Impact of training on flight time in female volleyball players aged 13-14 years

Impacto del entrenamiento en el tiempo de vuelo en jugadoras de voleibol de 13 a 14 años

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Abstract

Introduction: Vertical jump is a fundamental element of volleyball performance, particularly for young athletes whose physical development is still in progress.
Objective: The purpose of the study was to determine whether an 11-week circuit training regimen can improve volleyball players' jump height during the contact time and flight time phases.
Methodology: 50 female volleyball players were randomly selected from 4 sports associations in Tirana, Albania, and were divided into two groups: the experimental group (no = 25; 13.8±0.6 years; Body Height 167.1±3.8 cm; Body Weight 54.74± 4.3 kg and BMI kg/m² 19.54±3.3%) and the control group (no = 25; 13.9±0.1 years, Body Height 165.3±2.3 cm; Body Weight 53.4±3.6 kg and BMI kg/m² 20.92±1.4%). The experimental group was subjected to an 11-week circuit training program, 3 times a week with a duration of 15 minutes. Both groups were assessed for Squat Jump (SJ), Countermovement Jump (CMJ) and 20-cm Drop Jump (20-cm DJ), before and after the intervention.
Results: Vertical Jump flight time performance in the experimental group improved by 0.04 seconds, while in the control group by 0.02 seconds. No significant difference was observed in strength performance in the experimental group (P > 0.05).
Discussion: The findings suggest slight improvements in flight time that are consistent with results from similar training-based interventions in adolescent athletes, although statistical significance was not achieved.
Conclusions: It is concluded that circuit training may contribute positively to vertical jump performance by enhancing flight time, indicating potential improvements in explosive strength among young female volleyball players.

Keywords

Circuit; females; jump; training; volleyball.

Resumen

Introducción: El salto vertical es un elemento fundamental del rendimiento en voleibol, especialmente en atletas jóvenes cuyo desarrollo físico aún está en curso.
Objetivo: El propósito del estudio fue evaluar si un entrenamiento en circuito de 11 semanas mejora el salto vertical en voleibol, específicamente el tiempo de contacto y el tiempo de vuelo.
Metodología: 50 jugadoras fueron seleccionadas aleatoriamente de 4 asociaciones deportivas en Tirana, Albania, y dividas en dos grupos: el grupo experimental (n = 25; 13,8 ± 0,6 años; altura corporal 167,1 ± 3,8 cm; peso corporal 54,74 ± 4,3 kg e IMC kg/m² 19,54 ± 3,3%) y el grupo de control (n = 25; 13,9 ± 0,1 años, altura corporal 165,3 ± 2,3 cm; peso corporal 53,4 ± 3,6 kg e IMC kg/m² 20,92 ± 1,4%). El grupo experimental realizó entrenamiento en circuito durante once semanas, tres veces por semana, con sesiones de quince minutos. Ambos grupos fueron evaluados para salto vertical (SJ), salto con contra movimiento (CMJ) y Salto de caída de 20 cm (20-cm DJ), antes y después de la intervención.
Resultados: El tiempo de vuelo mejoró 0,04 segundos en el grupo experimental y 0,02 segundos en el grupo de control, sin diferencias significativas en la fuerza (P > 0,05).
Discusión: Estos resultados son consistentes con investigaciones similares en atletas adolescentes, que también reportaron mejoras leves sin alcanzar significación estadística.
Conclusiones: Se concluye que el entrenamiento en circuito mejora el tiempo de vuelo, sugiriendo mejoras en la fuerza explosiva de las jugadoras.

Palabras clave

Circuito; entrenamiento; hembras; salto; voleibol.

Introduction

Collective sports perform differently because of their game characteristics. Therefore, specific training is required to address the differences in the physical qualities of individual players and team performance. Volleyball, on its part, is a sport that requires strength in the upper and lower limbs (Forthomme et al., 2005). The development of muscular strength and the acquisition of specific technical skills are particularly important factors in achieving success for young players, especially for female athletes (Malousaris et al., 2007; Marques et al., 2009). Many studies have been conducted to understand the best training program required to develop the total body performance of a volleyball player, which might be explained by the enormous popularity of the sport (Felicissimo et al., 2012). Vertical jump, which is an important common element for a number of sports, is crucial in volleyball and its perfection is achieved through specific training that aims to increase the height of the jump. A vertical jump that is preceded by a rapid Stretch-Shortening Cycle (SSC) is called a countermovement jump (CMJ), as opposed to a jump that is not immediately preceded by a pre-stretch, for example a squat jump (SJ) (Baker, 1996). Tests such as the 20-cm Drop Jump (Bosco & Komi, 1979), can help determine the optimal drop height from which a volleyball player obtains the maximum jump and the relationship between the drop height, contact time and flight time.

Some studies have shown that both, plyometric exercises and weight training programs increase vertical jump performance, but combined programs show the greatest improvement in the vertical jump performance (Bendo & Mara, 2020). To achieve maximum efficiency in plyometric exercises, weights are implemented with the objective of greater force production in order to overcome resistance, which in turn generates greater muscular effort and consequently, greater strength in athletes (Silva et al., 2019; Marzano-Felisatti et al., 2022). Some authors have reported (Voelzke et al., 2012) that commanded plyometric training exercises are effective in boosting volleyball players' jump, speed, and skills. On the other hand, Vilela and colleagues (2020) report that plyometric training did not have positive effects on the jump performance of pubescent girls, who play volleyball.

A combined 8-week jump and ball toss training has been reported to improve muscle performance in young female volleyball players (Pereira et al., 2015). Therefore, coaches need to introduce exercises that take less time and help improve their players' vertical jumping ability. In line with the findings of past research, training to increase jumping height has focused on the role of building muscle strength through strength training exercises (Aragón-Vargas & Gross, 1997).

Research shows that vertical jump height also depends on the elastic energy stored by skeletal muscles through the strength of the muscle-tendon connection influencing the onset of concentric movement in increased jumping performance (Cavagna et al., 1968). According to existing research, it is crucial to know which is the most favorable period to develop and improve vertical jump (Cometti G & D, 2009). Several studies have focused on drop jumps and the possible effects of plyometric training; (Pacheco et al., 2011) concluding that static stretching has a significant effect on 40-cm drop jumps (Tsolakis et al., 2010); static stretching does not have a statistically significant effect on drop jumps (Behm & Kibele, 2007); static stretching maintained for 30s significantly decreases drop jump height (Fletcher, 2012); drop jump height increases significantly after a warm-up including resistance training and dynamic stretching. Soto (2023) suggests focusing on explosive strength with volleyball young players, considering the individual's sports experience and physiological development; it is also important that training programs include other components (e.g., strength and speed training, nutritional advice, and/or mental health counselling) that could influence explosive strength.

The majority of studies are based only on plyometric training in volleyball players, but not on the methodology that specific exercises require. Oliveira et al. (2023) suggest that further studies should look at the mechanisms that lead to improvements in horizontal jump, and the plyometric training program should possibly include more horizontal jump exercises to optimize this ability, as horizontal jumps have had moderate effects on volleyball players' performance, implying that coaches include more horizontal jumps in training programs to develop players' ability and improve their speed and lateral movement skills. Volleyball requires strength to be produced in both the vertical and horizontal planes of motion, but limited research has been conducted on the effect of plyometric training on horizontal jumping (Silva et al., 2019).

Circuit training is a form of body conditioning that involves endurance training, resistance training, and high-intensity aerobic exercises executed in a circuit, similar to high-intensity interval training. It targets building of strength and muscular endurance. Intervals between exercises in circuit training are short and transitioning to the next exercise is often achieved by a quick movement (Comyns, 2018). The training circuit does not require a long time to be completed.

Studying the effects of circuit training on jumping performance is a fairly new and promising field for Albanian volleyball players and coaches. The work of coaches with young players is more focused on technical elements. However, coaches need to spend some time during training to develop other physical components of volleyball players, such as jumping, speed, dexterity, strength, etc.

The purpose of the study was to determine whether 11 weeks of circuit training, over 15-20-min-sessions, three times a week, can improve volleyball players' jumping height, and compare through some tests jumping ability in the contact time phase and flight time phase.

Method

Participants

50 female volleyball players from 4 Sports Associations in Tirana, Albania were randomly selected for our study and were randomly divided into the Experimental group (EX-No. 25) and the Control group (CO-No. 25). The subjects are girls who play volleyball, with a minimum of a 2-year-experience and who train 3 (three) times a week, for 90 minutes. It was attempted that all subjects selected for the study from the 4 Sports Associations were comparable in terms of age, experience at competitive level and training practices; training hours, as well as training days, were similar between groups.

Both groups (EX & CO) included in the study were subjected to anthropometric measurements. According to the values presented in (Table 1), there was no significant difference in anthropometric measurements between the two groups.

Table 1. Anthropometric measurements of the female volleyball players

Measure	EX	CO
Age	(13.80 ± 0.60)	(13.9 ± 0.12)
BH cm	(167.10 ± 3.82)	(165.3 ± 2.36)
BW kg	(54.74 ± 4.35)	(53.4 ± 3.62)
BMI%	(19.54 ± 3.32)	(20.92 ± 1.46)

Body Height (BH), Body Weight (BW) and BMI kg/m^2 (BMI%).

Procedure

The intervention procedure was explained to all the volleyball players, who conceded to take part in the study. This study obtained approval from the Ethics Council of the Sports University of Tirana, Albania, and all participants and their parents/coaches signed a written informed consent, in accordance with the ethical standards of the Declaration of Helsinki.

Leonardo® Ground Reaction Force Plate (GRFP) platform was used to measure vertical jump of all subjects, before and after the 11-week intervention, through Squat Jump (SJ), Countermovement Jump (CMJ) and 20- cm Drop Jump (20-cm DJ) tests.

Instrument

Vertical jump tests were conducted using the Leonardo® GRFP platform, available at the lab facilities of the Sports University of Tirana. This piece of equipment provides an objective assessment of individual performance (power) and movement analysis. GRFP allows for the recording of the drop height at which an athlete achieves the maximum jump, as well as the analysis of the relationship between drop height, contact time, and flight mine from the center of gravity (COG).

Test protocol

All subjects performed a 10-minute warm-up before tests. Tests were conducted in both groups before and after the 11-week training period. All tests were performed 3 times, with one-hour interval between the retests, and the best jump of performance was selected. A 95% confidence interval was applied to all jump performance variables: SJ, CMJ and 20-cm DJ.

Squat Jump (SJ): The players, without the help of the arms, the jump starting from the athlete's position with the legs bent at a 90º angle, hands resting on the hips (waist) on the GRFP force platform. This protocol targets explosive strength without the reuse of elastic energy. In all tests, the best jump of three attempts was selected (Lleshi & Martiri, 2021).

Countermovement Jump (CMJ): The CMJ begins the test from an upright position and gains momentum by flexing the lower limbs to 90º degrees with the hands placed on the hips (waist) on the GRFP platform. This test evaluates explosive strength with the reuse of elastic energy. In all tests, the best jump of three attempts was selected (Mancilla et al., 2023).

20-cm Drop Jump Test (20-cm DJ): The DJ offers a progressive increase in drop cube height from 20cm, to 40cm, 60cm and 80cm positioned next to the GRFP force platform. This test evaluates the explosive strength of the lower limbs. Volleyball players take turns standing on the 20 cm high cube with their hands on their hips. Through a free fall from the height of the cube they fall onto the GRFP platform and react quickly after contacting the GRFP, by jumping as high as possible. In all tests, the best jump of three attempts was selected (Vilela et al., 2020).

Elasticity Index (EI): The difference between SJ and CMJ tests correspond to the elasticity index (EI = [CMJ-SJ)/SJ *100] (Bosco & Komi, 1979).

Intervention

The experimental group was subjected to a training program in the form of a circuit for 11 weeks, which was conducted 3 times a week (on Monday, Wednesday, Friday) with a duration of 15-20 minutes, preceded by an initial warm-up of 10 minutes and followed by a ball practice session. In contrast, the control group was subjected to only 3 training sessions as determined by the coach. The intervention program was built based on the principle of the "Progressive Load" (step load) which increases progressively in the first 2 weeks, while in the third week the load decreases slightly to enable the recovery of the athletes, a method suitable for U12 - U15 (Bompa & Carrera, 2015; Bompa & Sarandan, 2022).

The circuit contained 7 stations/exercises involving mainly horizontal movements and jumps; hexagon with one foot inside, the other outside, in 4 directions (front - back, left – right), horizontal jumps with left-right steps, 20 cm hurdle crossing and lateral displacement with 1 foot left, 20 cm hurdle crossing and lateral displacement with 1 foot right, side skips left and right on the stairs and horizontal left-right, jump horizontal Indian and cinch and run with change of direction (COD), the first two distances were to be covered with lateral running and the next 4 distances, straight running with change of direction.

Exercises performed with one leg had the highest intensity. The distance from station to station was 2-3 m, the ratio of working time to rest time 1:2. Thus, from a workload of 2 – 3 – 2 repetitions, it was progressed to a workload of 3 – 4 – 3. This was confirmed after continuous pulse monitoring, directly after completing the circuit and before starting the next repetition. This workload did not affect the duration of the training program. Special emphasis was placed on the phase of familiarizing and mastering the technique of performing the exercises, which extended over the first 2 weeks. Intensity scaling was used not only within a training session, but also from week to week.

Data analysis

Statistical analysis was performed using the IBM Statistics 26. The statistical techniques used in this study included general descriptive analysis, evaluation of data distribution (normality, homogeneity of variance, and sphericity), and differential techniques for group comparisons. ANOVA with repeated measurements for time and/or group factors (including sum of squares, degrees of freedom [df], mean square, F-value, and significance level) was applied to test the statistical significance of the differences between the two groups and thus, to determine the effects of training on the SJ, CMJ, and DJ tests results. The comparison between the experimental and control groups was conducted using a significance level of $p < 0.05$. Additionally, box plots were used for further analysis. The study also examined the means, standard deviation (SD), and effect size before and after the test, expressed with a 95% confidence interval.

Results

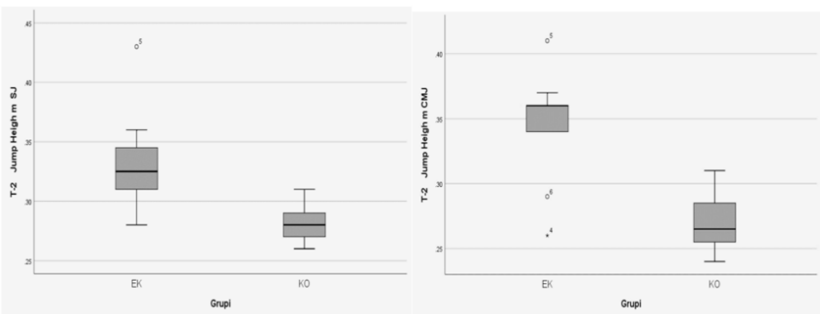
The results of the subjects' performance in the SJ and CMJ tests, before and after 11 weeks, presented in Table 2, show different values for the two groups. Training effects on jumping performance variables—SJ (Squat Jump), CMJ (Countermovement Jump), and 20-cm DJ (Drop Jump)—were analyzed with a 95% confidence interval. Differences in strength and power variables between the experimental and control groups were tested for statistical significance. The reliability of the tests is checked by the "test-retest" method, as one of the most used methods in similar tests, to minimize the effect of other factors that are not taken into account in the study. The main objective was to test the reliability of the results. According to the data obtained from the GRFP platform, presented in Tab. 2, show that there is a growth among volleyball players, but in very low values, where the difference between the groups is numerically relatively small in SJ (EX Pre_0.31-Post_0.33 and CO Pre_0.28-Post_0.29). EX group at the time of introduction to JH scored 0.04s after 11 weeks of training. Results in CMJ test for the EX group are Pre_0.33-Post_0.36 and for the CO group, Pre_0.31-Post_0.3.

Table 2. Descriptive statistics for SJ and CMJ tests Before & After Intervention

	Experimental Group Before				Experimental Group After			
SJ	Vmax m/s	Pmax kg	Fmax kg	JH m	Vmax m/s	Pmax kg	Fmax kg	JH m
Average	2.13	34.66	1.02	0.31	2.21	36.64	1.07	0.33
Max	2.31	37.89	1.37	0.36	2.41	46.65	1.41	0.43
Min	1.75	27.73	0.77	0.22	2.08	31.67	0.85	0.28
SD	±0.17	±3.38	±0.14	±0.03	±0.11	±3.83	±0.18	±0.03
	Control Group Before				Control Group After			
SJ	Vmax m/s	Pmax kg	Fmax kg	JH m	Vmax m/s	Pmax kg	Fmax kg	JH m
Average	2	33.3	1.25	0.28	2.08	34.93	1.19	0.29
Max	2.15	40.28	1.66	0.29	2.18	39.64	2.07	0.31
Min	1.83	28.51	0.66	0.25	1.83	31.1	0.72	0.26
SD	±0.09	±3.63	±0.34	±0.01	±0.1	±2.34	±0.37	±0.01
	Experimental Group Before				Experimental Group After			
CMJ	Vmax m/s	Pmax kg	Fmax kg	JH m	Vmax m/s	Pmax kg	Fmax kg	JH m
Average	2.11	36.1	1.29	0.33	2.16	37.62	1.3	0.36
Max	2.33	45.3	1.65	0.36	2.49	44.43	1.55	0.41
Min	1.79	27.78	0.81	0.26	1.79	27.78	1.03	0.26
SD	±0.13	±4.36	±0.24	±0.03	±0.18	±4.22	±0.17	±0.03
	Control Group Before				Control Group After			
CMJ	Vmax m/s	Pmax kg	Fmax kg	JH m	Vmax m/s	Pmax kg	Fmax kg	JH m
Average	1.99	36.06	1.43	0.31	2.18	36.88	1.44	0.32
Max	2.16	41.57	2.42	0.3	2.41	40.96	1.97	0.31
Min	1.62	26.53	0.75	0.22	2.01	26.53	1.07	0.24
SD	±0.13	±3.73	±0.5	±0.02	±0.09	±3.58	±0.34	±0.01

Data are presented as mean, maximum, minimum and standard deviation ± SD. (SJ-Squat Jump, CMJ-Countermovement Jump, Pmax- Power max, Vmax- Velocity max, Fmax-Force max, JH-Jump Height, SD-Standard Deviation). *Significant differences, p<0.05.

Figure 1. Differences in the Jumping Height between Groups in SJ & CMJ



(Jump Height Measurements (SJ and CMJ) for Experimental and Control Groups Post-Intervention)

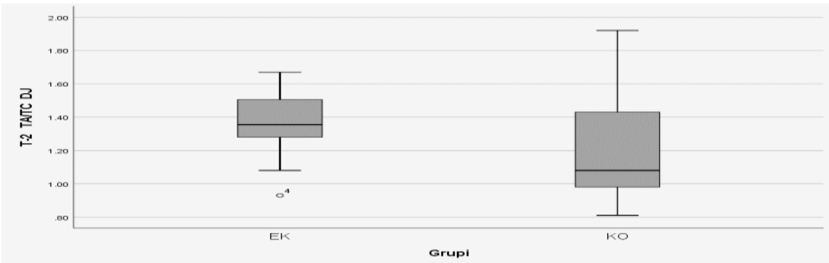
In the post intervention measurements, presented in Table 3, the 20-cm DJ test results of the EX group indicate an improvement of 0.04 seconds in the Air Time/ Contact Time (AT/CT) ratio, while the CO group showed an improvement of 0.02 seconds.

Table 3. Descriptive statistics of 20-cm DJ test results before & after the intervention

	Experimental Group Before					Experimental Group After				
DJ	Fmax kg	Pmax kg	CT	AT	AT/CT	Fmax kg	Pmax kg	CT	AT	AT/CT
Ave.	45.6	25.65	0.289	0.318	1.31	38.59	24.63	0.299	0.407	1.35
Max	59.4	36.21	0.344	0.437	1.83	46.33	29.05	0.333	0.486	1.67
Min	31.4	14.26	0.199	0.181	0.67	25.69	20.75	0.244	0.308	0.93
SD	8.24	5.8	0.047	0.07	0.2	5.57	2.35	0.03	0.053	0.2
	Control Group Before					Control Group After				
DJ	Fmax kg	Pmax kg	CT	AT	AT/CT	Fmax kg	Pmax kg	CT	AT	AT/CT
Ave.	42.71	21.89	0.304	0.338	1.26	40.85	23.48	0.342	0.404	1.28
Max	55.33	31.99	0.411	0.435	1.47	51.45	30.66	0.399	0.431	1.92
Min	26.78	14.46	0.199	0.196	0.81	34.54	16.56	0.209	0.365	0.81
SD	8.91	6.8	0.069	0.078	0.2	4.9	4.4	0.054	0.021	0.3

Data are presented as mean, maximum, minimum and standard deviation ± SD. (DJ-Drop Jump; CT-Contact Time; AT-Air Time; AV-Average; SD- Standard Deviation)

Figure 2. Differences in jumping height between Groups in 20-cm DJ test



(Air Time/Contact Time Contact (AT/CT) Ratio and Jump Height in 20-cm Drop Jump (DJ) for Control and Experimental Groups After Intervention)

Table 4. Analysis of Variance (ANOVA) for Jump Height (SJ & CMJ) and Air Time / Contact Time (AT/CT) in Drop Jump (DJ) Post-Training

		ANOVA				
		Sum of Squares	df	Mean Square	F	Sig. p-value
T-2 JH- SJ	Between Groups	2.172	2	1.086	14.077	.000
	Within Groups	5.324	69	.077		
	Total	7.497	71			
T-2 JH- CMJ	Between Groups	.670	2	.335	3.215	.046
	Within Groups	7.187	69	.104		
	Total	7.856	71			
T-2 AT/CT -DJ	Between Groups	3.641	2	1.821	28.022	.000
	Within Groups	4.483	69	.065		
	Total	8.124	71			

Discussion

Vertical jump is one of the most important elements in volleyball. By applying vertical jumping exercises, muscle strengthening is achieved, stability of joints improves, which reduces the risk of injuries in volleyball players. Jump training helps athletes develop explosive power and agility, essential for quick movements and transitions during the game. Taking into account the importance of jumping and the frequency at which it takes place during a volleyball game, it is important to assess jump performance by using specific protocol tests such as: Squat Jump (SJ), Counter Movement Jump (CMJ) and Drop Jump (DJ). The vertical jump evaluation is widely used as an alternative to direct maximal assessment of the strength and power of the lower extremities (Hara et al., 2005). The force development rate is the development of maximum force in minimum time and is commonly used as an index of explosive force (Yu et al., 1999).

It is widely agreed, that anthropometric characteristics are not influenced by systemic training, thereby, only physiological and technical abilities can be improved substantially (Balyi et al., 2005). Biological maturation may be a factor to consider when studying the effects of training among female players during the pubertal phase. Although no significant differences are identified, the effects may be smaller than those reported in other studies in males (Vilela et al., 2020). The box plot analysis on the impact of training on Jump Height (JH) in the experimental and control group, are presented in Figure 1. The difference between groups is numerically small in Squat Jump (SJ), with the EX group showing a pre-training value of 0.31 and post-training value of 0.33, while the CO group showed a pre-training value of 0.28 and post-training value of 0.29. The EX group improved by 0.04 seconds after 11 weeks of training. In the Countermovement Jump (CMJ) test, the EX group had pre- and post-training values of 0.33 and 0.36, respectively, while the CO group showed pre- and post-training values of 0.31 and 0.32. Buśko et al. (2012) has shown the age-related differences in maximum strength and elevation of the body mass center, measured through the CMJ and SJ tests in young male and female volleyball players, where the rating was not statistically significant in terms of the SJ, CMJ and maximum jump height, but had only the result of producing the elastic muscle energy of SJ. Battaglia et al. (2014) reported that, over three years of specific vertical jump training, 15-year-old female volleyball players showed higher jump values in the Squat Jump (SJ) (0.46) and Countermovement Jump (CMJ) (0.47) tests, compared to our study's results for the same age group (SJ: 0.33, CMJ: 0.36). A statistically significant difference was found between the experimental and control group for the CMJ variable in Jump Height (JH), F (1, df) = 3.215, p = 0.046, which suggests that the intervention was effective in improving JH in volleyball players.

It can therefore be concluded that the technique of these exercises (i.e., movement amplitude, flight time, ground contact) is an important factor to be considered by coaches. According to the results obtained from the GRPF platform and the data as seen from Table 4, SJ from is considered to be less specific than CMJ to evaluate jump performance in volleyball players.

Studies have shown that test subjects obtain higher results in the CMJ test than in the SJ test. The differences may depend on and the fact that men tend to develop more power than women in leg muscles (Bosco et al., 1983), while the difference between the SJ and CMJ tests corresponds to the elasticity index EI= [CMJ-SJ], and EI is essential in sports where jumping ability is more important and where fast and explosive movements are required, such as volleyball. The results of the study showed that both volleyball groups scored equal values of EI (0.03). De La Fuente Francisco and colleagues, (2013) found no statistically significant differences in EI between genders, where the highest levels of EI were achieved in the U13 categories in females (3.43) and in the youngest category in males (3.06). Lleshi and Kokoneci (2012), based on the results obtained from national team players aged 16-18 in Albania, tested in MuscleLab by Ergo test Technology and calculations based on the formula [(CMJ − SJ) × 100 / CMJ], have concluded that the reuse capacity of accumulated energy, preceding muscular contraction, reflects the elasticity of the lower extremities in volleyball players.

Elastic energy according to the formula [(CMJ − SJ) × 100 / CMJ] which shows the capacity for subsequent reuse of accumulated elastic energy resulting from the elastic stretch preceding muscular contraction, is low in female volleyball players with scores of 8.3% in the EX group and 9.3% in the CO group.

The descriptive analysis of Squat Jump (SJ) values obtained from GFRP at F max, as presented in Table 2, showed an increase by 0.05 in the experimental group, compared to the 0.06 increase in the control group. Similarly, SJ values SJ at V max showed an increase of 0.08 m/s in the experimental group, compared to the 0.08 m/s increase in the control group. Sheppard et al. (2008) reported very strong correlations between jumping performance in Squat Jump (SJ) (0.85, P ≤ 0.01) and Countermovement Jump (CMJ) (0.93, P ≤ 0.01). Jump Height (JH) for body displacement (center of gravity) showed an increase in the EX group after the training, with values of 0.02 in SJ and 0.03 in CMJ. In contrast, the control group showed smaller increase in JH, with values of 0.01 in both SJ and CMJ. During the CMJ test, comparing body height and body weight allows for assessing the coordination threshold at the start of the test and at the end of the jump phase according to GRFP (P < 0.01, force P ≤ 0.05). The CMJ test also showed significant results (P < 0.01, force P < 0.01) after 8 weeks, as reported by Chelly et al. (2013).

Drop jumps (DJ) are commonly implemented in plyometric training programs, in an attempt to enhance jump performance. Bosco et al. (1983) proposed the ‘‘estimated average mechanical power’’ from the relationship between air time (AT) and contact time (CT). The data obtained show that jumping performance can be assessed by many variables: AT, CT, height and estimated force, etc. Winter and Fowler (2009) showed that flight time and contact time are two sufficient factors to evaluate performance in a number of exercises. To jump high with short CT, which means short duration of force application, it is necessary to rapidly increase force to maximize the net final impulse (Knudson, 2009), as a result of this combination of AT versus CT (moderate AT and very short CT).

To assess vertical jump, Bosco tests such as the Drop Jump (Cometti & D, 2009) are used. These tests allow for the determination of the optimal drop height at which the volleyball player achieves maximum jump height, as well as evaluation of the relationship between drop height, contact time, and flight time. For the purpose of our study, differences between the two groups were observed in terms of contact time during the fall and air time during the jump.

Descriptive analysis of post-training measurements in the experimental group (EX-group) for the 20-cm DJ test, as shown in Table 3, indicate that the dependent variable 'Air Time / Contact Time ' (AT/CT) improved by 0.04 seconds. In comparison, the control group (CO-group) showed a smaller increase of 0.02 seconds in AT/CT. The analysis of normality distribution, using Kolmogorov- Smirnoff (Sig = 0.2) indicated that the variable AT/CT had acceptable deviations from normal data distribution, taking into consideration the small size of the sample. The results of variance analysis, ANOVA with 2 repetitive measurements, adjusted with Greenhouse-Geisser ($F(1, 18) = 21.7$, $p = 0.000$), revealed a statistically significant difference between the two measurements (sig<0.0005). These findings suggest that the 11-week intervention was effective in enhancing performance of volleyball players in the 20-cm Drop Jump test.

The ANOVA analysis results with 2 repeated measurements showed statistically significant difference between mean comparisons of Pre and Post intervention values. The study has shown that the jump technique is the amplitude of the movement and the Time of stay in the Air and the Contact time "AT/CT" (Lleshi & Prifti, 2015) is one of the most important factors to be considered for the implementation of a plyometric training program. GRFP evaluated the Vertical Jump not only by the height of its development, but also by the phase of staying in the air, where the EX group achieved values of 1.35 AT/CT after training compared to the starting 1.31 AT/CT and the CO group=1.28 compared to 1.26 AT/CT at the start. However, Young and colleagues (1999) have reported higher CT values than ours (> 400 m/s).

An analysis was conducted to check if the test and the measurement methods used were effective in identifying whether volleyball groups achieved high or poor performance. It was also analyzed whether the testing protocol was able to identify the changes that came from the 11-week intervention training of the Experimental and Control groups. In this experiment we noticed differences between the two groups at the Time of Contact during the fall and the Time in the Air during the jump.

These results show that practical experience suggests that volleyball training circuit with the use of comprehensive exercises should be using a progression with the lowest and rising volume, in a multipurpose state, so that the performance of jumps is carried out correctly to reduce the risk of damage that characterizes these activities.

Conclusions

According to the data obtained from GRFP platform, volleyball players demonstrated an increase in vertical jump, reaching values deemed sufficient for this age group after circuit training. The findings of this study show that the methodology used here is accurate and helps coaches to program more detailed, short-term training for the development of jumping skills in volleyball players. However, while the findings of this study indicate that an 11-week circuit training program can improve vertical jump performance in young female volleyball players, the small sample size presents a limitation. A limited number of participants reduces the statistical power of the study, making it more challenging to detect significant differences and increasing the potential for variability in the results. Additionally, the findings may not be fully generalizable to a broader population of volleyball players with different training backgrounds. Future research with larger sample sizes is recommended to strengthen the reliability and applicability of these results.

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