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Section I – Kinesiology

The Relationship Between Speed and Strength in the Beach Volleyball Serve

by
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The objective of this study was to analyze the relationship between isometric force produced in different joints and its effects on the power kick serve speed in beach volleyball as a predictive aspect to improve sports performance. Seven athletes competing at national and international levels (mean ± standard deviation; age: 21.6 ± 3.20 years; body height: 1.87 ± 0.08 cm; body mass 80.18 ± 7.11 kg) were evaluated using maximum isometric force contractions (i.e., spinal and knee extension, grip by a hand dynamometer (handgrip), internal shoulder rotation, shoulder flexion, elbow flexion and extension, and wrist flexion). Speed of the ball was recorded with a pistol radar and force was measured with a strain gauge. Results showed a relationship between isometric force developed in the internal rotation of the shoulder and speed of the ball (r = 0.76; p < 0.05). In the remaining isometric exercises, positive low to moderate correlations were found in the spine and knee extension (r = 0.56; p = 0.200) and elbow flexion (r = 0.41; p = 0.375). On the other hand, the remaining isometric exercises obtained weak or non-significant correlations. Force developed in the internal rotation of the shoulder highly correlated with the speed of the power kick, explaining, together with the elbow flexion and the extension of the knee and back, much of the variability of the power kick of beach volleyball athletes.*

Key words: *isometric strength, training, internal shoulder rotation , beach volleyball, serve speed.*

Introduction

In recent years, the number of studies on beach volleyball as a favorable form of physical activity has increased (Lidor and Ziv, 2010), along with technical-tactical aspects depending on the characteristics of the game (Buscá et al., 2012; Koch and Tilp, 2009; Medeiros et al., 2014; Pérez-Turpin et al., 2019), waste-of-energy (Zetou et al., 2008) and body composition (D'Anastasio et al., 2019; Palao et al., 2008). Considering the beach volleyball serve, it has also been the object of different interventions, we found that a jump serve was one of the most used (Jiménez-Olmedo et al., 2012) with a greater tendency to serve using the power kick in men, while from a static position in women (Lopez-Martinez and Palao, 2009).

Ball speed (Buscá et al., 2012), its trajectory (Katsikadelli, 1997; Selinger and Ackermann-Blount, 1992) and jumping ability (Pérez-Turpin et al., 2008) are elements which influence the service and reduce the receiver's reaction time, minimizing the opponent's attack options. These elements can be improved through strength training, becoming an important aspect in improving performance in beach volleyball (Correia et al., 2018; Rao and Rao, 2016).

In this respect, various strength assessment programs and strategies have been proposed to improve performance of beach volleyball athletes. Vibration platform strength training has been observed to cause significant improvements in *Squat jump and Countermovement jump* performance (Pérez-Turpin et al., 2014), together with the importance of improving the jump as a functional and transfer aspect for different actions which constitute the sports

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specialty (Voigt and Vetter, 2003). Considering other disciplines, strength levels have served as an indicator of serve speed in isokinetic tests (Cohen et al., 1994; Pugh et al., 2003; Signorile et al., 2005) and, with respect to isometric strength, positive correlations in performance have been observed (Ruiter et al., 2006; Stone et al., 2003) as well as others with no significance to the results (Wilson and Murphy, 1996). In this way, different protocols have been used in other disciplines for the evaluation through isometric force with the handgrip, as is the case of the tennis serve, in which the maximum isometric force is related to possible benefits in service speed in the dominant arm (Bonato et al., 2015; Pugh et al., 2003). Another study in female handball players assessed the range of motion (ROM) and isometric force with speed at which the ball was struck (Schwesig et al., 2016). It has been also shown how maximum isometric force allowed for the improvement of aspects related to soccer and wrestling (Kraska et al., 2009; McGuigan et al., 2006; McGuigan and Winchester, 2008; Stone et al., 2003, 2004). Furthermore, ROM and isometric strength of the shoulders and elbow contributed to the improvement in the speed of the ball in experienced handball players, according to Van Der Tillaar and Ettema (2004). In this respect, the work published by Baiget et al. (2016) compared the maximum isometric force developed with the speed of the ball during the tennis serve.

In volleyball, isokinetic force in the shoulder and its relationship with speed of the ball have been analyzed in elite athletes (Arslan and Albay, 2019). Also, concentric and eccentric strength have been both evaluated in volleyball players, considering changes in force production according to the angle of execution in the shoulder and elbow (Alfredson et al., 1998). In relation to the aforementioned work, greater maximum proximal force has been observed at the end of the acceleration phase in the power kick serve (Reeser et al., 2010). On the other hand, isometric strength has also been studied in volleyball, although no relationship was found with service speed (Hadzic et al., 2014; Lajtai et al., 2009).

Therefore, the objective of the study was to establish the relationship between maximum isometric force developed in eight upper and lower body actions and speed of the ball in the beach volley power kick serve. We also aimed to determine the interference existing between the maximum force of certain muscle groups measured in isometry and the strike speed in beach volleyball players.

Methods

Participants

Seven male beach volleyball athletes (mean ± standard deviation; age: 21.6 ± 3.20 years; body height: 1.87 ± 0.08 m; body mass 80.18 ± 7.11 kg) participated in the study. Players took part in leagues and competitions at regional, national and international levels. All the participants trained an average of 12-25 hours per week, which were divided into specific training modalities (technical-tactical aspects of the sport), aerobic and anaerobic exercises (i.e., acceleration exercises in the sand) and strength training (i.e., lower body strength). All players had a minimum of two year experience in competitive sport. No individual had suffered an injury in the past 12 months or followed a rehabilitation program in the previous 6 months. Players were also asked not to exercise vigorously 24 h before testing.

Procedures

Research was carried out in 2019, at the facilities of the University of Alicante, Spain. The intervention was carried out on the same day. The study was divided into two phases which consisted of maximum isometric strength and service speed testing. All participants were informed of the protocol to follow and were asked to maintain their normal lifestyle. The intake of caffeine, tea, creatine and nitrate was prohibited for at least 12 h before testing.

Maximum isometric force test

Participants performed a total of 7 maximum isometric strength exercises in preset order (knee and spine extension, hand grip dynamometer shoulder and elbow flexion, elbow extension, wrist flexion, and internal shoulder rotation). Players were tested only on their dominant side of the body using a strain gauge (Chronojump Bosco system) previously calibrated using a standardized weight. The use of a strain gauge allowed the evaluation of force (N) in each exercise. The position of each exercise was previously defined with the use of goniometry and based on ranges of movement reported by Norkin and Levangie (1992), where the angulation ranges were defined in each plane of the body segments.

All contractions lasted between 3 and 5 s with a 1-min rest interval between sets and 5 min between exercises (Baiget et al., 2016). Only verbal support was used to motivate players to perform at their best. For the interpretation of the developed force, the average of each repetition during the performance of isometric contractions was taken into account.

Firstly, the leg and back extensions were performed on a mat with an initial knee flexion position of 70º, 0º being the full extension of the knees. Athletes wore a protection belt attached to a strain gauge where the maximum isometric force was measured through the maximum production of muscle tension per unit of time. The gripping exercise was recorded with a dynamometer (TAKEI 5401 *handgrip*), adapting the gripping force with fingers practically extended, simulating the position of the hand in the power kick serve and, therefore, varying the position of the hand for each participant. Positive feedback on performance and force manifestation was provided. The upper body exercises were performed in a sitting position with hip flexion of 90º. The posterior thigh and the back were in a fixed position, allowing the isolation of the involved muscle groups. Shoulder flexion was performed with the arm abducted at 90º (Hurd et al., 2013) and with the elbow, at all times, remaining fully extended. In flexion, the force vector was directed against gravity. To avoid data errors, the posture was adjusted to isolate the shoulder without performing lateral spinal flexion. For the elbow flexion and extension, this was performed with a different methodology than the previous one. In this case, the shoulder was not abducted, but the elbows were close to the body and with flexion of 90º. Therefore, the elbow flexion was performed against gravity and the extension went with gravity. The wrist flexion was performed with the forearm supported, preventing the activity of the biceps brachii. Finally, for the internal shoulder rotation, attention was paid to the beach volleyball power kick gesture. Athletes were placed in a sitting position with their arms abducted at 90º. From this position, the elbow was flexed at 90º, placing the strain gauge in the opposite direction to the force of the participant. During the execution, the hand did not exceed the medial line of the participant's body, avoiding superior mechanical stress on the shoulder joint at the glenohumeral level. For this purpose, the strain gauge was adapted according to the lever arm and execution of each exercise through the use of goniometry. Chain weight and strain gauge data were recorded for further analysis.

Service speed test

The service speed test was carried out on the beach volleyball court of the University of Alicante using official balls (FIVB beach champ VLS300 MIKASA). First, athletes performed a general warm-up consisting of joint mobility (i.e., knee flexion and extension, shoulder rotation, ankle dorsiflexion) to subsequently develop a warm-up aimed at intra and intermuscular coordination based on the subsequent technical elements (i.e., jumping and running without the ball). Finally, they were encouraged to take ten serves per player on a trial basis. The warm-up lasted 15 min. Then, a total of 196 power kick serves were registered without opposition (28 per participant). After the execution of each isometric exercise, four hits per participant were carried out at their maximum intensity, thus determining the speed of the ball. In each and every one of them, participants were encouraged to execute the service as strongly as possible, trying to make it valid, knowing that this could interfere with the speed of the ball. The radar was placed 8 m behind the service line and 3 m above the ground (Buscà et al., 2012) in order to record the strikes at a height comparable to the moment at which the athlete's hand impacted the ball in motion. To record the speed of the ball, a radar gun was used (Stalker Sport Manual, EUA; Technology Drive TX 75074).

Statistical analysis

Descriptive (mean and standard deviation) and inferential tests were performed with SPSS 25.0 (SPSS, Inc., Chicago, IL, USA). The data normality was verified using the Kolmogorov-Smirnov test and the Pearson correlation coefficient was used to determine the relationship between the maximum isometric force developed and the speed of the service. Finally, multiple regression analysis was carried out observing the percentage of variance explained in the speed of the hit for each execution. The level of significance was set at $p < 0.05$.

Results

Altogether, a total of 196 strikes (28 per player) were recorded after the power kick, analyzing only valid services. The relationship between the maximum isometric force developed in the tests performed and the speed of the ball is presented in Table 1.

Force values showed that the highest positive correlation was found between the speed of the power kick serve and the internal rotation of the shoulder (r = 0.76*; p < 0.05). In the other variables, there was no strong positive correlation, although a moderate correlation was observed in knee and back extension (r = 0.56; p = 0.200) and elbow flexion (r = 0.41; p = 0.375), with no statistical significance. On the other hand, a null Pearson correlation value was found in wrist flexion, in which the p value did not show significant differences (r = -0.02; p = 0.955), and in the shoulder flexion (r = -0.01; p = 0.954). Information on speed of the ball is presented in Table 2, where the average speed values and standard deviation of the shots considered good are provided for players who took part in international, regional and national competitions.

On the other hand, using multiple regression analysis, we observed that the internal rotation of the shoulder explained 57% of the variance of the speed of the beach volleyball service, with significant differences (p = 0.047). When analyzing the extension of the spine and knee together with the internal rotation of the shoulder, we observed that they explained 62.5% of the variance of the speed of the service with a non-significant p value (p = 0.141). The service speed prediction regression equation was: Service speed = 71-99 + (0.03 × internal shoulder rotation) + (0.003 × knee and spine extension).

Finally, considering all the values of the isometric force obtained and speed of the ball, no correlation was observed in the entire set of body segments between isometric force and striking speed. Consequently, the developed isometric force of the analyzed variables did not correlate with the speed of the ball in the beach volleyball power kick serve (r = -0.25).

Table 1

Isometric force, standard deviation, r (Pearson's correlation), p (statistical significance)

Maximal isometric strength test	Maximum isometric force (N±SD)	r	***p***
Knee and back extension	1332.92 ± 201.19	0.56	0.200
Grip (handgrip)	429.94 ± 61.63	0.14	0.750
Shoulder flex	137.31 ± 8.61	-0.01	0.954
Elbow flex	241.26 ± 20.13	0.41	0.375
Elbow extension	179.43 ± 18.80	0.21	0.640
Wrist flex	251.05 ± 35.91	-0.02	0.955
Shoulder internal rotation	186.24 ± 24.28	0.76*	0.047

Table 2

Serve speed, standard deviation on serves considered good

	Half serve speed (km/h)	Considered good (%)
Players participating in national and regional competitions	70.97 ± 3.46	46.43%
Players participating in international competitions	72.98 ± 4.82	60.71%
Total of good hits	72.12 ± 1.09	100%

Discussion

The objective of the study was to establish the relationship between the maximum isometric force developed in eight upper and lower body movements and the speed of the ball in the beach volleyball power kick serve.

Our main finding was a moderate-high positive correlation between maximum isometric force developed by participants and the speed of the ball in the beach volleyball power kick serve when internal shoulder rotation was performed. In other cases, such as elbow flexion and knee and spine extension, a certain low-to-moderate positive relationship was found, yet without statistical significance. However, when analyzing isometric strength of all the exercises together, no correlation with the speed of the beach volleyball power kick serve was observed (r = -0.25), the conclusion being that maximum isometric force was not a fundamental aspect of the volleyball service as a whole, because it is a fully dynamic movement which requires great intra- and intermuscular coordination. On the other hand, when analyzing the extension of the spine and knee (r = 0.56; p = 0.200) and the internal rotation of the shoulder, we observed that they could explain 62.5% of the variance of the speed of the ball (R^2 = 0.625) without statistical significance (p = 0.141). Analyzing the technical gesture of the service, the success or error of a good service can be influenced by the player's jumping ability and, therefore, the coefficient found for achieving a successful service seems reasonable (Giatsis et al., 2004; Giatsis and Tzetzis, 2003). Thus, we can state that there may have been an interference between the speed of the service and the number of services considered good performed during the intervention.

The importance of isometric strength has been demonstrated in many sports (McGuigan and Winchester, 2008), both in terms of performance (Ishøi et al., 2018) and in favor of the prevention and treatment of sports injuries (Charlton et al., 2018). In volleyball, there is no literature which relates to the development of isometric force and the power kick serve. Our findings suggest the importance of internal shoulder rotation in beach volleyball. Several studies have been carried out in which force developed at different angles of the shoulder and elbows was analyzed concentrically and eccentrically (Alfredson et al., 1998), as well as aspects related to the way the ball was struck and the speed of the ball in beach volleyball (Buscá et al., 2012); furthermore. performance analysis has been conducted (Pérez-Turpin et al., 2008). Also, isometric shoulder assessment tests have been carried out which present some similarity to the present study, though fundamentally focusing on injuries of both the dominant and non-dominant arms (Hadzic et al., 2014). In addition, service speed has been studied in serves in the FIVB *World Tour* (Palao and Valades, 2014), and here is where the intervention carried out may possibly be relevant. Thus, the present work develops a novel approach in an attempt to establish a relationship between the speed of the service and strength which athletes are capable of exercising in an isometric way.

Regarding other sports, the relationship between the force developed by isometric exercise in different ROMs and the speed of the ball in motion has been studied, and the tests carried out yielded positive correlations (Baiget et al., 2016; Schwesig et al., 2016). In tennis, no strong relationship between the internal rotation of the shoulder and the speed of the service has been found using isokinetic tests (Cohen et al., 1994; Pugh et al., 2003). On the other hand, beach volleyball players have to perform repeated maximal overhead movements of the upper extremities when serving (Seminati and Minetti, 2013), thus, improving shoulder strength is important for proper functionality. In isokinetic tests, however, optimal force values have been found in the dominant arm at 57.18 ± 7.58º, reaching an average service speed of 70.55 ± 3.66 km/h, with no direct relationship between developed isokinetic force and shoulder rotation (Arslan and Albay, 2019).

Another aspect worth highlighting in the intervention was the speed at which the ball was struck. It has been seen that at a faster strike speed, athletes had higher error rates. Only good services were analyzed in our study, probably interfering with the speed of the ball. Moras et al. (2008) observed that serving at high and medium speed might not be the best option due to the percentage of errors and that it varied depending on the sports level and sex. In this respect, the sports level of our athletes was varied and, therefore, the success rate of the services and the speed of the serve could have been influenced.

On the other hand, when analyzing the variance explained by the strike speed, it coincides with that of other studies. More than half of this corresponds to the internal rotation of the shoulder (57%) and, if we add the extension of the spine and knee, 62.5% of the variance in serve speed could be explained. Baiget et al. (2016), in the tennis service, showed similar data to those of the present study. Accordingly, we can affirm that isometric tests can be a good option for evaluating the beach volleyball serve, because different body segments involved in the discipline can be analyzed. Conversely, some studies carried out in tennis have not found any relationship between the work of the internal rotation of the shoulder and the speed of the serve in a force test using isokinetic dynamometers (Cohen et al., 1994; Pugh et al., 2003; Signorile et al., 2005). In any case, carrying out training programs related to isometric strength can be associated with significant improvements in actions of a dynamic nature (Folland et al., 2005) and, therefore, can be considered a good option for beach volleyball athletes.

There are certain limitations of the study. On the one hand, variables such as technique, coordination or flexibility of participants were not considered, since the study sample consisted of players of different sports levels. On the other hand, the explained variance of the speed of the service may have been influenced by isometric measurements. Here participants were evaluated within the same joint ranges, without differentiating the ability to generate force based on the position and individual ROM. Therefore, the static positions cannot replicate all the ROMs which determine a beach volley power kick serve (Murphy and Wilson, 1997) and, therefore, a direct transfer cannot be established. Furthermore, when performing the intervention on the same day and uninterruptedly, factors such as fatigue could cause distortions both in the execution of each isometric exercise and in the speed of the ball itself. In conclusion, the present study demonstrated a strong correlation between maximum isometric force developed during internal shoulder rotation and the speed of the beach volleyball power kick serve.

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