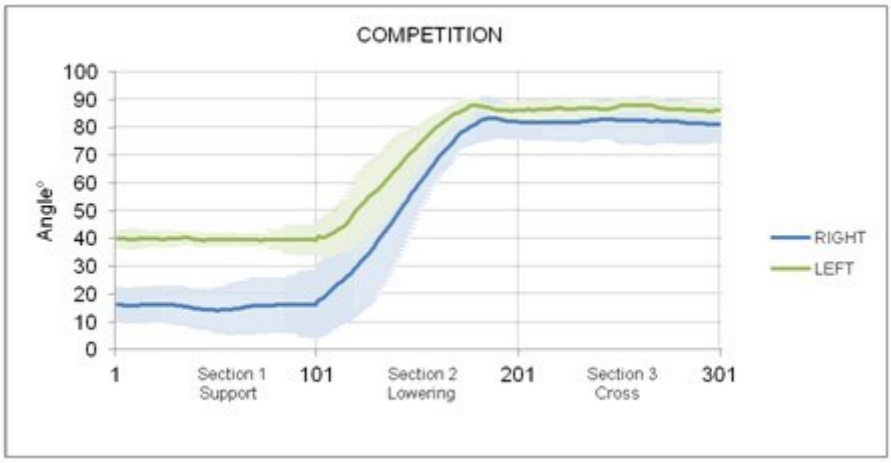

Figure 3A. Elite gymnast's shoulder angles profiles of three attempts (M ± SD), for support to the cross performed on competition rings. Gymnast 2.

Figure 3B. Elite gymnast's shoulder angles profiles of three attempts (M ± SD), for support to the cross performed on training rings. Gymnast 2.

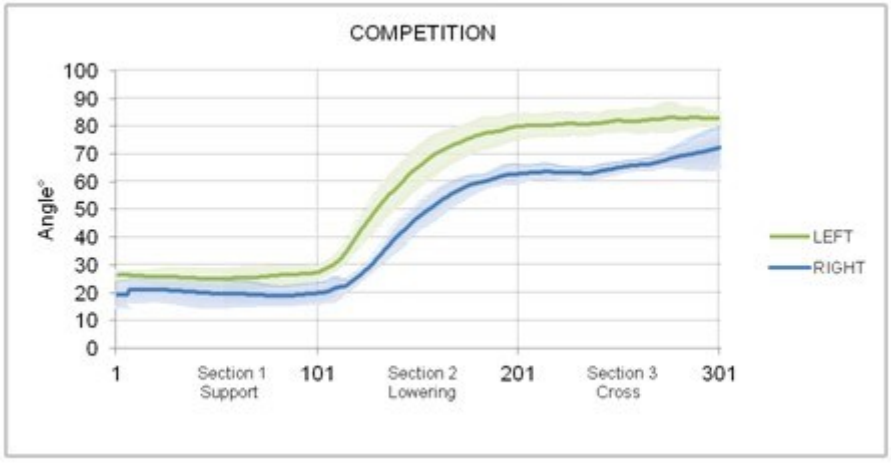

Figure 4A. International gymnast's shoulder angles profiles of three attempts (M ± SD), for support to the cross performed on competition rings. Gymnast 12.

Figure 4B. International gymnast's shoulder angles profiles of three attempts (M ± SD), for support to the cross performed on training rings. Gymnast 12.

Shoulder angles were higher (closer to 90º) with the training rings. The training rings influenced elite group right ($F_{7.290}$=109 p=0.01, η^2=0.18), and left shoulder angle ($F_{12.180}$= 411 p=0.001, η^2=0.26); and international group right ($F_{11.719}$=349 p=0.002, η^2=0.26) and left ($F_{13.892}$= 575 p<0.001, η^2=0.30) shoulder angles. Asymmetry values were lower (closer to zero) for training rings. The asymmetry values were affected by the ring type only for the elite group ($F_{4.779}$=17.3 p=0.03, η^2=0.12).

Shoulder angles were higher (closer to 90º) for the elite group. One way ANOVA was applied to check the effect of the group level (elite or international) over shoulder angles during the cross. The elite group influenced competition rings right ($F_{31.768}$=1015 p<0.001, η^2=0.48, power 0.95) but not left ($F_{3.967}$=200 p=0.054, η^2=0.10) shoulder angles; while training rings affected the right ($F_{43.540}$=559 p<0.001, η^2=0.56) and left ($F_{4.413}$=108 p=0.04, η^2=0.12) shoulder angles. Asymmetry values were lower (closer to zero) for the elite group. One way ANOVA was applied to check the effect of the group level (elite or international) over the asymmetry values. The asymmetry values for competition and training rings were not affected by the group level.

RMSD between groups on the competition rings were 10.62° for the right and 4.71° for the left shoulder; and on the training rings were 7.88° for the right and 3.48° for the left shoulder. Furthermore, there is a statistically significant interaction between the side and the ring type ($F_{4.985}$=94.2 p=0.02, η^2=0.07).

Table 1

Gymnasts' shoulder angles, RMSD and asymmetry values (θ_{SYM}) on cross for competition (C) and training (T) conditions.

		Elite						International				
Rings	Gymnast	RSHOθ (°)	CV (%)	LSHOθ (°)	CV (%)	θ_{SYM}	Gymnast	RSHOθ (°)	CV (%)	LSHOθ (°)	CV (%)	θ_{SYM}
C		84.89±0.58	2	80.10±0.275	1	1.85		71.10±1.25	2	79.23±2.66	3	3.43
T	1	87.35±1.77	2	85.78±2.31	3	0.82	7	71.75±2.89	4	79.19±2.95	4	3.12
RMSD		2.46		5.68		-		0.65		0.04		-
C		86.82±1.88	3	82.08±6.83	8	2.55		77.35±2.31	5	76.94±4.19	10	1.76
T	2	85.16±2.15	3	85.33±2.27	3	0.86	8	79.69±3.93	5	85.94±2.68	9	2.42
RMSD		1.66		3.25		-		2.34		9.00		-
C		74.71±2.42	3	73.64±1.46	2	0.48		76.60±2.78	4	71.63±5.70	8	2.18
T	3	84.77±1.82**	4	82.67±1.22**	2	0.80	9	75.78±5.81	8	74.38±1.47	2	2.11
RMSD		10.06		9.03		-		0.82		2.75		-
C		77.28±2.19	3	71.95±2.13	3	2.27		68.29±6.04	9	64.04±3.18	5	1.99
T	4	85.28±0.75*	1	86.72±2.24*	3	0.81	10	75.95±0.88	1	75.56±2.14*	3	0.81
RMSD		8.00		14.77		-		7.66		11.52		-
C		85.32±3.04	2	67.73±3.34	4	7.28		61.33±2.77	5	62.74±4.59	8	2.75
T	5	84.02±3.02	1	74.66±2.23*	1	3.75*	11	79.36±4.86*	6	80.85±7.19*	9	0.95
RMSD		1.30		6.93		-		18.03		18.11		-
C		80.36±3.70	5	84.07±1.24	1	1.45		70.97±3.01	4	76.69±3.82	5	2.46
T	6	83.73±2.50	3	84.96±1.28	2	0.54*	12	80.47±3.92*	5	83.34±2.54	3	1.13
RMSD		3.36		0.88		-		9.50		6.65		-
C		81.56±5.05	3	76.59±6.71	3	2.65		70.94±6.20	5	71.88±7.47	7	2.42
T	Group Mean	85.05±2.14**	2	83.35±4.73**	2	1.26*	Group Mean	77.17±4.59**	5	79.87±5.19**	5	1.76
RMSD		3.49		6.76		-		6.23		7.99		-

Note: RSHOθ: Right shoulder angle; LSHOθ: Left shoulder angle; CV: Coefficient of Variation (%). θ_{SYM}: Asymmetry index; Rectified values of θ_{SYM}. C: Competition; T: Training. RMSD: Root Mean Square Difference. Group CV mean values of all gymnasts. Group θ_{SYM} mean values of all gymnasts. * $p<0.05$; ** $p<0.01$; between conditions (competition versus training, three trials of each gymnast considered).

DISCUSSION

This research aimed to verify the use of a training device as a specific drill for the cross static posture on rings and whether it may improve technical performance. Additionally, the study aimed to determine the suitability of the training device for gymnasts of different competitive levels in improving their performance at the cross.

Considering all gymnasts, the type of ring influenced shoulder angles and asymmetry, providing insight into training rings as a drill for improving the posture of the cross. To achieve maximum training specificity, an exercise must imitate the angle of the skill performed (Bompa & Buzzichelli, 2015; Zatsiorsky et al., 2020). Moreover, training improved the position of the body posture closer to the ideal 90° of shoulder frontal plane abduction position of the cross. Considering all gymnasts' attempts, the group level influenced shoulder angles but not asymmetry, indicating that group differences are more related to strength levels than the posture of the cross.

Both gymnast groups performed the drill on the training rings with fewer shoulder angle deviations from the 90° objective. High similarities between gymnastics skills over training and competition conditions are required to replicate the biomechanics of the target skill during the drill (Irwin et al., 2013; Irwin & Kerwin, 2005; Irwin & Kerwin, 2007). Improving the execution of the cross deviations on shoulder angle from 90° (up to 15°, 30°, 45°, or more without recognizing the skill value) consequently will lower score penalties (0.1, 0.3, or 0.5 points) (FIG, 2018).

Gymnasts shoulder angles RMSD from competition to training rings device were larger within international gymnasts (6.23° right and 7.99° left) than within elite (3.49° right and 6.76° left), as the international group is farther to 90° ideal posture. Thus, the null hypothesis was rejected, as (a) the elite group performed the cross posture with less shoulder deviation than the international level group in both types of rings; and (b) both groups had a better performance using the training rings.

Analyzing CV, the gymnasts of both group levels in this study have showed reduced variability for shoulder angle, as expected for elite gymnasts, who presented low variability in the mechanically important aspects of gymnastics performance (Hiley et al., 2013). This constancy was also observed in former Olympic champion in the execution of the cross on rings, which is characteristic of high-level gymnasts (Carrara et al., 2016).

Considering MAG regulations, it is desirable to employ training devices that approach the drill execution to the accomplishment of the rules requirements (Readhead, 1997), as that facilitates training performance with less deviation from 90° of shoulder abduction. Research on gymnastic skills has suggested specific kinematic modifications to progressions in a trial to make them more similar to the target skill (Irwin & Kerwin, 2005). The training device improved the gymnast’s proficiency at the cross, decreasing the angular deviation from the required position. It could thus be useful for technical preparation, which includes maintenance and improvement of the elements already acquired (Goto et al., 2022).

Group differences resting on maturational stage (2.5 years old) and training experience (1.67 years of practice) could justify the observed shoulder angles RMSD, as the cross depends on strength and posture coordination capacities to

accomplish the static posture (Arkaev & Suchilin, 2004). However, there are seniors and juniors gymnasts in both groups. According to the skill development table provided by the FIG (Fink & Hofmann, 2015), gymnasts around 16-17 years old should already perform the cross at a competent stage in their development, without other connected skills. The older international participants in the present study performed the cross in similar conditions. Gymnastics' skills analysis over a wider age range (14 to 20 years old) showed similar coordination for the longswing skill (Busquets et al., 2013). Although differences between groups in the present research might be dependent on the gymnast's level, age or time of practice.

The asymmetry shoulder angle values were lower when using the training device than on competition rings. This finding supports the use of the training device, allowing gymnasts to train closer to the desired 90° shoulder angle and positively influencing the important aspect of asymmetry. For the elite gymnasts, shoulder asymmetry was significantly ($P<0.001$) larger on competition rings (θ_{SYM} 2.65) than on training (θ_{SYM} 1.26) rings, indicating an improvement in performing the drill posture. This suggests enhanced balance and stability distributed over shoulders on unstable support of rings.

While shoulder asymmetry did not show a significant difference between the competition and training device conditions for the international group, there was an improvement observed on the training rings. This improvement in shoulder angles and RMSD moved from a 0.3 points penalty (deviations of over 15º from 90º) to a 0.1 points penalty (deviations of less than 15º from 90º), as per FIG regulations (FIG, 2018). The close proximity of asymmetry values between group levels suggests that the training rings serve as a specific drill that prompts international gymnasts to perform angles similar to those of elite gymnasts. This contributes to the development of gymnasts, enabling them to enhance the skill. Additionally, the isometric exercises on the training rings may lead to strength gains at the trained angle, as isometric strength training at longer muscle lengths is known to result in greater muscle hypertrophy and strength increments due to length-specific adaptations (Lum & Barbosa, 2019).

The deficiency in strength is closely linked to exercise execution and errors in meeting the requirements, such as maintaining a shoulder angle of 90°, for executing the cross (Smolevskiy & Gaverdovskiy, 1996; Zatsiorsky et al., 2020). As per the principle of specificity, when transitioning to specific strength, body positions and limb angles should resemble those required for the specific skills (Bompa & Buzzichelli, 2015). The transfer of angles to competitive rings relies on the improvement of specific strength coordination patterns in isometric conditions (Zatsiorsky et al., 2020).

Understanding shoulder asymmetries in different conditions can enhance the comprehension and development of gymnastic skills (Exell et al., 2016), ultimately improving gymnasts' performance and facilitating the safe and effective development of more complex skill combinations (Readhead, 1997). The use of training devices is suggested to be beneficial for enhancing the performance of key skills in Men's Artistic Gymnastics (MAG) (Irwin & Kerwin, 2007). The cross, being a key skill, can be incorporated into routines along with 34 other strength/swing skills, as

outlined in the current MAG code of points (FIG, 2018).

Asymmetries in strength skills on rings directly impact performance scores, with penalties of 0.1 points for holding static positions with swinging rings cables (FIG, 2018). The unstable nature of the apparatus construction can lead to unbalanced forces when there is asymmetry in the posture, causing rings to swing (Brewin et al., 2000). Therefore, the use of the training device is suggested to enhance the score performance of the cross on rings, especially for high-level gymnasts.

The training device enables gymnasts to train closer to the desired 90° target shoulder abduction angle, thereby improving posture stability as the postural position becomes better balanced within the rings' cables. Asymmetry values in the present study were small, with the largest value being 7.28%. In comparison, other kinematic studies involving non-static skills, such as gymnasts performing handsprings in floor exercises (ranging from 4% to 25%) (Exell et al., 2016) and in sprinting (6.68%) (Exell et al., 2012) using the same θSYM method. The description and analysis of the left and right shoulder angles during the cross performance on training and competition rings provide novel insights into understanding gymnastics skills, especially for coaching this specific gymnastic skill. While it may subjectively appear symmetrical (Exell et al., 2016), the findings reveal significant asymmetry improvement with training rings. Understanding these asymmetries can contribute to the development of insights into the mechanisms of this gymnastic skill, thereby informing strength and conditioning regimes (Arkaev & Suchilin, 2004; Smolevskiy & Gaverdovskiy, 1996).

This research faced logistical constraints related to the availability of expensive cameras at gymnast training locations. However, the training facilities and apparatuses employed advanced the ecological validity of the study compared to previous research on rings. One limitation is the potential influence of the rings' movement on shoulder angles, even in a static posture, as the rings were assembled as a pendulum, and gymnasts performed the cross independently.

This is particularly relevant for rings apparatus, considering that 3D sensing technology is still under development in collaboration with the FIG (Fujiwara & Ito, 2018). Future developments in this technology aim to establish digital judging rules, involving the creation of a database for joint position recognition software (Fujiwara & Ito, 2018). Concerns about the accuracy of the system have been raised by gymnastics stakeholders (Allen et al., 2021). As a result, efforts are underway to create scoring rules for all elements, incorporating joint angles measured and applicable penalties (Fujiwara & Ito, 2018). Additionally, asymmetry values may contribute to the need for data input into database models or the development of new rules for evaluating gymnasts, aiming to prevent shoulder overloads.

Future research endeavors could expand beyond video analysis to incorporate additional instruments, such as force-instrumented rings and electromyography (EMG), to achieve a more comprehensive understanding of the neuromuscular and kinetic demands associated with gymnastics skills (Irwin et al., 2013; Irwin & Kerwin, 2007). Subsequent investigations should focus on elucidating the similarities in coordination and musculoskeletal demands between the training drill and the targeted

skills. While existing biomechanical research has primarily concentrated on the mechanical loads on the shoulders in gymnastics (Brewin et al., 2000; Irwin & Kerwin, 2005; Irwin & Kerwin, 2007; Serafin et al., 2008), studies specifically on rings are not as extensive as those on other apparatuses (Prassas et al., 2006). Future studies could explore the generalizability of the findings from this study to different group levels, including gymnasts in the developmental stages of acquiring the skill.

CONCLUSIONS

The use of training rings with forearm support appears to provide benefits for both elite and international gymnasts in performing the cross posture with shoulders more abducted (closer to 90°) and reducing asymmetry between limbs. This suggests that the drill aims to meet the specific requirements of gymnastics. Following the principle of training specificity, it is reasonable to infer that the cross drill is effective in developing the ideal shoulder angle posture of 90°. The drill is expected to facilitate the transfer of training to gymnastics performance, allowing improvement in the execution of the cross and other complex skills that involve strength or swing movements through the cross posture position.

The use of the training device could enhance the performance of the cross on rings. However, to ensure the similarity between the types of rings investigated, replication of biomechanics should encompass kinematics, kinetics, and neuromuscular activity.

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