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Isokinetic Strength of the Dominant and Non-dominant Elbow in Elite Male Volleyball Players

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Abstract

The purpose of this research is to compare the elbow isokinetic strength applied at different angular velocities on the dominant and non-dominant side in elite male volleyball players. Fifteen elite volleyball players participated in the research. Isokinetic elbow flexion and extension strength were separately obtained on concentric/concentric dominant and non-dominant side as 5 repetitions at $60^{\circ}.s^{-1}$ angular velocity, 10 repetitions at $180^{\circ}.s^{-1}$ and 15 repetitions at $300^{\circ}.s^{-1}$. In the research, the peak torque (PT), peak torque/body weight (PT/BW), flexion/extension ratio (B/T), angle of PT, work and power parameters were compared between the dominant and non-dominant elbows. No significant difference was found between the dominant and non-dominant side in the elbow isokinetic strength parameters of the subjects at three different velocities. A significant difference was found at three different velocities only in the angle of PT flexion ($p < 0.05$). It is thought that this difference may result from the muscle shortening that may occur on muscle length (longitudinal effect) as a result of the more concentric contraction of the muscle on the dominant side compared to the non-dominant muscle. Consequently, there is not any isokinetic strength difference between the dominant and non-dominant elbow in elite male volleyball players. Isokinetic elbow test can provide important information regarding the potential risk factors for elbow injuries. For this reason, it is recommended to include this test in the functional screening of volleyball players.

Keywords: isokinetic strength, volleyball, dominant, elbow, upper extremity

1. Introduction

Volleyball differs from other sports in terms of having very different, frequent and rapidly changing game situations (Öz, 2019). This game has been one of four popular international sports in males and females since the 1964 Olympic Games (Tilp, 2017).

In elite athletes, muscle strength and power are among the most important factors affecting success in a competition in addition to technical and tactical skills (Cardoso Marques, González-Badillo, & Kluka, 2006; Marques, van den Tillaar, Vescovi, & Gonzalez-Badillo, 2008). An elite spiker exhibits spike performance in a total of 16–20 hours of training per week and performs approximately 40000 spikes in a year (Kugler, Kruger-Franke, Reininger, Trouillier, & Rosemeyer, 1996). Volleyball players should gain strength to apply technical elements successfully and increase muscle endurance to maintain throughout a competition (Cardoso Marques et al., 2006). Häkkinen (1993) noted that the magnitude of both strength and explosive power training stimuli should be carefully observed during the competition season to protect explosive power. Cardoso Marques et al. (2006) suggested that although volleyball is not a sports branch consisting of mere strength, athletes should perform maximal strength training at least for 8 weeks during the preparation process for the long-term season due to the need for the strength parameters.

Maximal isokinetic strengths of athletes should be monitored during a season. Following these evaluations, it is very important to determine the strengths and weaknesses of athletes and to prevent sports injuries that may occur during the season. In addition, strength trainings can be planned individually in line with the findings obtained from maximal isokinetic data. However, elbow isokinetic strengths of elite male volleyball players are still not very clear.

In many sports branch, athletes perform strength training and volleyball is one of these sports (Marques et al., 2008). Spike is the most important technical component affecting the score in volleyball (Palao, Santos, & Ureña, 2004). During a spike, the velocity in the hand is presented with a kinetic chain through the participation of hip, body, elbow and hand (Cisar & Corbelli, 1989; Rokito, Jobe, Pink, Perry, & Brault, 1998). This is associated with elbow and shoulder joint extension velocity (Ferris, Signorile, & Caruso, 1995; Singh & Rathore, 2013). Vint and Hinrichs (2004) determined in a 3D analysis of US national team female players that the spike velocity realized with 44.9% elbow and 30.5% shoulder joint velocity. The explosive power and pronation occurring in the forearm are like a "whip". This position extends the spike arm (lever arm) and thus maximizes the potential velocity of the hand (Cisar & Corbelli, 1989). Forthomme, Croisier, Ciccarone, Crielaard, and Cloes (2005), proved that there was a significant relationship between the spike velocity and the strength of the internal rotators of the dominant shoulder and the strength of the flexors and extensors of the dominant elbow. Wagner et al. (2014) and Coleman, Benham and Northcott (1993) defined that high ball velocity is associated with maximal humeral velocity. The increase in the range of motion of the elbow joint is the main factor of the spike technique and varies between elite players and beginners. A coordinated muscle activity increases moment (Tilp, 2017).

Isokinetic tests are used to determine torque values in different ranges of motion at a constant velocity (Gallagher, Cuomo, Polonsky, Berliner, & Zuckerman, 1997). Agonist and antagonist muscle imbalance and weakness are generally accepted as the sign of an injury. Muscle imbalance can be revealed as a result of isokinetic evaluations (Ruivo, Pezarat-Correia, & Carita, 2012).

It was determined that the research conducted on isokinetic power in volleyball mostly focused on knee flexion and extension (Çelenk, Öz, Öner, & Öz, 2019; Dervišević & Hadžić, 2012; Hadzic, Sattler, Markovic, Veselko, & Dervisevic, 2010; Magalhaes, Oliveira, Ascensao, & Soares, 2004; Sattler, Sekulic, Esco, Mahmutovic, & Hadzic, 2015; Schons et al., 2018). In terms of the upper extremity, isokinetic strength of the shoulder joint was mostly examined (Cingel et al., 2006; Hadzic, Sattler, Veselko, Markovic, & Dervisevic, 2014; Stickley, Hetzler, Freemyer, & Kimura, 2008; Wang & Cochrane, 2001). The studies, whose number is limited, and which examine the elbow isokinetic strength, are on female volleyball players (Alfredson, Nordström, Pietilä, & Lorentzon, 1998; Alfredson, Pietilä, & Lorentzon, 1998). As mentioned above, considering the importance of the elbow joint in spike and serve which are the most commonly used technical motions in volleyball, it is very important to determine the elbow isokinetic strength and to investigate strength imbalance if any. According toAlfredson et al. (1998), spike and serve occur at high angular velocities in volleyball. Therefore, they reported that it would be more appropriate to measure muscle strength at high angular velocities like $60^{\circ}.s^{-1}$ and $180^{\circ}.s^{-1}$. However, I think that measurements should be taken also at the angular velocities like $300^{\circ}.s^{-1}$ at which movements can be performed with more repetitions in terms of maintaining the current strength during the competition. Accordingly, the purpose of this research is to compare the elbow isokinetic strength applied at different angular velocities on the dominant and non-dominant side in elite male volleyball players.

2. Method

2.1 Participants

Fifteen healthy elite male volleyball players participated in the research voluntarily. All participants are super league players and 10 of them are national team players. Before starting the research, the subjects were informed regarding the study design and possible risks. The players, who had an upper extremity injury or surgery in the last six months, were not included in the research.

2.2 Research Protocol

Measurements were performed on the players who completed their one-month pre-season trainings before the competition period. The dominant arm (spiked hand) of all players is right. Before the measurement, the subjects completed warm-up with line drills and dynamic stretching for approximately 30 minutes.

The test protocol was performed on four separate days. One day rest was given between each measurement day. The body height, body weight, body mass index (BMI) and fat percentage of the players were determined on the first day. The isokinetic strength of the dominant and non-dominant elbows was obtained on three separate days at three different angular velocities.

The bilateral elbow isokinetic strengths of the subjects were measured at three different angular velocities in flexion and extension movements: $60^{\circ}.s^{-1}$, 5 repetitions (low angular velocity), $180^{\circ}.s^{-1}$, 10 repetitions (moderate angular velocity), $300^{\circ}.s^{-1}$, 15 repetitions (high angular velocity). Elbow flexion and extension movements were performed in concentric-concentric mode. Elbow isokinetic strength was determined by using the IsoMed 2000 isokinetic dynamometer (D.&R. Ferstl GmbH, Hemau, Germany). The subjects were asked to perform 3 submaximal and 1 maximal repetitions on the isokinetic dynamometer before starting the test. During the test, the participants were in a sitting position on the dynamometer and stabilized from their shoulders and hips to the dynamometer in accordance with the protocol. During the test, the subjects were encouraged verbally.

2.3 Statistical Analysis

The following parameters were included in the research for elbow isokinetic strength measurements: PT, PT/BW, B/T, angle of PT, work and power. The descriptive statistics were performed through Sigma Plot 11.0 software (Systat Software, Inc). Paired t-test (Wilcoxon) was used for the comparison of the isokinetic strength of the subjects on the dominant and non-dominant sides. The significance level was determined as $p < 0.05$.

3. Results

The mean height of the subjects participating in the research was determined as 194.2 ± 6.2 cm, mean body weight 89.7 ± 8.0 kg, mean BMI 23.8 ± 1.7 kg.m^{-2} and mean fat percentages 9.3 ± 4.4 (Table 1).

Table 1. Characteristics of the subjects

	Mean ± SD	Min	Max
Age (year)	24.7 ± 4.8	18	34
Years of experience (year)	13.2 ± 5.1	6	25
Body height (cm)	194.2 ± 6.2	184.3	209.0
Body weight (kg)	89.7 ± 8.0	80.3	109.5
BMI (kg/m^2)	23.8 ± 1.7	20.7	27.7
Fat percentage (%)	9.3 ± 4.4	3.2	16.0

The players' PTs produced during the flexion at different angular velocities were determined to be lower than the PTs produced during the extension (Tables 2, 3, 4).

Table 2. Elbow isokinetic strengths of the subjects at 60˚.s^{-1} angular velocity

	Dominant	Non-dominant	p
PT flex (Nm)	25.0 ±8.0	28.1 ± 12.9	.519
PT ex (Nm)	57.2 ± 10.4	52.7 ±10.0	.217
PT/BW flex (Nm/kg)	0.34 ± 0.15	0.35 ± 0.11	1.00
PT/BW ex (Nm/kg)	0.78 ± 0.15	0.75 ± 0.15	.272
Flex/Ex ratio (B/T)	46.4 ± 10.9	47.5 ± 9.4	.391
Angle of PT flex (degree)	76.6 ± 19.9	59.7 ± 14.6	.013*
Angle of PT ex (degree)	69.3 ± 14.0	64.5 ± 11.4	.293
Work flex (Joule)	48.5 ± 16.8	48.5 ± 12.7	.784
Work ex (Joule)	114.4 ± 21.1	109.9 ± 20.9	.131
Power flex (Watt)	22.1 ± 8.2	22.1 ± 5.9	.787
Power ex (Watt)	53.1 ± 11.2	50.3 ± 9.8	.103

Note. *: $p < 0.05$, PT flex: peak torque flexion, PT ex: peak torque extension, BW: Body weight, B: Biceps, T: Triceps.

The highest PT was obtained at 180˚.s^{-1} angular velocity on both dominant and non-dominant elbow (PT flexion 49.2 ± 20.1 Nm, PT extension 118.1 ± 20.7 Nm in dominant, PT flexion 50.4 ± 15.6 Nm, PT extension 115.1 ± 18.5 Nm in non-dominant).

Table 3. Elbow isokinetic strengths of the subjects at 180˚.s^{-1} angular velocity

	Dominant	Non-dominant	p
PT flex (Nm)	49.2 ± 20.1	50.4 ± 15.6	.854
PT ex (Nm)	118.1 ± 20.7	115.1 ± 18.5	.422
PT/BW flex (Nm/kg)	0.30 ± 0.15	0.27 ± 0.11	.469
PT/BW ex (Nm/kg)	0.60 ± 0.21	0.62 ± 0.14	1.00
Flex/Ex ratio (B/T)	52.8 ± 24.2	45.9 ± 11.6	.295
Angle of PT flex (degree)	73.5 ± 25.1	56.8 ± 18.0	.038*
Angle of PT ex (degree)	71.8 ± 28.2	63.3 ± 17.7	.144
Work flex (Joule)	35.8 ± 16.3	37.0 ± 12.9	.809
Work ex (Joule)	88.1 ± 21.1	89.0 ± 17.9	.814
Power flex (Watt)	37.6 ±19.1	40.1 ± 15.4	.671
Power ex (Watt)	99.6 ± 25.7	99.2 ± 20.3	.932

Note. *: $p < 0.05$, PT flex: peak torque flexion, PT ex: peak torque extension, BW: Body weight, B: Biceps, T: Triceps.

This is followed by the PT produced at 300 °.s^{-1} (PT flexion 48.6 ± 22.6 Nm, PT extension 116.6 ± 40.8 Nm in dominant, PT flexion 49.3 ± 19.5 Nm, PT extension 116.6 ± 25.9 Nm in non-dominant) and 60°.s^{-1} (PT flexion 25.0 ± 8.0 Nm, PT extension 57.2 ± 10.4 Nm in dominant, PT flexion 28.1 ± 12.9 Nm, PT extension 52.7 ± 10.0 Nm in non-dominant) angular velocities, respectively.

Table 4. Elbow isokinetic strengths of the subjects at 300°.s^{-1} angular velocity

	Dominant	Non-dominant	p
PT flex (Nm)	48.6 ± 22.6	49.3 ± 19.5	.542
PT ex (Nm)	116.6 ± 40.8	116.6 ± 25.9	.993
PT/BW flex (Nm/kg)	0.22 ± 0.12	0.17 ± 0.11	.250
PT/BW ex (Nm/kg)	0.50 ± 0.17	0.51 ± 0.12	.818
Flex/Ex ratio (B/T)	48.0 ± 14.5	44.5 ± 12.6	.395
Angle of PT flex (degree)	77.7 ± 27.6	52.5 ± 28.8	.033*
Angle of PT ex (degree)	81.9 ± 9.0	82.3 ± 6.9	.561
Work flex (Joule)	25.9 ± 12.4	25.6 ± 10.8	.561
Work ex (Joule)	59.3 ± 23.5	60.0 ± 16.7	.864
Power flex (Watt)	36.1 ± 20.0	37.1 ± 17.3	.463
Power ex (Watt)	93.3 ± 40.0	94.7 ± 27.9	.853

Note. *: $p < 0.05$, PT flex: peak torque flexion, PT ex: peak torque extension, BW: Body weight, B: Biceps, T: Triceps.

The lowest elbow isokinetic PT is at 60°.s^{-1} angular velocity. In the isokinetic strength parameters of the subjects, only the angle of PT flexion was found to be significantly different at three different angular velocities (dominant vs. non-dominant) ($p < 0.05$). On the other hand, the angle of PT extension was not found to be significantly different at three different angular velocities. In terms of all remaining variables, no significant difference was found between the dominant and non-dominant elbow.

4. Discussion and Conclusion

Elbow and shoulder strength are important for serve and spike performance (Lidor & Ziv, 2010). An explosive extension occurs on the elbow joint during a spike (Cisar & Corbelli, 1989). For this reason, it is suggested to protect elbow isokinetic muscle strength with regular trainings to prevent elbow joint injuries that can occur during spike and serve movements that require explosive strength and block movement requiring good stabilization in volleyball.

The spike velocity was determined positively and significantly associated with the arm extension torque at 270°.s^{-1}angular velocity in NCAA Division I female volleyball players (r = .64, Ferris et al., 1995). Alfredson, Nordström, et al. (1998) measured the dominant and non-dominant elbow flexion and extension isokinetic strength in female volleyball players at 60°.s^{-1} and 180°.s^{-1} angular velocities. As a result of their research, they detected a significant difference between the dominant and non-dominant elbow isokinetic strength (except for 180°.s^{-1} elbow flexion). Alfredson, Pietilä, et al. (1998) determined that the PT of the shoulder and elbow rotator muscles in volleyball players was higher than the sedentary females. However, no significant difference was found between the two groups in terms of elbow flexion PT. The researchers stated that this may have resulted from the fact that elbow flexors are used to decelerate the arm after hitting the ball in the technical elements such as spike and serve in volleyball. From this point of view, it is possible to state that elbow extensors are more active than elbow flexors and affect performance more in volleyball technical elements. In this research, the elbow flexion isokinetic strength was found to be quantitatively lower than the elbow extension isokinetic strength at all angular velocities.

Gallagher, Cuomo, Polonsky, Berliner, and Zuckerman (1997) compared elbow isokinetic strength in sedentary males at different angular velocities on the dominant and non-dominant sides. In their research, the subjects were divided into two groups as 20–30 years of old and 50–60 years of old. Although there was a significant difference between the dominant and non-dominant side in elbow flexion in terms of the isokinetic parameters (PT, work, power) of the subjects, no difference was detected between the dominant and non-dominant sides in elbow extension. They found that the elbow flexion and extension PT at high velocity (180°.s^{-1}) was significantly lower than the PT produced at low velocity (90°.s^{-1}). I think that the differentiation of these findings from the findings of this research results from the volleyball player subject group who performed a sports-specific upper extremity movement for many years.

Wittstein, Queen, Abbey, and Moorman (2010) did not find a significant difference between the dominant and non-dominant sides in terms of the elbow flexion PT in healthy adult males. The elbow flexion PT at $60^{\circ}.s^{-1}$ angular velocity shows similarity with current research (dominant side 55.4 ± 9.7 Nm, non-dominant side 52.0 ± 7.6 Nm). However, the elbow flexion strength at $180^{\circ}.s^{-1}$ angular velocity was very lower than the values that I obtained in this research (dominant side 86.1 ± 7.7 Nm, non-dominant side 85.9 ± 8.6 Nm). I think that this difference results from the fact that the participants in this research are athletes.

Forthomme et al. (2005) found that the spike velocity in male volleyball players was significantly correlated with the strength of dominant elbow flexors and extensors (concentric mode). They determined the mean concentric PT of the subjects as $60^{\circ}.s^{-1}$ elbow flexion 60.6 ± 8.6 Nm, elbow extension 68.5 ± 15.9 Nm, $180^{\circ}.s^{-1}$ elbow flexion 47.9 ± 8.3 Nm, elbow extension 55.4 ± 9.3 Nm. They detected the B/T ratio as 0.91 ± 0.14, $180^{\circ}.s^{-1}$ 0.87 ± 0.1 at $60^{\circ}.s^{-1}$ angular velocity. They obtained the highest PT at low angular velocity. This finding conflicts with current study findings. I think that the strength produced at high angular velocities is more similar to the range of motion of spike, which is the most repetitive technical element in volleyball, compared to the strength produced at low velocities. In current study findings, the highest PT was obtained in dominant and non-dominant flexion and extension at $180^{\circ}.s^{-1}$ and $300^{\circ}.s^{-1}$ angular velocities. In addition, the $180^{\circ}.s^{-1}$ elbow extension isokinetic strength (the agonist muscle of this motion is triceps) that I obtained in this research is almost two times more than the value obtained in Forthomme et al. research (while the $180^{\circ}.s^{-1}$ elbow extension PT is 118.1 ± 20.7 Nm in current research, it is 55.4 ± 9.3 Nm in the study of Forthomme et al. (2005)). When the year of the research is taken into consideration, the differences in the findings obtained can be clarified when the changing game velocity and requirements are considered.

Following the literature review, it was determined that the elbow joint isokinetic strength was investigated in volleyball players in a limited number of studies. It is obvious that the focus is mostly on the isokinetic strength of the shoulder. Therefore, I think that this research will bridge an important gap in the literature. The fact that the years of the researches conducted are also out of date makes our study attention-grabbing. Moreover, the fact that the subject group consists of national and super league players is one of the strengths of this current research. However, the limited number of the sample group is one of the limitations of this research. Consequently, there is not any isokinetic strength difference between the dominant and non-dominant elbow in elite male volleyball players. The lowest elbow isokinetic strength (flexion & extension) was obtained at low angular velocity ($60^{\circ}.s^{-1}$). The elbow extensor muscle strength was higher than the elbow flexor muscle strength on the dominant and non-dominant side. These findings can also be used as a reference by volleyball team coaches, trainers and conditioners. Due to the need for strength in volleyball, it is important to measure and follow the strength measurements of the players throughout the season. However, strength imbalance can cause sports injuries. In order to determine this, it is suggested to evaluate the dominant & non-dominant or agonist-antagonist strength of players.

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