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ACCURACY OF REPLICATING STATIC TORQUE AND ITS EFFECT ON SHOOTING ACCURACY IN YOUNG BASKETBALL PLAYERS

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ABSTRACT
Purpose. Accurate shooting in basketball is a prerequisite for success. Coordination ability, one of the abilities that determine the repeatability of accurate shooting, is based on kinesthetic differentiation. The aim of the study was to evaluate the strength component of kinesthetic differentiation ability and determine its relationship with shooting accuracy. **Methods.** Peak muscle torque of the elbow extensors under static conditions was measured in 12 young basketball players. Participants then reproduced the same movement at a perceived magnitude of 25%, 50%, and 75% of static peak torque, with error scores calculated as a measure of kinesthetic differentiation. The results were compared with players' field goal percentages calculated during game play in a regional championship. **Results.** No statistically significant relationships were found between the level of kinesthetic differentiation ability and field goal percentage. Additionally, no upper limb asymmetry was found in the sample. **Conclusions.** The relatively high levels of elbow static peak torque suggest the importance of upper limb strength in contemporary basketball. The lack of a statistically significant difference between the right and left limbs decreases the risk of suffering injury. It is likely that choosing other suitable tests would demonstrate the relationships between field goal percentage and kinesthetic differentiation ability.

Key words: kinesthetic differentiation, proprioception, upper limb asymmetry

Introduction

Shooting is the most important skill in basketball as it directly tied with scoring points. In contemporary basketball, the jump shot is the most commonly performed, with training designed to automate its movement so that, regardless of external factors, maximum repeatability and accuracy can be attained [1]. The high level of specialization of the jump shot requires players to maximize jumping (speed–strength) and coordination abilities [2]. Although the shooting technique used by basketball players may appear to be similar, significant differences, not the least those as a result of different upper body proportions, give rise to individual shooting styles [1]. However, regardless of shooting technique (itself dependent on external factors such as in-game shot situations), the defining criterium of any type of shot is the attained accuracy rate. As only accurate shots are significant in basketball, improving those abilities connected with shot accuracy and repeatability appear to be of critical importance.

Every sport contains a number of specific technical elements an athlete has to master, where performance level determines, either directly or indirectly, competitive success. One indicator of neuromuscular efficiency is the level of motor coordination ability. Despite the importance of this factor in sporting success, there is nonetheless a paucity of research on coordination ability in the literature. This may possibly stem from the lack of standardized measurement methodologies [3], although numerous studies have investigated the level of other motor abilities such as speed, strength, and endurance in team sports [4, 5]. This is surprising as without an adequate level of coordination ability, many athletes would be unable to maximize their full athletic potential. For instance, a sprinter with a higher running speed may lose to other runners due to a longer start reaction time coupled with poor technique when taking off from the starting blocks [3].

In the game of basketball, almost every shot taken is performed from a different place and in different conditions. As a result, one of the most common manifestations of coordination ability in shot-taking is through kinesthetic differentiation [3, 6]. Kinesthetic differentiation ability is based on the sensation or perception of the strength (muscle tension), temporal (movement speed) and spatial (position of body segments with respect to one another) components a particular motor task or activity. It is connected with movement accuracy and precision (and therefore economy), as improved kinesthetic differentiation ability allows for optimum performance in a variety of conditions [6].

Measurement of static torque is frequently used to evaluate athletic progress and skill level among athletes. However, despite the high test–retest reliability of this method, it has seen little use in the evaluation of the strength component of kinesthetic differentiation ability. Generally, athletes from different sports are characterized by different static torque profiles [7], although within-subject differences are also found in a given sport. In basketball, differences in the distribution of static torque meas-

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ures were found to depend on age, experience, and playing position [8]. A similar relationship between the above variables was observed in the measurement of torque in isokinetic conditions [9].

Similar to other motor abilities, kinesthetic differentiation is subject to exercise-induced fatigue. Zatoń et al. [10] tested replicating force in a flexion and extension movement at the elbow joint in a group of cyclists. Using a 'kinethesiometer' built with two force plates, this group of researchers showed a decrease in the ability to reproduce movement by both upper limbs after an exercise test, which signified reduced kinesthetic differentiation ability. Another study measured kinesthetic differentiation ability in lower limb extensors in a group of monofin swimmers [11] using a device similar to the above-mentioned 'kinethesiometer'. The subjects were asked to use the same force in repeating a movement 'by feel' twelve times. These authors found that the best scores obtained during the measurement resulted from individual adaptations to those movements performed in-water. They concluded that technical training should be supplemented with individual drills aimed to improve kinesthetic differentiation ability. Bańkosz [12] used a goniometer to evaluate the accuracy of performing pronation and supination movement with the forearm at the elbow joint in a group of table tennis players. The subjects were asked to replicate this movement but at different angles as a way to measure the spatial component of kinesthetic differentiation ability. The author found more accurate and precise scores in individuals with more table-tennis experience. Bajdziński and Starosta [3] used a dynamometer to examine the accuracy in replicating force (the strength component of kinesthetic differentiation ability) with the upper limbs. After recording the peak force of an elbow-joint flexion, the participants performed a flexion at 50% of their perceived peak force. Their analysis of the error scores (number of deviations from the actual 50% value) indicated no relationship between this component of differentiation ability and age.

Bilateral asymmetry is often observed in athletes due to the specificity of the practiced sport and natural use of one's stronger side of the body (laterality). This naturally involves loading one side of the body [13], although the amount of asymmetry differs depending on age and skill level [14]. Increased lower limb strength asymmetry is discussed extensively in the literature as it is a common occurrence in team sports due to asymmetric movement structures. However, this phenomenon is regarded as unfavorable as it has been associated with an increased risk of injury [15], whereas movement symmetry has been found to improve athlete versatility, increase movement quality, and stimulate proper body growth [13, 14]. Upper limb symmetry is especially important in basketball, as it allows players to take shots with either the right or left hand as well as maintain fluid ball control when dribble and passing.

In basketball, kinesthetic differentiation ability manifests itself in the ability to accurately shoot a ball from different distances and different positions. The aim of the study was therefore to evaluate the above-mentioned strength component of kinesthetic differentiation ability and determine its relationship with shooting accuracy. With this in mind, the study was formed to answer whether a higher level of this ability would be related with a higher in-game field goal percentage? Such a relationship would be helpful in determining which athletes would be most effective in taking shots during play. Additionally, a very useful trait in basketball would be upper limb symmetry, as it would allow for better performance with right- or left-handed shots and with dribbling and passing. Therefore, would a group of competitive basketball players be characterized by this property?

Material and methods

The study was carried out on 12 right-handed basketball players belonging to a local junior basketball team from the city of Wrocław, Poland. Each participant had several years training experience and had played at least five games in a 2012/2013 regional championship. Basic characteristics of the study group are presented in Table 1. The study was conducted at the Biomechanical Analysis Laboratory (ISO: 9001:2009 accredited) of the University School of Physical Education in Wrocław, Poland after receiving approval by the university's research bioethics committee. The participants were familiarized with the purpose and procedures of the study and provided their or their parents' written informed consent if underage.

Kinesthetic differentiation ability was evaluated by the accuracy of replicating particular values of static torque by the elbow extensors. Muscle torque was measured under static conditions using a UPR-01 B exercise armchair (OPIW, Poland) pictured in Figure 1. A torquemeter was used to allow for the direct measurement of static torque without needing to measure the length of the lever arm to which force is applied. This direct measurement of torque rather than force allows for a more accurate recording of the amount of work performed by an individual body segment when performing a rotational movement.

Testing began by fastening the participant in the armchair of the machine (hips pressed against the chair back) with a belt around the thoracic region to prevent the involvement of adjacent muscle groups. This allowed for a more accurate measure of elbow flexor torque. Motiva-

Table 1. Characteristics of the study group (mean ± *SD*)

n	Body height (cm)	Body mass (kg)	Age (years)	Training experience (years)
12	190.6 ± 9.1	83.1 ± 10.7	16.8 ± 0.9	7.3 ± 1.9

Figure 1. Test stand for measurement of manifestations of strength components of kinesthetic differentiation ability

tion and guidance was provided throughout the test. Measures were taken separately for each limb at an angle of 75° at the elbow joint and 90° at the shoulder joint, where 0° at the elbow joint was considered to be a full extension and, for the shoulder joint, when the arm was located alongside the trunk. These angular values were selected to obtain maximum static torque values for these muscle groups [16]. Furthermore, this angle at the elbow joint approximately corresponded to the initial angle of this joint when taking a shot in basketball [17].

Immediately after the peak static torque values were recorded (best value out of three trials) for the right and left elbow extensors (M_{max}), the participant was asked to reproduce the movement but this time at what they perceived to be 25%, 50%, and 75% of their peak static torque. The participant was allowed to practice with visual feedback for each of the percentages of peak torque for 60, 30 and 15 seconds, respectively. Duration times were decreased with an increase in the percentage value in order to normalize the total load. During the actual measurement, the subject was not informed of the results. The accuracy in replicating each percentage of peak torque was based on the mean value of three trials for each percentage value (D_x), with an error score calculated both as a percentage (1) and as total error (2):

$$(1)\ D_x = \frac{\sum_{i=1}^{3} | 0{,}x \cdot M_{max} - M_{(x-i)} |}{3 \cdot 0{,}x \cdot M_{max}} \cdot 100, \quad x \in <25,50,75>,$$

$$(2)\ D_x = \frac{\sum_{i=1}^{3} | 0{,}x \cdot M_{max} - M_{(x-i)} |}{3}, \quad x \in <25,50,75>.$$

The symbol $M_{(x-i)}$ denotes successive measurements of static torque for a particular percentage x. Based on the above formulas, a score of 0 would denote the most accurate replication of a percentage of static peak torque, while a higher value would denote lower accuracy.

In order to compare the above results with players' shooting accuracy, the games the participants played in during the 2012/2013 junior championships were analyzed (these games were played before the present study) to calculate field goal percentage.

Statistical analysis included Student's t test for dependent samples to evaluate differences between the variables of the right and left upper limb. Pearson's correlation coefficient (r) was employed to measure the relationships between the individual variables. The level of significance was set at $\alpha = 0.05$. The results were first analyzed by group means and then individually for each participant.

Results

Table 2 presents the mean peak static torque generated by the right and left elbow extensors and how accurate the participants were in replicating a percentage (25%, 50%, and 75%) of static peak torque, calculated as a relative (percentage) and total error. No statistically significant differences were found between the right and left upper limbs neither for static peak torque nor in the accuracy of replicating the three percentage target values as calculated by the two methods. No statistically significant correlations were observed between the accuracy of replicating static torque for any of the percentages of static peak torque either as a percentage or total error and the field goal percentage calculated for the players (group mean field goal percentage: 42.2%) during their

Table 2. Means and standard deviations of peak static torque generated by the elbow extensors (M_{max}) of the right (R) and left (L) upper limbs and the accuracy in replicating 25% (D_{25}), 50% (D_{50}), and 75% (D_{75}) of the static peak torque expressed as a percentage and total error

Upper limb	M_{max} (N · m)	Percentage			Total errors		
		D_{25} (%)	D_{50} (%)	D_{75} (%)	D_{25} (N · m)	D_{50} (N · m)	D_{75} (N · m)
R	70.3 ± 16.5	33.5 ± 9.5	27 ± 15.8	11.0 ± 5.7	5.6 ± 1.7	8.8 ± 5.2	5.7 ± 2.6
L	63.2 ± 20.8	42.3 ± 29.5	36.7 ± 19.8	15.0 ± 9.4	6.9 ± 4.7	10.3 ± 5.0	6.7 ± 3.5

Table 3. Comparison of mean field goal percentage, accuracy of replicating static torque (mean from the three percentage values of D_{25}, D_{50} and D_{75}) expressed as a percentage ($D_{\%}$) and total error (D_{te}) for the right upper limb

Athlete No.	Field goal percentage		Percentage		Total errors	
	FG (%)	Ranking	$D_{\%}$ (%)*	Ranking	D_{te} (N · m)*	Ranking
1.	61.3	1	21.7	7	5.1	3
2.	54.5	2	24.1	9	6.1	7
3.	44.7	6	20.3	6	8.7	11
4.	40	8/9	43.9	12	13.6	12
5.	50	3	17.6	3	4.1	1
6.	43.3	7	30.7	10	8	10
7.	50	4	15.3	1	5.8	6
8.	36.8	10	20.1	5	5.3	4/5
9.	20	12	22.2	8	7.1	9
10.	33.8	11	35.1	11	6.4	8
11.	40	8/9	16	2	4.6	2
12.	46.4	5	18.6	4	5.3	4/5

* statistically significant correlation between variables ($p < 0.02$)

participation in a regional championship. Furthermore, analysis performed individually for each participant also did not demonstrate any relationships (the results for the right upper limb are presented in Table 3).

Discussion

When comparing the results of the present study with those in the literature, the basketball players obtained higher static peak torque for the elbow extensors than their peers also involved in basketball [8, 18]. However, similar mean static torques for the elbow joint were reported in a group of senior basketball players by Buśko [19]. The above comparisons suggest that the basketball players in the present study were characterized by a relatively high level of elbow extensor torque production. This result suggests the importance of upper limb strength in contemporary basketball.

Basketball players have been found to commonly exhibit significant muscle strength asymmetry and, as a result, are at risk of suffering various injuries [20]. This has been credited to the specificity of basketball technique (dribbling, shooting, one-handed passing, jump take-offs, pull-up jump shots) and the habitual use of the stronger side of the body [13]. In turn, the elevated risk of limb injuries due to asymmetry [15] has been found to advance body asymmetry even further [20, 21]. Besides basketball, substantial muscle torque asymmetry measured in isokinetic conditions was found in both the lower and upper limbs of volleyball players [22]. Additionally, unequal muscle growth has been even found to reduce the strength of those muscles responsible for movement at a particular joint on the weaker side of the body, also resulting in an increased risk of injury [23]. Therefore, the lack of statistically significant differences between the static torque values and kinesthetic differentiation ability of the right and left upper limbs should be regarded very positively and may arguably be the effect of properly selected coaching methods and training loads. Training oriented towards equally developing the body should be considered necessary so as to improve player efficiency in performing both offensive and defensive actions. However, when measuring the anthropometric characteristics of basketball players, no significant asymmetry was found by Tomkinson et al. [13]. Furthermore, Theoharopoulos and Tsitskaris [24] did not find any significant asymmetry for the ankle joint (plantar/dorsiflexion ratio, plantar/dorsiflexion peak torque, and range of motion) in basketball players.

Tests based on basketball shooting at different distances have often been mentioned as a measure of kinesthetic differentiation ability [6]. In the present study, no significant relationships were found between the in-game field goal percentage of the participants during a championship and the results evaluating the strength component of kinesthetic differentiation ability. This may be due to the numerous interacting factors present during a game, all of which may impair shooting accuracy (opponents, time pressure, fatigue, stress, etc.), although it can be argued that competitive basketball athletes are expected to successfully cope with such factors. It may be possible that the present experiment's focus on only the strength component is too restrictive in using kinesthetic differentiation ability as a predictor of shooting accuracy. The inclusion of additional tests measuring, for example, the temporal component of this ability may provide better relationships with shooting movement. The usefulness of this measure can be seen in a study by Tang and Shung [25], who found a significant and positive relationship between shooting accuracy and elbow extensor torque measured in isokinetic conditions.

Conclusions

1. The analyzed group of basketball players obtained relatively high elbow extensor static torque values, sug-

gesting the importance of upper limb strength in basketball.

2. No statistically significant differences were found between the right and left upper limbs neither for peak static torque nor in the accuracy of replicating 25%, 50%, and 75% of peak static torque.

3. No statistically significant relationships were found between the accuracy of replicating the static peak torque percentages and field goal percentage. In order to verify the above relationships, future research should include other suitable tests measuring kinesthetic differentiation ability as well as shooting accuracy.

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