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Research Article

The Effect of TRX Training on Spike-Serve Speed and Grip Strength in Adolescent Volleyball Players

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Abstract: In volleyball, performance components such as spike speed, serve speed, and grip strength are critical for athletic success. This study investigated the effects of an eight-week TRX training program on these variables in female volleyball players aged 12 to 14. Participants were randomly assigned to a TRX training group (TRX-G, n=16) or a serve and spike training group (SS-G, n=16). Pre- and post-tests measured spike speed, serve speed, and grip strength. Repeated measures ANOVA and correlation analyses were used to analyze the data. The TRX-G showed significant improvements in spike speed ($p<0.01$), serve speed ($p<0.001$), and grip strength ($p<0.001$). The SS-G improved only in serve speed ($p<0.05$). Between-group comparisons revealed that TRX training was significantly more effective across all performance measures ($p<0.001$). A significant positive correlation was found between spike and serve speed ($r=0.62$; $p<0.01$), while grip strength showed no significant relationship with speed variables. These findings suggest that TRX training effectively enhances key volleyball performance skills and may be integrated into training routines to support athletic development in youth volleyball players.

Keywords: Grip strength, serve speed, spike speed, TRX, volleyball.

1. Introduction

Volleyball is a team sport played on a confined court that requires multidimensional performance capacities (Orkunoğlu, 1997). Enhancing the physical and conditional attributes of players is essential for optimizing their overall performance in the sport (Gabbett & Georgieff, 2007). During this stage, targeted training programs are implemented to improve specific motor abilities such as speed, explosive power, and agility, among which muscular strength plays a foundational role in elevating athletic performance (Atıcı & Bayrakdar, 2025). In volleyball, the development of shoulder flexors and antagonist muscles is particularly critical for generating forceful and technically efficient movements, especially during offensive actions such as spiking (Cingel et al., 2006). The spike is considered one of the most decisive actions influencing the outcome of a set or match (Marcelino et al., 2008). Consequently, spike performance is frequently monitored in training and match settings, with metrics such as ball speed and shot accuracy used to assess effectiveness (Cisar & Corbelli, 1989). Research has indicated that while the average hand speed during ball contact is approximately 13 km/h, elite volleyball players can generate ball velocities of up to 120 km/h (Kugler et al., 1996).

The biomechanical process of spiking and serving is commonly segmented into four distinct phases: the approach, arm cocking, arm acceleration, and follow-through. These phases function in a coordinated manner within the kinetic chain, facilitating the shift of the athlete's center of mass from a horizontal to a vertical orientation. Effective performance in these movements necessitates coordinated activation of the hip, trunk, shoulder, elbow, and wrist musculature (Wagner

et al., 2014; Reeser et al., 2010). Notably, key muscle groups activated during spiking and serving include the shoulder internal rotators, anterior deltoid, teres major, latissimus dorsi, and pectoralis major (Rokito et al., 1998).
TRX suspension training, originally developed by the U.S. Navy SEALs in 2002–2003 to maintain conditioning without access to traditional equipment, has emerged as a viable method for targeting the musculature integral to volleyball performance, particularly the shoulder complex. The TRX system utilizes a portable, adjustable strap apparatus that can be anchored to various points and adapted for a wide range of bodyweight-based exercises (Açak, 2024). Its versatility, portability, and capacity for progressive resistance make it accessible across training contexts. The fundamental principle of TRX training involves suspending the body against gravity, thereby creating instability and requiring neuromuscular control, core engagement, and multi-planar strength development. This instability is thought to enhance joint stabilization, proprioception, and overall functional strength (Ghervan, 2014; Rostami et al., 2023).
In volleyball, complex motor skills such as spiking, serving, and blocking demand both upper and lower extremity strength as well as the efficient application of that strength (Sheppard et al., 2009). Accordingly, functional strength—defined as strength expressed in sport-specific movement patterns—is a key determinant of performance. TRX training, as a form of functional training, has gained popularity for its ability to meet the sport-specific demands of volleyball, particularly in supporting multi-directional movement and core stabilization. Studies comparing traditional resistance training with TRX-based programs suggest that TRX may elicit superior muscle activation and enhance force transmission efficiency (Carbonnier & Martinson, 2012). Furthermore, TRX training has been associated with technical improvements in skill execution and greater control of scapular motion, contributing to more effective force production in the spike and serve (Tomljanovic et al., 2011; Dawes, 2017).

TRX exercises promote shoulder mobility and stability, potentially allowing for more powerful overhead movements. Enhanced neuromuscular coordination between the core and shoulder girdle, fostered by TRX training, may improve kinetic chain efficiency and thereby contribute to increased spike and serve velocities (Willardson, 2007). Despite the growing interest in TRX and its documented benefits for balance, muscular strength, and core stability (Snarr & Esco, 2014), limited empirical research has directly examined its effects on specific volleyball performance indicators such as spike speed, serve speed, and hand grip strength. These parameters are critical contributors to individual and team success in volleyball. The present study, therefore, seeks to address this gap by investigating the effects of an eight-week TRX training program on these key performance metrics in adolescent female volleyball players aged 12–14.

2. Materials and Methods

2.1. Research Design

This study employed a pre-test–post-test comparative experimental design with two intervention groups to examine the effects of an 8-week TRX training program and a spike–serve training program on spike speed, serve speed, and hand grip strength in adolescent volleyball players (Büyüköztürk, 2018).

2.2. Research Group

The population of the study consisted of volleyball players actively engaged in sports schools in the province of Çanakkale. The sample was determined using a purposeful sampling method and included 32 volleyball players aged between 12 and 14, who had been regularly training for at least two years, were affiliated with Çanakkale Fenerbahçe Sports School, and had no known health issues. The participants were homogeneously divided into two groups:spike and serve training group (SS-G, n = 16) and TRX training group (TRX-G, n = 16).

The required sample size was calculated using the G*Power software. For a dependent samples t-test with an effect size of d = 0.8 and a test power of 99% (1-β), the required number of participants was determined to be 31 (Faul et al., 2007). To increase statistical power, one additional participant was included in the study.

2.3. Training Protocol

In addition to their regular volleyball training twice per week, the SS-G performed only spike and serve drills, while the TRX-G completed a structured TRX training program. The TRX program consisted of 9 exercises: Row, Push-ups, Triceps Extension, Chest Press, T-Fly, Standing Ab Rollout, Biceps Curl, Roll Ups, and Saw Pikes. The training was performed twice per week on non-training days over a period of 8 weeks. Exercise design and progression were based on the TRX training manual by Dawes (2017).

The SS-G continued their regular volleyball sessions supplemented by 20 minutes of spike drills and 20 minutes of serve practice twice a week, matching the additional training volume of the TRX-G group.

Table 1. The 8-Week TRX Training Program

Movement	Training Volume		Movement	Training Volume	
	First 4 weeks	Second 4 weeks		First 4 weeks	Second 4 weeks
Row	Tuesday & Thursday 2x15	Tuesday & Thursday 3x15	Push Ups	Tuesday & Thursday 2x15	Tuesday & Thursday 3x15
Triceps	Tuesday & Thursday 2x15	Tuesday & Thursday 3x15	Chest Press	Tuesday & Thursday 2x15	Tuesday & Thursday 3x15
T-Fly	Tuesday & Thursday 2x15	Tuesday & Thursday 3x15	Standing Ab Rollout	Tuesday & Thursday 2x15	Tuesday & Thursday 3x15
Biceps Curl	Tuesday & Thursday 2x15	Tuesday & Thursday 3x15	Roll Ups	Tuesday & Thursday 2x15	Tuesday & Thursday 3x15
Saw Pikes	Tuesday & Thursday 2x15	Tuesday & Thursday 3x15			

2.4. Data Collection

This study was approved by the Çanakkale Onsekiz Mart University Institute of Graduate Education Scientific Research Ethics Committee (Decision Date: 23.11.2023; Decision No: 14/11). Since the participants were minors, informed consent was obtained from their parents or legal guardians. Participants also completed a personal information form and were verbally informed about the procedures. Pre-test and post-test measurements included height (cm), body weight (kg), spike speed (km/h), serve speed (km/h), and hand grip strength (kg), collected before and after the 8-week intervention period.

2.4.1. Spike and serve speed measurement

Spike and serve speeds were measured using the V-MAXX Speed Radar, a Doppler radar-based system with demonstrated validity and reliability. The device operates at a frequency of 24.150 GHz and can measure speeds ranging from 4–199 km/h, with an accuracy tolerance of less than 1.5 km/h (Bitter, 2009).

All participants completed a standardized 10-minute warm-up prior to testing. For spike measurement, participants stood on a 60 cm platform at position 4 on the court and performed a non-jumping spike over the net toward the radar positioned 5 meters away. For serve measurement, participants executed three tennis-style serves from behind the service line. The fastest successful attempt was recorded (Palao & Valades, 2009; Cingel et al., 2006).

2.4.2. Anthropometric Measurements

Body Weight: Measured using a digital Aprilla scale with 0.1 kg precision.

Height: Measured with a Mesilife wall-mounted stadiometer with 0.01 m sensitivity.

Hand Grip Strength: Assessed using a Lafayette (USA) brand hand dynamometer. Each participant used their dominant hand, and the best of two attempts was recorded (Dhara et al., 2009).

2.5. Data Analysis

All statistical analyses were conducted using SPSS. The Shapiro-Wilk test confirmed normal distribution of the data (p > 0.05). Paired sample t-tests were used for within-group comparisons. Independent sample t-tests were used to compare the pre-post differences between the TRX-G and SS-G. Effect sizes were calculated using Cohen's d. In addition, to examine the relationships between spike speed, serve speed, and hand grip strength in the post-test results of each group, Pearson correlation analysis was performed separately for the the TRX-G and SS-G. Statistical significance was set at p < 0.05.

2.6. Ethical Approval

The necessary ethical approval for this study was obtained from the Çanakkale Onsekiz Mart University Graduate Education Institute Ethics Committee, with the decision dated 24.10.2024 and numbered 15/36. All procedures were conducted in accordance with the principle of voluntary participation and adhered strictly to ethical standards. The research was carried out in line with the Directive on Scientific Research and Publication Ethics of Higher Education Institutions and the ethical principles of the Declaration of Helsinki. Prior to data collection, participants were fully informed about the purpose and procedures of the study and subsequently provided written consent.

3. Results

Table 2. Descriptive Statistics of Participants' Demographic Characteristics

Variables	Group	n	$\bar{X}$	±
Height (cm)	TRX-G	16	167	6.97
	SS-G	16	165	4.59
Weight (kg)	TRX-G	16	51.1	7.56
	SS-G	16	55.0	7.73
Age (years)	TRX-G	16	14.7	0.704
	SS-G	16	14.9	0.806

Descriptive statistics summarizing the demographic characteristics of the study participants are provided in Table 2. The average height of the participants in the TRX-G was determined as 167 ± 6.97 cm, while the average height in the SS-G was 165 ± 4.59 cm. The body weight of the TRX-G was found to be 51.1 ± 7.56 kg, and 55.0 ± 7.73 kg in the SS-G. In terms of age, the average age in the TRX-G was 14.7 ± 0.704 years, while the SS-G had an average age of 14.9 ± 0.806 years.

Table 3. Comparison of Pre-Test Results Between Groups

Variables	TRX-G (n: 16)		SS-G (n: 16)		t	p
	$\bar{X}$	±	$\bar{X}$	±		
Serve speed (km/h)	37.1	4.76	37.8	1.73	-0.587	0.566
Spike speed (km/h)	41.6	4.21	39.9	1.91	1.606	0.129
Grip strength (kg)	22.6	2.90	23.1	3.38	-0.449	0.660

The results of the independent samples t-test conducted to compare the pre-test values of the TRX-G and SS-G before the 8-week training program are presented in Table 3. According to the results, there was no statistically significant difference between the groups in terms of serve speed (TRX-G: 37.1 ± 4.76 km/h, SS-G: 37.8 ± 1.73 km/h, p = 0.566), spike speed (TRX-G: 41.6 ± 4.21 km/h, SS-G: 39.9 ± 1.91 km/h, p = 0.129), and grip strength (TRX-G: 22.6 ± 2.90 kg, SS-G: 23.1 ± 3.38 kg, p = 0.660). These findings indicate that both groups were homogeneous in terms of initial performance levels.

Table 4. Within-Group Comparison of Pre-Test and Post-Test Results

Group	Variable	Pre-test		Post-test		t	p	d
		$\bar{X}$	±	$\bar{X}$	±			
TRX-G (n: 16)	Serve speed (km/h)	37.1	4.76	43.8	5.54	-10.08	< .001	-2.52
	Spike speed (km/h)	41.6	4.21	51.3	6.23	-7.75	< .001	-1.94
	Grip strength (kg)	22.6	2.90	26.5	2.99	-9.77	< .001	-2.44
SS-G (n: 16)	Serve speed (km/h)	37.8	1.73	38.4	2.06	-2.440	0.028	-0.610
	Spike speed (km/h)	39.9	1.91	40.3	2.41	-1.192	0.252	
	Grip strength (kg)	23.1	3.38	23.2	3.35	-0.436	0.669	

Table 4 presents the results of the dependent samples t-test used to examine within-group changes from pre-test to post-test. In the TRX-G, a statistically significant improvement was observed in all measured variables after the 8-week training program. Serve speed increased from 37.1 ± 4.76 km/h to 43.8 ± 5.54 km/h (p < .001, d = -2.52), spike speed increased from 41.6 ± 4.21 km/h to 51.3 ± 6.23 km/h (p < .001, d = -1.94), and grip strength increased from 22.6 ± 2.90 kg to 26.5 ± 2.99 kg (p < .001, d = -2.44). These changes also showed large effect sizes. In the SS-G, a statistically significant increase was observed only in serve speed, which increased from 37.8 ± 1.73 km/h to 38.4 ± 2.06 km/h (p = 0.028, d = -0.61). However, no significant changes were found in spike speed (39.9 ± 1.91 km/h to 40.3 ± 2.41 km/h, p = 0.252) or grip strength (23.1 ± 3.38 kg to 23.2 ± 3.35 kg, p = 0.669).

Table 5. Comparison of Pre-Test/Post-Test Difference Scores Between Groups

Variable	TRX-G (n: 16)		SS-G (n: 16)		t	p	d
	$\bar{X}$	±	$\bar{X}$	±			
Serve speed (km/h)	6.62	2.630	0.62	1.025	9.49	< .001	2.37
Spike speed (km/h)	9.68	5.003	0.75	0.775	6.91	< .001	1.73
Grip strength (kg)	3.87	1.586	0.56	0.727	8.17	< .001	2.04

To better demonstrate the effect of the TRX training program, Table 4 shows the results of an independent samples t-test comparing the difference scores (post-test minus pre-test) between the TRX-G and SS-G. The average increase in serve speed was 6.62 ± 2.63 km/h in the TRX-G, compared to 0.62 ± 1.03 km/h in the SS-G (p < .001, d = 2.37). Similarly, spike speed increased by 9.68 ± 5.00 km/h in the TRX-G and 0.75 ± 0.78 km/h in the SS-G (p < .001, d = 1.73). For grip strength, the TRX-G showed an increase of 3.87 ± 1.59 kg, whereas the SS-G showed only 0.56 ± 0.73 kg improvement (p < .001, d = 2.04). These findings demonstrate that the TRX training program led to significant and high-level performance improvements in serve speed, spike speed, and grip strength compared to the SS-G.

Table 6. Correlation Analysis of TRX-G Post-Test Results

Variables	p	1	2	3
Serve Speed (km/h)	r	-		
	p	-		
Spike Speed (km/h)	r	0.642**	-	
	p	0.007	-	
Grip Strength (kg)	r	0.008	0.104	-
	p	0.976	0.702	-

1: Serve Speed, 2: Spike Speed, 3: Grip Strength

When the correlation analysis results of the TRX-G's post-test data were examined (Table 5), a positive and statistically significant correlation was found between spike speed and serve speed (r = 0.642, p = 0.007). This suggests that athletes with higher spike speeds tend to also have higher serve speeds. However, no statistically significant correlation was found between grip strength and serve speed (r = 0.008, p = 0.976), nor between grip strength and spike speed (r = 0.104, p = 0.702).

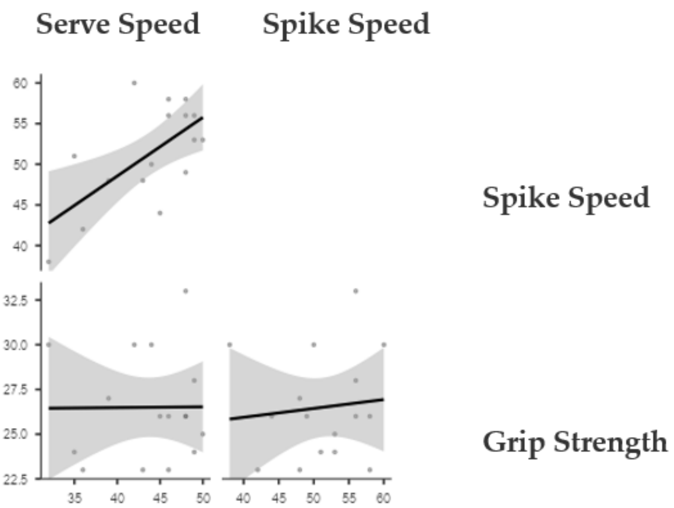

Figure 1. Correlation Graph of TRX-G Post-Test Results

Figure 1 presents the visual distribution of correlations among spike speed, serve speed, and grip strength based on the post-test results of the TRX-G.

Table 7. Correlation Analysis of SS-G Post-Test Results

Variables		1	2	3
Serve Speed (km/h)	r	-		
	p	-		
Spike Speed (km/h)	r	0.484	-	
	p	0.058	-	
Grip Strength (kg)	r	-0.040	-0.082	-
	p	0.884	0.763	-

1: Serve Speed, 2: Spike Speed, 3: Grip Strength

As shown in Table 7, in the SS-G's post-test results, there was a positive but statistically non-significant correlation between spike speed and serve speed ($r = 0.484$, $p = 0.058$). Additionally, no significant correlations were found between grip strength and serve speed ($r = -0.040$, $p = 0.884$), nor between grip strength and spike speed ($r = -0.082$, $p = 0.763$). These findings suggest that unlike in the TRX-G, performance variables in the SS-G were less interrelated.

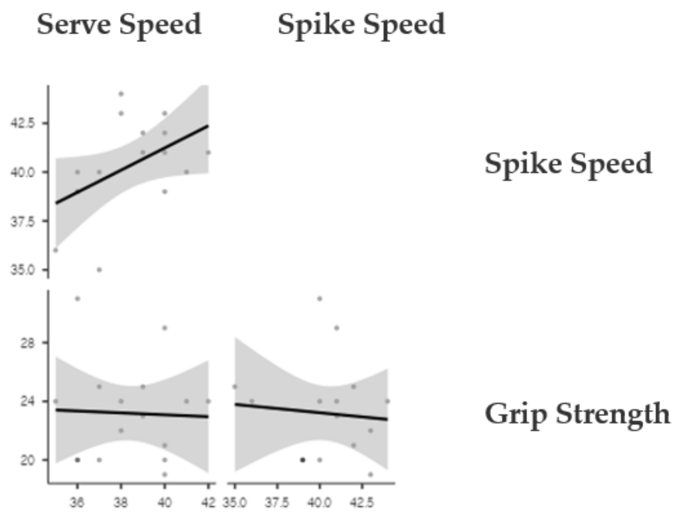

Figure 2. Correlation Graph of SS-G Post-Test Results

Figure 2 presents the visual distribution of correlations among spike speed, serve speed, and grip strength based on the post-test results of the SS-G.

4. Discussion

This study examined whether TRX training has a greater effect on spike speed, serve speed, and grip strength in 12-14-year-old volleyball players compared to performing only serve and spike exercises. The main finding was that adding TRX training to regular volleyball practice significantly increased spike speed, serve speed, and grip strength after an 8-week training period. Conversely, serve and spike exercises combined with standard volleyball training led to an increase only in serve speed. When comparing changes between the two training methods based on repeated measures, it was shown that TRX training improved spike speed, serve speed, and grip strength more effectively than serve and spike exercises alone.

In volleyball, pivotal actions such as spiking and serving involve rapid, explosive movements, including sprinting, vertical jumping, and ball striking, which are typically responsible for scoring the majority of points in a match (Challoumas et al., 2018; Drikos & Vagenas, 2011; Marcelino et al., 2009; Palao et al., 2004). Both spikes and serves follow a similar motor sequence composed of four phases: approach, arm pull, arm acceleration, and follow-through (Reeser et al., 2010; Wagner et al., 2014). These phases work in concert to maximize momentum transfer through the kinetic chain, facilitating the acceleration of the body's center of mass from a horizontal to a vertical axis (Wagner et al., 2009). Consequently, the efficient transfer of force to the ball depends on the coordinated activation of musculature involving the hip, trunk, shoulder, elbow, and wrist (Reeser et al., 2010; Wagner et al., 2014; Coleman et al., 1993).

Before the study, it was hypothesized that TRX training would enhance spike speed, serve speed, and grip strength more than traditional spike and serve training, regardless of the underlying physiological mechanisms. The results support this hypothesis. The improvements seen in the TRX group are likely due to the training's ability to simultaneously enhance mobility, muscle strength, and joint stability across all anatomical planes, as well as positively influence the motor control system by improving proprioceptive accuracy (Khorjahani et al., 2021), thereby increasing movement precision.

Previous research has documented muscle adaptation and strength gains from TRX training (Ghervan, 2012; Janot et al., 2013; McGill et al., 2014; Byrne et al., 2014; Pancar et al., 2021). However, studies focusing on adolescent volleyball players are scarce. This limits direct comparisons, yet findings from similar populations support the current results. For example, Özdamar et al. (2023) showed that TRX training improved spike speed more than traditional weight training in young volleyball players, consistent with our results. Similarly, Yıldız and Savaş (2022) reported that a TRX-based core training program significantly increased spike and serve speeds in volleyball players aged 15-20. Other studies in different populations, such as male police cadets (Zhang, 2018) and female university students (Kiani & Fattahi, 2021), also found TRX training effective for improving muscle strength and core endurance compared to other methods. In adolescent female wrestlers, TRX training improved maximal muscle strength and sport-specific skills (Elashram et al., 2024). Taken together, these findings suggest that TRX training, through its impact on proprioceptive feedback, is an effective alternative to instrumented resistance exercises.

Correlation analysis of the TRX-G's post-test data revealed a positive relationship between spike and serve speed, but no significant relationship between grip strength and these skills. While literature on the spike-serve speed relationship is limited, some studies indicate that these skills share similar physiological and mechanical characteristics, supporting a positive correlation. Baena-Raya et al. (2021) found that force-speed profiles, assessed through vertical jump, sprint, and chest shot tests, were related to spike and serve speeds in male volleyball players. Das et al. (2015) also reported positive correlations between arm and back strength and spike/serve speed, highlighting the role of strength development in these skills.

Despite TRX training improving grip strength in our study, no correlation was found between grip strength and spike or serve speed. Moghimiinchehboroun (2024) similarly found that although grip strength increased after an 8-week program, it was not related to serve speed. Contrarily, Das et al. (2015) reported moderate correlations between grip strength and spike/serve speeds. Differences in sample age, sports experience, and training program content may explain these discrepancies.

5. Conclusions

This study is limited to young female volleyball players and an eight-week intervention focusing on TRX versus traditional serve and spike exercises. Although literature supports TRX's benefits for muscle strength, further research is needed to compare its effects with other training methods in similar populations. Currently, few studies exist with participants comparable to our sample. Nevertheless, findings suggest that TRX training is an effective functional training method that can be integrated into programs aimed at increasing spike and serve speeds in young female volleyball players.

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