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Muscular Endurance and Strength as Predominant Factors on Spike among Young Volleyball Athletes
Resistencia y Fuerza Muscular como Factores Predominantes en el Remate entre Jóvenes Atletas de Voleibol

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Abstract. Most of physiological investigation in volleyball studies only discussed which body part is dominant when someone doing spike. There are still few studies to explore in more detail on what muscle works and roles of muscle is so crucial. This study aims to determine which part of the muscle has a more specific effect during spike movements. This study uses a quantitative descriptive method, participants in this study were female and male adolescent athletes obtained 42 participants, divided into 20 males and 22 females. Data on muscle endurance and strength were obtained by measuring the leg and back dynamometer, while the spike hit results collected from The Volleyball Test Skills for Smasher and performance were obtained using observation using a range of points 1-4, which is based on five spike phases: Initial Attitude, Initial Motion, Contact Motion, Follow through Motion, and Ball Placement. Data analysis used ANOVA test and simple regression. The results showed that the performance was significantly increased by the strength of the back muscles ($p = 0.005 < 0.05$) and abdominal muscles ($p = 0.012 < 0.05$), while the other components were supportive but not significant. Likewise, the strength of the inner leg muscles ($p = 0.010 < 0.05$) which has a very significant level of influence ($p < 0.01$) on the spike results. Strengthening back muscle and abdominal muscle endurance need to be the focus of the training program for young volleyball athletes because they are needed during spike movement and inner leg muscle strength is needed to obtain maximum spike jumps.
Keywords: spike; endurance; strength; muscle; young athletes; volleyball

Resumen. La mayor parte de la investigación fisiológica en los estudios de voleibol solo discutió qué parte del cuerpo es dominante cuando alguien está rematando. Todavía hay pocos estudios para explorar con más detalle sobre qué músculos funcionan y las funciones de los músculos son tan cruciales. Este estudio tiene como objetivo determinar qué parte del músculo tiene un efecto más específico durante los movimientos de remate. Este estudio utiliza un método descriptivo cuantitativo, los participantes en este estudio fueron atletas adolescentes femeninos y masculinos obteniendo 42 participantes, divididos en 20 masculinos y 22 femeninos. Los datos sobre la resistencia muscular y la fuerza se obtuvieron midiendo el dinamómetro de piernas y espalda, mientras que los resultados de los golpes con remates recopilados de The Volleyball Test Skills for Smasher y el rendimiento se obtuvieron mediante la observación utilizando un rango de puntos 1-4, que se basa en cinco puntos. fases: actitud inicial, movimiento inicial, movimiento de contacto, movimiento de seguimiento y colocación de la pelota. El análisis de datos utilizó la prueba ANOVA y la regresión simple. Los resultados mostraron que el rendimiento aumentó significativamente por la fuerza de los músculos de la espalda ($p = 0{,}005 < 0{,}05$) y los músculos abdominales ($p = 0{,}012 < 0{,}05$), mientras que los otros componentes fueron de apoyo pero no significativos. Asimismo, la fuerza de los músculos internos de la pierna ($p = 0{,}010 < 0{,}05$) que tiene un nivel de influencia muy significativo ($p < 0{,}01$) en los resultados de remate. El fortalecimiento de los músculos de la espalda y la resistencia de los músculos abdominales debe ser el enfoque del programa de entrenamiento para los jóvenes atletas de voleibol porque son necesarios durante el movimiento de los remates y la fuerza de los músculos internos de las piernas es necesaria para obtener los máximos saltos con remates.
Palabras clave: espiga; resistencia; fortaleza; músculo; atletas jóvenes; vóleibol

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Introduction

Volleyball has always been known as a highly dynamic sport for it involves some sprints, jumps (blocking and spiking) as well as high-intensity on-court movements repeated during the game (Viitasalo et al., 1987). Volleyball has so far been one of five most-played sports in the world, while spike is one of factors determining an attack, significantly affecting the results of the game (Challoumas & Artemiou, 2018). In volleyball, spike techniques require special skills along with excellent body coordination in, for example, running, countermovement jump, a set of explosive overhead movements in the air and landing (Marquez et al., 2011). A previous study found that a successful spike depends greatly on anthropometry and physical performance variables (Reeser, 2017).

Spike is important in volleyball. However, a comprehensive training in the technique remains rare, especially among young athletes. Elementary mistakes keep occurring in all phases, from preparation to landing, and if not taken care of since the beginning, they may prevent the young athletes from reaching their fullest potentials, as they grow older. In the end, winning the game in a match season would be hard (Pires & Ugrinowitsch, 2021). In addition, in a field observation, it found that the muscles used for spiking were disproportionate, which seen from, for example, tall athletes' disproportionate muscles when compared to their height (underweight) (Gabbett & Georgieff, 2007). From anthropometry perspective, this may lead to poor spike performance. In other observations, athletes jumped well but swung their arms too narrowly, hence a less powerful, easy-to-anticipate hit. The fact that spike requires special skills contradicts the young athletes' ability during training, creating a gap between how spike is supposed to be done and how the young athletes actually do it (Sarvestan et al., 2021). Other factors also contribute to this gap, and

they include players' age when joining the training (Rubajczyk & Rokita, 2020), human anatomy and fitness components related to skills barely discussed by coaches. In the end, this will lead to a decrease young athletes' performance due to physical or mental exhaustion, decreased motivation to win, and sport devaluation (Vitali et al., 2015). Until now, there are still many coaches not completely understanding how a training program should be conducted as well as how to practically implement bio motor components.

Elite volleyball athletes need pre-match training to improve their physical conditions as well as techniques and strategies to be used during the game. Muscular strength and endurance, particularly in the upper and lower extremities, determine results of a serve, pass, spike, and blocking (Nasuka et al., 2020). The complexity of spike analysis has grown in this past decade and contributed practical implications for coaches and athletes. A successful spike depends on physical attributes (Reeser, 2017) and psychological attributes (Güldenpenning et al., 2013) that can be captured by kinematic variables to movement (Challoumas & Artemiou, 2018; Seminati et al., 2015) and ball speed after a contact with the hands (Challoumas & Artemiou, 2018). Most previous studies, however, still focused on experimental studies and model development related to the method of volleyball spike teaching and training (Halim et al., 2019; Suhairi et al., 2020). Some other researchers still boast about the methods or models they have developed. In other words, academicians are still testing all the training methods they consider best, but the results remain unsatisfactory. If studied more closely and specifically, students or young athletes need more individual-based training approaches (Kenney et al., 2015) to match spike coordination pattern that is highly specific based on one's ability (Sarvestan et al., 2020). Having a high aerobics ability is an advantage to improve skills and fitness, including spike skill for young volleyball players (Lakhdar & Zerf, 2019). Some studies that focused on strength training reported that implementation of circuit method was able to improve strength of muscles on the left and right parts of the body that support flexion-extension motion in the pelvis. In addition to stronger back muscle strength and flexibility, muscle endurance improved, side step for agility increased, while jump speed, serve speed, and spike speed also increased significantly during intensive circuit training (Noh et al., 2019). In a study, examining both endurance and strength, an eight-week strength and endurance training was found to have certain effects on power and VO_2Max (Hama & Magied, 2014). Weightlifting training can increase muscular endurance and strength directly (Hong et al., 2014). For instance, some muscles that play important roles in spike—such as triceps and elbow flexors—experienced a significant increase in power after eight weeks of weightlifting training.

Other consequences of the complexity and technical-coordinative requirements in vertical spike jump are the differences that have been observed in biomechanical movement characteristics and performance between sexes (Fuchs, Menzel, et al., 2019). Sex differences in Vertical Spike Jump were previously reported in the vertical decrease of CoM, torso incline angle, minimal knee angles, the asymmetric usage of arm swing, and lower limb extension (Fuchs et al., 2020; Fuchs, Fusco, et al., 2019).

Coaches and teachers can analyse each player's weaknesses and strengths. Therefore, coaches must be fully aware that training materials must be adjusted to suit individual's needs. Because of this, there is a need for a comprehensive study on young athletes' performance and their imperfect spike techniques to improve their techniques. In addition, it also expected that this study would will improve the quality of hits and movement. Unfortunately, only few studies discussed how muscles—of the upper or lower extremities—involved in spike could affect performance and results of the hits. *The study purpose was* to identify which muscles are dominant in volleyball spike.

Method

Design

As a descriptive quantitative study, a descriptive correlational method was adopted in attempt to describe the relationship between independent and dependent variables in the analysis. This study analysed key variables-spike performance and result-to identify their relationship with bio motor abilities, particularly muscular endurance, and strength. Ultimately, the dominant muscles used when doing spike were identified.

Subjects/ Participants

Table 1.
Age Characteristics of all participants

Gender	N	Mean ± SD
Male	20	18.30 ± 1.00
Female	22	16.09 ± 1.35
Overall	42	17.14 ± 1.63

This study used total sampling 42 participants with regional competition experience more than 2 years. As presented in the table 1, the 42 young volleyball athletes (22 female and 20 male) who participated during data time collection (Mean Age=17.40; SD=1.63) with additional player positions (Table 2) are prepared for local competition. The research protocol that confirmed by the Ethics Committee Approval with reference number: 00169/KT.7.4/VI/2021.

Table 2.
Percentage of Participants based on volleyball position

Player's Position	Male (%)	Female (%)
Libero	5	13.64
All round	20	13.64
Open Spike	35	27.27
Quicker	30	22.73
Setter	10	22.73

Using anthropometric measurements, participants' characteristics identified and presented in Table 3.

Table 3.
Anthropometrical Characteristics of All Participants

Anthropometry Components	Mean ± SD		
	Male	Female	Overall
Height (cm)	178.3 ± 5.16	164.04 ± 6.47	170.83 ± 9.23
Weight (kg)	66.95 ± 8.76	58.09 ± 9.61	62.31 ± 10.22
Body Mass Index (BMI)	21.02 ± 2.3	21.52 ± 2.81	21.285 ± 2.59
Lower limb (cm)	42.17 ± 2.46	39.47 ± 2.18	40.76 ±2.68
Upper limb (cm)	47.82 ± 3.9	47.88 ± 3.92	47.85 ± 3.91
Foot (cm)	25 ± 0	20 ± 0	22.38 ± 2.49
Limb length (cm)	115 ± 4.86	107.36 ± 5.17	111 ± 6.51
Lower arm (cm)	27 ± 3.41	23.71 ± 0.82	25.13 ± 2.83
Upper arm (cm)	30.25 ± 3.32	29.6 ± 3.63	29.88 ± 3.51
Sitting height (cm)	90 ± 3.16	83.16 ± 2.62	86.15 ± 4.44

Research Instruments and Procedures

Data were collected using instruments that can measure the strength and endurance of muscles. These instruments included a leg dynamometer (assess leg strength muscle), a back dynamometer test, a one-minute plank fitness test to measure the endurance of the arm muscles, followed by sit up and back up test to measure the endurance of the abdominal and back muscles during one-minute.

Leg dynamometer was begun with stand shoulder-width apart on the dynamometer base. Hold the bar centrally with both hands, palms towards the body, by letting your arms hang straight down. Adjust the chain to 110 degrees. Back dynamometer was measured muscle strength of the lower back, which is important in core stability and for preventing lower back pain. The test involves holding a horizontal position while hanging over the edge of a bench. Participants must lie face down on a bench with their waist hanging over the end. The participant's arms and feet must be kept down. When ready, they must lie horizontally for a predetermined time (e.g., 45 seconds). Plank fitness test requires holding an elevated position as long as feasible. Start with the elbows and forearms supporting the upper body and the legs straight with the weight on the toes. Straight from head to toe, the hip is lifted. The stopwatch starts when the subject is in correct position. The person has passed the test when they are unable to keep their back in a straight position and their hip is dropped. On the other hand, strength and endurance of abdominal muscles are essential for core stability and back support. This sit-up test evaluates the stomach and hip flexor muscles' strength and endurance. Participants should tighten stomach, flatten your back, and lift until hands can glide down your thighs and touch the tops of knees. Do not pull with head or neck, and maintain a flat lower back on the floor. Afterward, return to the initial position. Back-up test evaluates the back muscles' strength and endurance. Initially, lying on your stomach, feet together, and hands together behind your head is a backup workout, followed by elevating your body with your chest not contacting the floor. A sequence of back-up motions that use the belly as a support and create back contractions.

Meanwhile, The Volleyball Test Skills for Smasher (Alnedral et al., 2020) was used to test how spike done. The target areas for spike data collection were like those in the previous study (Alnedral et al., 2020). Scores were calculated using guidance presented in Table 4. Target areas and the field situation presented in Figure 1.

Table 4.
Scoring system for the volleyball skills test instrument

Target Area	Points given
A	4
B	3
C	2
D	1
Out of bounds	0

Participants were given five chances to perform a spike from IV position. They directed the ball to the target areas that had been set. Points were awarded depending on where the ball landed (A/B/C/D/out of bounds), and this scoring system was presented in Table 4. Should participants' touch the net, the ball is declared dead and is replayed. Each participant was given five times to spike. These scores were accumulated to generate a final score.

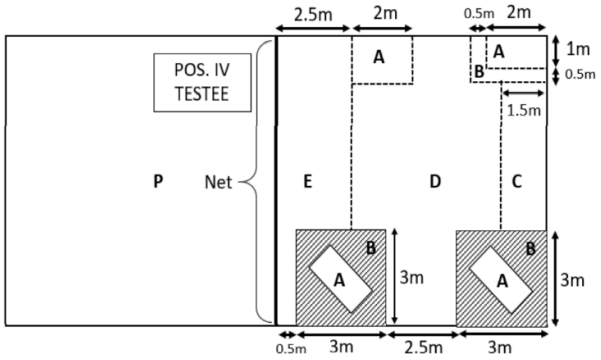

Figure. 1. Spike result data collection (Alnedral et al., 2020)

Besides results of spike, another instrument was used to measure and collect data on Spike Performance (scores ranging from 1 to 4), and it was based on five motions in spike: (1) Initial Position; (2) Initial Motion; (3) Contact Motion; 4. Follow Through Motion; (5) Ball Placement. Testers filled out forms to record data based on results of observation at all stages. Observation criteria were divided into five phases seen in Table 4. Initial position, initial motion, contact motion, follow through motion, and ball placement were defined one by one so that testers knew what needed to be measured during data collection process. Initial position and follow through motion phases consist of four criteria, while initial motion and contact motion phases comprise of six criteria and ball placement phase has only one criterion. As to scoring, there were four selections (1-4), each representing certain criterion. It is expected that results of the observation meet all criteria in all stages.

Statistical Analysis

Data were analysed using the ANOVA tests and simple regression to identify the influence of muscular endurance and strength on spike performance or result. It expected that data analysis results could help identify which muscles play significantly important roles in spike motion and determine spike results as a follow-up of motion analysis.

Results

Data can be divided into comparisons between gender and significant differences between muscular and strength

muscle compared with spike performance and result. As presented on Table 6, comparison between sexes figured out with significant value in between. Back muscle strength and abdominal muscle endurance between male and female significantly differ rather than any variables.

Table 5.
Spike performance scoring criteria

Criteria	Description	Score	Notes
	High initial position in spike		
1	Stand up with front and back legs apart at a medium distance	4	Passing through all 4 stages correctly
2	Weight equally distributed on both legs	3	Passing through 3 stages correctly
3	Knees bend a little	2	Passing through 2 stages correctly
4	Eyes looking at the ball	1	Passing through 1 stage correctly
	Initial motion in spike technique		
1	Begin approaching the ball when it is halfway to smasher		
2	Two last steps include small steps to the left and right, or stepping for jumping	4	Passing through all 6 stages correctly
3	Swing both arms to the back up to the waist	3	Passing through 4-5 stages correctly
4	Stand on the heel	2	Passing through 2-3 stages correctly
5	Transfer the weight	1	Passing through 1 stage correctly
6	Swing arms front and up		
	Contact with the ball in spike.		
1	Hit the ball with arms stretched as much as possible		
2	Hit the ball right in front of smasher's shoulder	4	Passing through all 6 stages correctly
3	Hit the ball with an open palm of the hand	3	Passing through 4-5 stages correctly
4	Hit the ball in its center-back area	2	Passing through 2-3 stages correctly
5	Bend wrist powerfully	1	Passing through 1 stage correctly
6	Hands aim the ball up		
	Follow through phase in spike.		
1	Eyes on the ball when hitting	4	Passing through all 4 stages correctly
2	Back to the floor	3	Passing through 3 stages correctly
3	Knees bend to absorb shock	2	Passing through 2 stages correctly
4	Drop hands to the waist forcefully	1	Passing through 1 stage correctly
	Ball placement using smash technique		
1	Using spike technique, aim the ball to the opponent's area	4 3 2 1	Ball can pass the net Ball can pass the net and is aimed at parts of the court hard for the opponents to catch, such as the corner or the side of the court Ball can pass the net and is then aimed inside the court Ball can pass the net, and goes inside the court but then goes out of bounds.

Table 6.
Comparison between male and female on muscular endurance and strength components.

Muscular	Mean ± SD		Sig.
	Male	Female	
Limb muscle strength	39.67 ± 17.49	33.61 ± 10.94	0.053
Back muscle strength	56.27 ± 22.70	33.54 ± 9.74	0.003**
Arm muscle endurance	132.70 ± 37.18	142.68 ± 46.74	0.232
Abdominal muscle endurance	29.00 ± 4.23	27.95 ± 2.83	0.029*
Back muscle endurance	50.70 ± 4.84	55.50 ± 5.99	0.306
Inner thigh muscle strength	32.41 ± 7.95	25.03 ± 5.84	0.088
Outer thigh muscle strength	50.55 ± 9.76	39.20 ± 9.82	0.842

*Significant at 0.05, **Significant at 0.01

Data on the muscular and strength components and their connection to spike performance and results displayed on Table 7. It seen that spike performance must be fully supported by back and abdominal muscle strength without considering other components whose influence is significant ($p < 0.01$). In contrast, only the strength of inner thigh muscles significantly influences ($p < 0.01$), spike result while other variables contribute but not significantly.

Table 7.
The influence of strength and endurance of dominant muscles for overall participants (N=42)

Dominant Muscles	Mean ± SD	Spike Performance		Spike Result	
		r	Sig.	r	Sig.
Limb muscle strength	36.50+14.58	0.191	0.113	0.135	0.198
Back muscle strength	44.37+20.48	0.393	0.005**	0.183	0.123
Arm muscle endurance	137.93+42.25	0.166	0.146	0.094	0.277
Abdominal muscle endurance	28.45+3.56	0.350	0.012**	0.205	0.097
Back muscle endurance	53.21+5.93	0.092	0.281	0.040	0.401
Inner thigh muscle strength	28.55+7.79	0.064	0.343	0.357	0.010**
Outer thigh muscle strength	44.61+11.25	0.137	0.194	0.156	0.162

* significant at 0.05
**significant at 0.01

Table 8.
The influence of strength and endurance of dominant muscles on male players (N=20)

Dominant Muscles	Mean ± SD	Spike Performance		Spike Results	
		r	Sig.	r	Sig.
Limb muscle strength	39.67 ± 17.49	0.415	0.069	0.140	0.557
Back muscle strength	56.27 ± 22.70	0.157	0.510	0.045	0.849
Arm muscle endurance	132.70 ± 37.18	-0.356	0.123	0.027	0.911
Abdominal muscle endurance	29.00 ± 4.23	-0.145	0.542	0.044	0.855
Back muscle endurance	50.70 ± 4.84	0.190	0.423	0.400	0.080
Inner thigh muscle strength	32.41 ± 7.95	0.136	0.566	0.350	0.130
Outer thigh muscle strength	50.55 ± 9.76	-0.121	0.611	-0.086	0.719

Table 9.
The influence of strength and endurance of dominant muscles on female players (N=22)

Dominant Muscles	Mean ± SD	Spike Performance		Spike Results	
		r	Sig.	r	Sig.
Limb muscle strength	33.61 ± 10.94	0.152	0.501	0.034	0.881
Back muscle strength	33.54 ± 9.74	-0.349	0.111	0.175	0.437
Arm muscle endurance	142.68 ± 46.74	0.338	0.124	-0.144	0.523
Abdominal muscle endurance	27.95 ± 2.83	-0.391	0.072	0.374	0.087
Back muscle endurance	55.50 ± 5.99	-0.087	0.699	-0.051	0.822
Inner thigh muscle strength	25.03 ± 5.84	-0.413	0.056	0.241	0.280
Outer thigh muscle strength	39.20 ± 9.82	-0.338	0.124	0.190	0.398

Discussion

Anthropometric measurement and morphological characterization play critical roles in determining athletes' success (Kenney et al., 2015). It is necessary to gather data on the strength and endurance of muscles in order to evaluate the strength of leg and back muscles, the endurance of arm muscles, and the endurance of stomach and back muscles in order to maximize spike performance and determine the outcomes of spike. An earlier study revealed that the long-term effects of core training for knee injury prevention in adolescent volleyball players require additional investigation. In contrast, the average isokinetic strength of the hip flexors and external rotators, as well as the knee flexors and extensors, rose dramatically (Tsai et al., 2020). This situation will increase the effectiveness of spikes, although it does have to be considered regarding the role of flexibility for flexible coordination of motion during the spike (Rossato et al., 2022). And, temporary rectus abdominis fatigue reduces the jump height of the athlete and causes a change in the landing strategy (Lin et al., 2021). To empower the whole sequence from the beginning of the preparation phase to the jump phase, spike movements, and landing, it is necessary to rebuild power not only in the limbs but also in the core (particularly the rectus abdominis). Therefore, this study was considered to assess muscular strength and stamina for perfect spike movements. A study specifically examined triceps muscle condition during spike, and data showed a decrease in performance due to degradation of potassium in the muscles as a result of malnutrition, not drinking enough water, and playing in hot weather (Alsayigh et al., 2017). These factors lead to ion imbalance in the cells which result from essential potassium deficiency during muscles contraction (Alsayigh et al., 2017; Galloway, 2011). Results of a study on potassium content in triceps muscle showed the critical importance of potassium in muscle contraction, and this phenomenon occurs in all muscles in the body without exception. Aside from bone and muscle, dietary intake should be enhanced to facilitate the process in achieving optimal spike ability.

The analysis of this study demonstrates that the spike and muscle characteristics of men and women differ dramatically in their range of abilities. If the data are disaggregated by gender, the following table 7.'s notable findings for the back, abdominal, and inner thigh muscles are no longer applicable. Men, for instance, have an average score of 56 for their average back muscle, whereas women have an average score of 33. It is demonstrated by these results that the range of muscular abilities between the sexes is huge. Therefore, it is not surprising that the data generally exhibits significant differences from the combined averages of the two genders, whereas when separated, the results for each gender, men and women, will be insignificant. This remains applicable to the variable abdominal and inner thigh muscles as well. In accordance with previous research, the comparison of muscle abilities between men and women, particularly volleyball players, is completely different (Albaladejo-Saura et al., 2022).

Spike is a volleyball technique performed in two ways: single-leg or double-leg (Tai et al., 2021). Using a kinematic analysis, it is known that while doing a single-leg spike, a player runs three steps faster and exerts a greater vertical jump force, with an excellent and safe contact in the ankles, knees, and waist, a shorter jump, shorter length of the last step, shorter push-off duration, lower knee joint flexion and waist flexion at initial contact of the feet, and smaller knee joint range of motion, compared to doing a double-leg spike. Thus, this study recommends the use of a double-leg spike technique. As for spike results, particularly ball speed, the anthropometry of the upper extremity and joint rotation speed are considered as two most important criteria (Fuchs, Fusco, et al., 2019). Moreover, this study found that abdominal muscle strength is one of components of an accurate spike technique, like the finding of a previous study saying that abdominal training is needed to improve balance of the core muscles (Tsai et al., 2021). Abdominal muscle training is also recommended for reducing the risks of knee injuries among volleyball athletes.

This previous study concluded that elite and non-elite volleyball players show differences in muscular strength, arm muscle strength and aerobic endurance (Nasuka et al., 2020). Elite volleyball athletes need pre-match trainings, supported by volleyball techniques and strategies, to improve their physical conditions. Strength and endurance of the muscles—particularly of the upper and lower extremities—determine the results of a serve, passing, spike, and blocking (Nasuka et al., 2020). Various training programs allow players to practice different adaptability skills and adjust themselves optimally to techniques components that determine performance (Fuchs et al., 2020), particularly in long-term strength and aerobic training program (Kafkas et al., 2019). In addition, young players' age, the length, and age of training, as well as knowledge about techniques will contribute significantly to all motor skills of the players (Pocek et al., 2020).

In a study that involved female athletes and tried to identify the characteristics of movement during spike, it was found that the key aspects determining the height of a spike

jump includes (1) optimization of approach and energy conversion, (2) a wide range of arm swing that allows for a strong countermovement, and hence increased range of lower limb motion, and (3) high angular velocities in ankles and knees, especially on the dominant side (Fuchs, Fusco, et al., 2019). This study has generated a more specific result showing that the ability of inner thigh muscles plays a dominant role in determining the results of a spike. Limb muscle domination shows how stabilizing muscles contribute to spike results during a high jump. It is also supported by latest findings saying that motion speed of lower extremity joint is extremely important for higher jump in volleyball (Sarvestan et al., 2021). In addition to spike performance and result, other research on spike studied the initial phase of spike using a simulation of steps and revealed that the more the initial steps are taken, the greater the step length before take-off will be; this is due to changes in acceleration in initial step types that lead to greater inertial force (Santoso, Ari, 2018).

A successful spike normally follows a motion strategy which includes accelerated arm swing to make use of the momentum in the jump that will help produce greater vertical velocity during take-off. Vertical velocity is the main factor increasing jump height (Sarvestan, Svoboda, Baeyens, et al., 2020). Implementation of this strategy results in significantly higher jump and spike. Implementing this strategy will result in significantly higher take-off and spike. The successful and wrong time elevation depends on (a) knee flexion-extension angle, (b) foot flexion-extension angle, (c) dominant shoulder horizontal adduction abduction, and (d) dominant elbow flexion-extension. Take-off phase followed by faster jump in a successful trial. In general, this mechanism allows players to control their spike position and ball's direction when passing opponent's area, as well as select the best moment to hit the ball (Fuchs et al., 2020; Fuchs, Fusco, et al., 2019). Although some factors such as failure to block or set the ball may not allow them to select the best ball-hitting momentum during an attack, players can control their blocking position or spot to hit the ball to reduce external disturbances (Sarvestan, Svoboda, & Linduška, 2020).

For athletes, an adequate range of energy has been the most critical issue (Zapolska et al., 2014). For maximum results, athletes must be trained according to their genetic tendency (Galloway, 2011). For instance, an athlete with a greater proportion of slow-twitch muscle fibres will adapt better to weekly training and muscle endurance program, with more repetitions but less weight. Meanwhile, an athlete with a greater proportion of fast-twitch muscle fibres benefits greatly from sprint training and muscle strength program, with fewer repetitions but more weight (Kenney et al., 2015; Sharon A. Plowman, 2017; Van Schaardenburgh et al., 2016). Volleyball is apparently supported by type IIA muscle fibres that is fast-twitch, intermediate, and not maximal. This muscle fibre type uses aerobic and anaerobic metabolism almost equally to produce energy. Therefore, type IIA muscle fibres are a mix of Type I and Type II muscle fibres (Herrick et al., 2017). Knowing which muscle fibres are dominant will make it easier for players and coaches to implement training program considering how a balance between aerobic and anaerobic muscle fibres help future elite players adapt to all types of training.

Strength is defined as the maximum effort muscles can make against pressure. In volleyball, almost all muscles play equally important roles (Sattler et al., 2015). Strength is the maximum effort resulting from muscle contraction to overcome pressure. In a volleyball game, almost all muscles play equally important roles (Alsayigh et al., 2017; Sattler et al., 2015). The strength of arm muscle is critical in volleyball games. Arm and leg both provide dominant supports when jumping, making them inseparable. Arm strength is one of factors used in predicting the quality of volleyball players (Ahmad & Ahmad, 2018). In relation to spike motion, handgrip strength positively correlates with spike strength, with stronger handgrip generating stronger ball hits (Koley & Kaur, 2011). It is certain that strength negatively correlates with potential for injuries as excellent muscle abilities increases resistance to injuries and less frequent strength training increases the potential for injury during the game. As to volume, the more the athletes play (Lesman et al., 2020), the higher the risks of injury are, and ankles, fingers, knees, and shoulders rank from the riskiest to the least risky parts of the body (Wasser et al., 2021). To anticipate this, training program with stretching or warming-up exercises is recommended to minimize the risks of injuries (Gouttebarge et al., 2020).

Endurance is all about cardiorespiratory fitness. Aerobic endurance is related to how efficient the body is while transferring oxygen to all organs during practice. According to the World Health Organization, maximum oxygen intake (VO2max) has been the only and the best indicator for cardiorespiratory fitness. In volleyball games adopting relay point system, games are played for relatively long duration. Cardiorespiratory capacity significantly influences players' performance during the game (Ahmad & Sahar: 2019). Those with greater cardiorespiratory capacities will be able to maintain their performance, and thus increase chances to win the game. In a multi-level competition, athletes will compete with opponents having similar skills and performance. This study aims at describing power, strength and endurance among volleyball athletes based on their skill levels, although all muscles are equally dominant in volleyball (Herrick et al., 2017). However, in addition to implementing strength and endurance trainings, it is also important to add exercise that can improve coordination among male and female athletes to help them improve their spike skills (Fuchs, Menzel, et al., 2019). Indeed, strength, endurance, and coordination are not the only skills needed in volleyball. Other components such as speed, power, agility, and flexibility are necessary for developing a comprehensive bio motor skill (Bompa & Haff, 2009). In volleyball trainings or games, the role of flexibility is often forgotten although studies revealed that cyclical warmups are good for flexibility and shoulder strength among volleyball players (Çelik,

2017) and must be a part of every exercise unit (Gouttebarge et al., 2020). Players with high-speed aerobic fitness enjoy increased fitness skills (Hama & Magied, 2014).

A theoretical review defined volleyball as an anaerobic and aerobic dominant sport (Herrick et al., 2017) in which motions are repeated and performed in multiple sets, with equally distributed effort since the beginning until dozens or hundreds of repetitions. Doing this sport is not easy. Results of this study even show how back strength, abdominal endurance, and inner thigh strength significantly influence spike performance and result. Considering this, coaches are expected to consider these three components without ignoring the contributions of other bio motor components for spike performance and result. Fierce competitions have forced athletes to improve their capacities through careful preparation. Physical exercises make athletes stronger, more powerful, and more resistant to injury. Other variables need to be developed (strengthening all muscles of the upper extremity, improving spike techniques, and so forth) in addition to strengthening ankles and shoulders to improve spike speed (AKA et al., 2019). Other benefits of physical exercise include such as a faster arm swing, stronger jump, better blocking, better landing mechanism, and greater power. It is important for players to spend some time lifting weight and practice strength training regularly.

Men and women demonstrated no substantial correlation between strength and endurance alongside spike performance and results when compared across gender. It is supporting by a previous study that examined five distinct arm swing techniques during the cocking phase (Straight, Bow-and-arrow high, Bow-and-arrow low, Snap, Circular), the Straight and Bow-and-arrow high techniques were significantly less prevalent in both sexes. Therefore, there were no significant disparities between gender and playing positions in arm swing techniques (Giatsis & Tilp, 2022), however, the interaction between rotation and reception area had significant impacts on male spike performance (López et al., 2023). These various new findings can enrich understanding of coaches and help them make more specific training program with the help of biomechanics to maximize capacities and make achievement.

Conclusions

Back muscle strength and abdominal endurance are necessary for doing spike. As to results, it was found that limb muscle strength significantly influences jump results. Additionally, both men and women demonstrated no significant correlation between strength and endurance along spike performance and results.

It is expected that future studies can further investigate the internal muscles comprehensively. It is also expected that volleyball practitioners can consider this study results while creating and implementing strength-training program for young athletes.

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Conflict of interest

The authors declare that there are no conflicts of interest.

References

Albaladejo-Saura, M., Vaquero-Cristóbal, R., García-Roca, J. A., & Esparza-Ros, F. (2022). The Effect of Age, Biological Maturation and Birth Quartile in the Kinanthropometric and Physical Fitness Differences between Male and Female Adolescent Volleyball Players. *Children*, *9*(1). https://doi.org/10.3390/children9010058

Alnedral, Zonifa, G., & Yendrizal. (2020). A volleyball skills test instrument for advanced-level students. *Journal of Physical Education and Sport*. https://doi.org/10.7752/jpes.2020.s3297

Alsayigh, H. A., Athab, N. A., & Ghazi, F. M. (2017). The study of electrical activity of the triceps brachia muscle according to the chemical changes of Water Loss during Spike in Volleyball. *Journal of Global Pharma Technology*.

Fuchs, P. X., Fusco, A., Bell, J. W., von Duvillard, S. P., Cortis, C., & Wagner, H. (2019). Movement characteristics of volleyball spike jump performance in females. *Journal of Science and Medicine in Sport*, *22*(7), 833–837. https://doi.org/10.1016/j.jsams.2019.01.002

Fuchs, P. X., Fusco, A., Bell, J. W., von Duvillard, S. P., Cortis, C., & Wagner, H. (2020). Effect of differential training on female volleyball spike-jump technique and performance. *International Journal of Sports Physiology and Performance*. https://doi.org/10.1123/ijspp.2019-0488

Fuchs, P. X., Menzel, H.-J. K., Guidotti, F., Bell, J., von Duvillard, S. P., & Wagner, H. (2019). Spike jump biomechanics in male versus female elite volleyball players. *Journal of Sports Sciences*, *37*(21), 2411–2419. https://doi.org/10.1080/02640414.2019.1639437

Galloway, S. (2011). Exercise Biochemistry. In *Sport and Exercise Nutrition*. https://doi.org/10.1002/9781444344905.ch3

Giatsis, G., & Tilp, M. (2022). Spike Arm Swing Techniques of Olympics Male and Female Elite Volleyball Players (1984-2021). *Journal of Sports Science and Medicine*, *21*(3), 465–472. https://doi.org/10.52082/jssm.2022.465

Gouttebarge, V., Barboza, S. D., Zwerver, J., & Verhagen, E. (2020). Preventing injuries among recreational adult volleyball players: Results of a prospective randomised controlled trial. *Journal of Sports Sciences*, *38*(6), 612–618. https://doi.org/10.1080/02640414.2020.1721255

Kafkas, A., Kafkas, M. E., & Savaş, S. (2019). Effect of long-term training adaptation on isokinetic strength in college male volleyball players. *Physical Education of Students*. https://doi.org/10.15561/20755279.2019.0504

Kenney, W. L., Wilmore, J. H., & Costil, D. L. (2015). Physiology of Sport and Exercise. Sixth Edition. In *Human Kinetics*.

Lakhdar, L., & Zerf, M. (2019). Maximal aerobic speed as a useful tool to understand specific training demand among elite male volleyball. *Pedagogy and Psychology of Sport*. https://doi.org/10.12775/pps.2019.05.01.001

Lesman, J., Jóźwik, M., Domżalski, M. E., Luceri, A., Mangiavini, L., Peretti, G. M., & Luceri, F. (2020). Sport injuries in professional volleyball players. *Journal of Biological Regulators and Homeostatic Agents*.

Lin, H. T., Huang, Y. C., Li, Y. Y., & Chang, J. H. (2021). The effect of rectus abdominis fatigue on lower limb jumping performance and landing load for volleyball players. *Applied Sciences (Switzerland)*, *11*(15). https://doi.org/10.3390/app11156697

López, E., Molina, J. J., Díaz-Bento, M. S., & Díez-Vega, I. (2023). Spike performance in K1: influence of rotation and reception area on high level men's volleyball teams. *Retos*, *48*, 213–221. https://doi.org/10.47197/retos.v48.93875

Nasuka, N., Setiowati, A., & Indrawati, F. (2020). Power, strength and endurance of volleyball athlete among different competition levels. *Utopia y Praxis Latinoamericana*. https://doi.org/10.5281/zenodo.4155054

Pocek, S., Vukovic, J., Jaksic, D., Lakicevic, N., Messina, G., Bianco, A., & Drid, P. (2020). Fitness profile of young female volleyball players. *Medicina Dello Sport*. https://doi.org/10.23736/S0025-7826.20.03698-4

Rossato, J., Tucker, K., Avrillon, S., Lacourpaille, L., Holobar, A., & Hug, F. (2022). Less common synaptic input between muscles from the same group allows for more flexible coordination strategies during a fatiguing task. *Journal of Neurophysiology*, *127*(2), 421–433. https://doi.org/10.1152/jn.00453.2021

Sarvestan, J., Svoboda, Z., Baeyens, J. P., & Serrien, B. (2020). Whole body coordination patterning in volleyball spikes under various task constraints: exploratory cluster analysis based on self-organising maps. *Sports Biomechanics*. https://doi.org/10.1080/14763141.2020.1788132

Sharon A. Plowman, D. L. S. (2017). Exercise Physiology for Health, Fitness, and Performance. In *Journal of Chemical Information and Modeling*.

Tai, W. H., Peng, H. Te, Song, C. Y., Lin, J. Z., Yu, H. Bin, & Wang, L. I. (2021). Dynamic characteristics of approach spike jump tasks in male volleyball players. *Applied Sciences (Switzerland)*. https://doi.org/10.3390/app11062710

Tsai, Y.-J., Chia, C.-C., Lee, P.-Y., Lin, L.-C., & Kuo, Y.-L. (2020). Landing Kinematics, Sports Performance, and Isokinetic Strength in Adolescent Male Volleyball Athletes: Influence of Core Training. *Journal of Sport Rehabilitation*, *29*(1), 65–72. https://doi.org/10.1123/jsr.2018-0015

Van Schaardenburgh, M., Wohlwend, M., Rognmo, Ø., & Mattsson, E. J. R. (2016). Mitochondrial respiration after one session of calf raise exercise in patients with peripheral vascular disease and healthy older adults. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0165038

Wasser, J. G., Tripp, B., Bruner, M. L., Bailey, D. R., Leitz, R. S., Zaremski, J. L., & Vincent, H. K. (2021). Volleyball-related injuries in adolescent female players: an initial report. *Physician and Sportsmedicine*. https://doi.org/10.1080/00913847.2020.1826284