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Strength and vertical jump performance changes in elite male volleyball players during the season

Cambios en el rendimiento en fuerza y salto vertical en jugadores de élite masculinos de voleibol durante la temporada

[1]Miguel Sánchez-Moreno; [2,3]Carlos García-Asencio; [2]Juan José González-Badillo, [3]David Díaz-Cueli
[1]San Isidoro University (Spain), [2]Pablo de Olavide University (Spain), [3]CajaSol Volleyball Foundation

Abstract. This study aimed to analyze the effect of strength training on physical performance in elite male volleyball players during the competitive season. Athletes were assessed at the start of season (SS), midpoint of the competitive season (MS), and at the end of the season (ES). Significant increases were observed in vertical jump height (CMJ), jump squat height (JS) and mean propulsive velocity (MPV) from SS to ES ($P < 0.05$). Likely beneficial increases were observed on CMJ from SS to MS, on JS from SS to MS and from MS to ES. In addition, likely beneficial effect was found on MPV from MS to ES. Over the full season (SS to ES), very likely beneficial effect was observed on CMJ, MPV and JS. In conclusion, increase in strength of lower limb and vertical jump can be achieved in professional volleyball players over a full playing season.
Keywords: resistance training, vertical jump, lower limb, velocity based training.

Resumen. El objetivo del estudio fue analizar los efectos de un programa de entrenamiento de fuerza sobre el rendimiento en la fuerza del miembro inferior y la capacidad de salto vertical en jugadores de voleibol masculinos durante la temporada de competición. Los atletas fueron evaluados al inicio (SS), a la mitad (MS) y al final de la temporada (ES). Se observaron aumentos significativos en la altura del salto vertical (CMJ), del salto con cargas (JS) y en la velocidad media propulsiva (MPV) alcanzada con las cargas comunes en el ejercicio de sentadillas entre SS y ES ($P < 0.05$). El análisis basado en la magnitud del cambio reveló un aumento *probable* en CMJ de SS a MS, y en JS de SS a MS y de MS a ES. Además, un incremento *probable* se encontró en MPV de MS a ES. Durante la temporada completa (SS a ES), se observó un aumento *muy probable* en CMJ, en MPV y JS. En conclusión, se puede lograr un aumento en la fuerza de la extremidad inferior y el salto vertical en jugadores profesionales de voleibol durante una temporada de juego completa.
Palabras claves: Entrenamiento de fuerza, salto vertical, extremidad inferior, entrenamiento basado en la velocidad.

Introduction

Volleyball is a sport characterized by the requirement to perform movements commonly considered as explosives, such as jumps, arm hitting and short displacements. The attack and blocking are crucial game actions for attaining victory in top-level competition (Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, De Saá & García-Manso, 2011). Part of the success of these actions is determined by the height at which they are performed (Voigt & Vetter, 2003), which are influenced by the vertical jump ability of the players. The jumping abilities are one of the key elements in successful volleyball practice. The reported differences in vertical jump height between volleyball players of different competition level highlight the importance of this ability to the volleyball performance (Forthomme, Croisier, Ciccarone, Crielaard & Cloes, 2005).

Some authors suggest that only skill-based conditioning program could not be enough for the improvement of vertical jump performance in volleyball players and, the combination of it with resistance training (RT) could be a better stimulus for specific volleyball conditioning (Trajkovic, Milanoviæ, Sporis, Miliæ & Stankoviæ, 2012). Previous studies conducted with female volleyball players have used heavy-load RT (Häkkinen, 1993), or a combination of heavy-load RT and plyometrics (Marques, van den Tillaar, Vescovi & González-Badillo, 2008) to improve strength and power characteristics. These investigations have demonstrated the positive effects that result from the application of these methods, reporting significant increases in vertical jump height. On the other hand, studies conducted with male volleyball players have observed improvements in the vertical jumping ability after performing a short-term (Sanchez-Moreno, Garcia-Asencio & González-Badillo, 2014) and long-term (García-Asencio, Sánchez-Moreno & González-Badillo, 2016) RT program with moderate loads and low number of repetitions. Therefore, little information is available in the literature concerning strength training program used in professional male volleyball players during the competition season.

RT performed with heavy loads seems to be associated with a high fatigue degree (Sanchez-Medina & González-Badillo, 2011), which, in team sport may difficult the practice during subsequent technical-tactical training (Apriantono, Nunome, Ikegami & Sano, 2006). Several authors have suggested that it is not necessary to cause excessive fatigue to improve strength performance (Pareja-Blanco et al. 2017) and RT program with moderate loads and a low number seems to be enough to improve the physical performance in young soccer players (González-Badillo, Pareja-Blanco, Rodríguez-Rosell, Abad-Herencia, del Ojo-López & Sánchez-Medina, 2015). In addition, lifting the load at maximal velocity seems to be a key factor to optimize the adaptations induced by RT (Pareja-Blanco, Rodríguez-Rosell, Sánchez-Medina & González-Badillo, 2014). Thus, the aim of this study was to measure the effect of seasonal RT, using lift velocity as a reference to prescribe the training load, characterized by moderate loads and low number of repetitions per set combined with jumps on lower limb muscle strength, and jumping ability among professional male volleyball players during the entire season. We hypothesize that this type of strength training would enhance muscular strength with no concomitant interference on technical-tactical volleyball training.

Methods

Subjects

Eleven professional male volleyball players playing in the first national division of the Spanish National League participated in this study (mean ± s: age 22.9 ± 3.0 years, height 189,5 ± 5.4 cm, body mass 83.4 ± 9.7 kg., %fat 11.4 ± 2.0). All participants were informed about the experimental procedures and possible risks and benefits associated with the study. They provided written consent before participation in this study, which was approved by the Research Ethics Committee of Pablo de Olavide University.

Experimental Design

RT was implemented by the club's coaching staff, and the training season was divided into two training phases consisting of six weeks each of early season, and late season. Testing sessions occurred at the transition between training phases: at the start of season (SS); at the midpoint of the season (MS); and at the end of the season (ES).

Body Composition Measurements

Body weight was determined using a calibrated digital scale (Tanita,

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Carlos García Asensio
asencio9@gmail.com

BC-543, Tokyo, Japan) with the subjects wearing only underwear. Skinfolds thicknesses were measured with a Holtain LTD lipocaliper (Crymych, United Kingdom) (range 0-40 cm; resolution 0.2 mm. at a pressure of 10 g·mm^{-2} across the full opening range). The skinfolds measured were the tricipital, subscapular, abdominal, suprailiac, anterior thigh, and mid leg. The exact positioning of each skinfold measurement was in accordance with the procedure described previously (Norton, Whittingham, Carter, Kerr, Gore & Marfell-Jones, 1996). All measurements were made in duplicate by the same trained operator. If the differences between the two values were less than 5%, the average value of both measurements was used for analysis. When the differences exceeded 5% we performed a third measure and the average value of the three measurements was used. Percent Fat was estimated using the Faulkner equation (Faulkner, 1968) [Percent Fat (%) = (tricipital+ subscapular + suprailiac + abdominal skinfolds x 0.153) + 5.783].

Jump Measurements (CMJ and JS)

The CMJ and JS were performed on an infrared platform Optojump (Microgate, Bolzano, Italy) that calculated jump height (h) through flight time (t) and the acceleration due to gravity (g) as follows: $h = t^2 \times g/8$. The CMJ was performed with both hands on the waist, while making a downward movement approximately to 90º-knee flexion followed by a vertical jump of maximum effort. The participants were required to do three trials separated by 1 min. rest, mean height being recorded. Just after the CMJ test, the JS test was performed with progressive loads ranging from 20 kg. up to the load allowing the participant to jump up no more than 20 cm. high. The JS test was performed using a Smith machine (Multipower Fitness Line, Peroga, Murcia, Spain), which allows a smooth vertical displacement of the bar along a fixed pathway. The athletes performed two JS separated by 2 min. rest with each load. The mean heights of the two jumps of each of the common loads performed in the three tests were used for the subsequent statistical analysis.

Full Squat Test (FS)

FS test was performed on the same machine as the JS, placing the barbell behind the head on the top of the back. From this position, there was a deep flexion of the legs to exceed the horizontal, and then there was an immediate extension of the legs to the fullest extent. Subjects were instructed to perform a controlled eccentric phase and a concentric phase at the highest possible velocity. After warm-up, initial load was set at 20 kg. for all participants and was gradually increased in 10 or 5 kg. increments until the attained mean propulsive velocity (Sánchez-Medina, Pérez & González-Badillo, 2010) was <«1 m·s»1 (<«60% 1RM for full back squat exercise, Sánchez-Medina, Pallarés, Pérez, Moran-Navarro & González-Badillo, 2017). This velocity was considered a sufficient load to evaluate lower limb strength because the lowest load employed during the RT was displaced approximately to 1 m·s»1. The subjects performed between one and four attempts with each load. The best result accompanied by a correct execution was used for the subsequent statistical analysis. We performed a 3 min. rest among each load. Bar velocity was measured using a linear velocity transducer (T-Force System, Ergotech, Murcia, Spain) sampling at 1000 Hz. The mean propulsive velocity (MPV) attained against all absolute loads common to SS, MS and ES were used for analysis.

Resistance training program

The RT program consisted of two times per week, on non-consecutive days, for two periods of six weeks, with each season lasting approximately 50 minutes and consisting of the following components: 10 minutes of standard warm-up (7 min. submaximal running, stretching exercises for 3 min.), 35 min. of specific strength training; and 5 min. of cool down including stretching exercises. The training seasons were realized in the morning (10:00 a.m.), whereas the volleyball training seasons were realized in the afternoon (6:00 p.m.). The main exercises of the training program were full squats, squat jumps and unloaded jump. Table 1 shows in detail the characteristics of the RT program.

Statistical Analysis

All the data are reported as mean value ± standard deviation (SD). The normal distribution of the data was verified with the Shapiro-Wilk test. Statistical analyses for changes throughout the season were assessed using one-way repeated measures analysis of variance (ANOVA) with Bonferroni adjustment. A related sample-test was used to analyze the changes between SS and ES for the different body composition variables. Significance was accepted at the *p* d» .05 level. All analyses were performed using SPSS software version 17.0 (SPSS, Chicago, IL, USA). In addition to this null hypothesis testing, data were assessed for clinical significance using an approach based on the magnitudes of change (Hopkins, Marshall, Batterham, & Hanin, 2009; Batterham & Hopkins, 2006). Effect sizes (Es) were calculated using Hedge's g on the pooled SD. Probabilities were also calculated to establish whether the true (unknown) differences were lower, similar or higher than the smallest worthwhile difference or change (0.2 x between-subject SD) (Cohen 1988). Quantitative chances of better or worse effects were assessed qualitatively as follows: <1%, almost certainly not; 1-5%, very unlikely; 5-25%, unlikely; 25-75%, possibly; 75-95%, likely; 95-99%, very likely; and >99%, most likely. If the chances of obtaining beneficial/better or detrimental/worse were both >5%, the true difference was assessed as unclear (Hopkins, et al. 2009; Batterham & Hopkins, 2006). Inferential statistics based on the interpretation of magnitude of effects were calculated using a purpose-built spreadsheet for the analysis of controlled trials (Hopkins, 2006).

Results

Body composition

No significant differences were observed in any body composition variable evaluated (table 2). Practically worthwhile differences showed *possibly* beneficial effects of RT on six skinfolds (74/25/0) and percent fat (64/36/0) from SS to ES (figure 1).

Table 1.
Resistance training program

Resistance training program employed during early season					Resistance training program employed during late season				
	Exercises					Exercises			
Weeks	sesions	FS (%V1LOAD)	JS (%load-20 cm.)	VJ	Weeks	sesions	FS (%V1LOAD)	JS (%load-20 cm.)	VJ
1	1	2x6 (70%)	2x5 40%	3x3	7	13	2x6 (90%)	3x4 50%	4x3
	2	3x6 (70%)	3x5 40%	3x3		14	3x6 (90%)	4x4 50%	4x3
2	3	3x6 (70%)	3x5 40%	3x3	8	15	3x6 (90%)	3x4 60%	4x3
	4	2x6 (80%)	2x5 60%	3x3		16	2x4 (100%)	4x4 60%	4x3
3	5	3x6 (80%)	3x5 60%	3x3	9	17	3x4 (100%)	4x3 70%	4x3
	6	3x6 (80%)	3x5 60%	3x3		18	2x5 (100%)	5x3 70%	4x3
4	7	3x4 (90%)	3x4 70%	3x3	10	19	3x5 (100%)	6x3 70%	4x3
	8	3x5 (90%)	3x4 70%	3x3		20	3x3 (105%)	4x2 80%	4x3
5	9	3x6 (90%)	3x5 70%	3x3	11	21	3x4 (105%)	5x2 80%	4x3
	10	3x4 (100%)	3x4 80%	3x3		22	4x4 (105%)	5x2 80%	4x3
6	11	3x4 (100%)	3x4 80%	3x3	12	23	3x4 (105%)	5x2 80%	4x3
	12	3x4 (100%)	3x4 80%	3x3		24	3x4 (100%)	4x3 70%	4x3

Training summary				Training summary			
Exercises	Intensities	Sets x reps§	% total rep†	Exercises	Intensities	Sets x reps§	% total rep†
FS	70%	48	27,7	FS	90%	48	31,2
	80%	48	27,7		100%	57	37,0
	90%	41	23,7		105%	49	31,8
	100%	36	20,8				
JS	40%	40	25,8	JS	50%	28	18,5
	60%	40	25,8		60%	28	18,5
	70%	39	25,2		70%	57	37,7
	80%	36	23,2		80%	38	25,2
VJ	---	108	---	VJ	---	144	---

FS = squat; SJ = jump squat; VJ = unloaded vertical jump; %V1LOAD = percentage of the load that elicited ~ 1 m/s in the squat test; %load-20 cm. = percent of the load with which the players jumped ~ 20 cm. in the squat jump test
§The total number of repetitions lifted during the training cycle with each intensity
†Percentage of total repetitions performed with each intensity

Unloaded vertical jump (CM.J)

Significant increases were observed in vertical jump height from SS to ES ($p < .05$; table 2). RT presented *likely* and *very likely* beneficial effects on CM.J from SS to MS (82/17/0) and from SS to ES (95/5/0), respectively (figure 1).

Table 2.
Changes in selected neuromuscular performance variables.

	SS	MS	ES	SS to MS dif	SS to MS ? (%)	SS to MS Es (90%CI)	MS to ES dif	MS to ES ? (%)	MS to ES Es(90%CI)	SS to ES dif	SS to ES ? (%)	SS to ES Es (90%CI)
CM.J (cm.)	46.1 ± 5.4	48.0 ± 5.5	48.8 ± 7.3*	1.9 ± 2.5	4.1	0.32 (0.09; 0.55)	0.8 ± 3.4	1.6	0.13 (-0.18; 0.45)	2.7 ± 2.8	5.8	0.46 (0.20; 0.71)
JS (cm.)	25.2 ± 2.0	25.9 ± 1.9	26.7 ± 2.5*	0.7 ± 1.0	2.7	0.32 (0.06; 0.58)	0.8 ± 1.4	3.1	0.38 (0.03; 0.73)	1.5 ± 1.2	6.0	0.70 (0.38; 1.01)
MPV ($m \cdot s^{-1}$)	1.24 ± 0.06	1.26 ± 0.08	1.29 ± 0.06*	0.02 ± 0.05	1.3	0.25 (-0.16; 0.66)	0.03 ± 0.03	2.2	0.43 (0.16; 0.70)	0.04 ± 0.05	3.6	0.68 (0.26; 1.10)
Body weight (kg.)	83.4 ± 9.7	84.1 ± 10.1	85.1 ± 10.2	0.7 ± 1.9	0.9	0.07 (-0.03; 0.17)	1.1 ± 1.6	1.3	0.10 (0.01; 0.19)	1.8 ± 2.8	2.1	0.17 (0.02; 0.32)
? 6 skinfold	54.1 ± 15.2	---	59.0 ± 13.2	---	---	---	---	---	---	4.8 ± 7.6	9.0	0.29 (0.04; 0.55)
Percent fat (%)	11.4 ± 2.0	---	12.0 ± 1.9	---	---	---	---	---	---	0.5 ± 1.0	4.8	0.25 (0.00; 0.50)

Data are mean ± SD; SS: star season; MD: midpoint season; ES: end season; dif: differences between test; ? : percent change; Es: effects size; CI: Confidence Interval; CM.J: countermovement jump; JS: jump squat; MPV: mean propulsive velocity attained against all loads common. * $p < .05$ (respect to SS)

Jump Squat (JS)

Significant increases were observed in jump squat height from SS to ES ($p < .05$; table 2). In additions, RT presented *likely* beneficial effects on JS from SS to MS (79/20/0) and from MS to ES (89/19/1), respectively. Finally, *very likely* beneficial effects from SS to ES (99/1/0) were observed (figure 1).

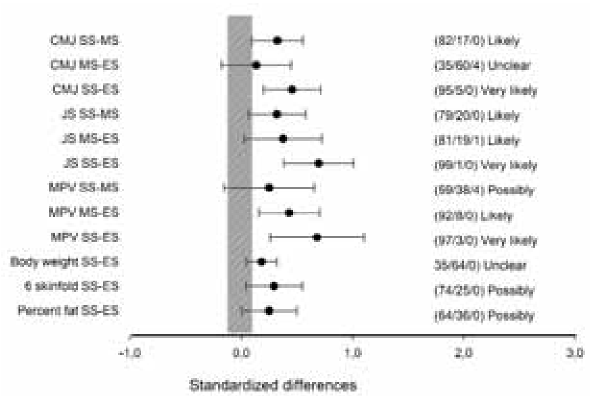

Figure 1. Differences (90% confidence intervals) in CM.J and JS height, MPV in FS, body weight, S 6 skinfold and percent fat between different measures. Shaded areas represent trivial differences. See methods for the descriptions of the qualitative outcomes

Full squat (FS)

Significant increases were observed in MPV from SS to ES ($p < .05$; table 2). Practically worthwhile differences showed *very likely* beneficial effects on MPV from MS to ES (92/8/0) and from SS to ES (97/3/0; figure 1).

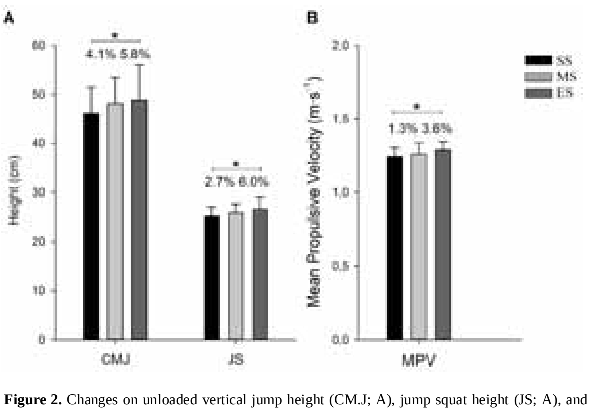

Figure 2. Changes on unloaded vertical jump height (CM.J; A), jump squat height (JS; A), and mean propulsive velocity attained against all loads common in FS (MPV; B) between star season (SS), midpoint season (MS) and end season (ES). The data are expressed as mean ± standard deviation. Significant interaction for the percentages of changes between measures: * $p < .05$

Discussion

The main finding of this study was that a RT with moderate loads and low volume combined with jumps exercises, in addition to the normal volleyball training, induced enhancements in vertical jump ability and lower limb strength in professional male volleyball players during the entire season.

Previously, Häkkinen (1993) reported significant increases in CM.J (32.8 ± 1.6 to 34.3 ± 1.3 cm., 4.6%; $p < .05$) in nine competitive female volleyball players after 10 weeks of RT with loads > 75% 1RM. Similar results were observed by Marques et al. (2008) in 10 professional female volleyball players after 12 weeks of RT with training loads ranging from 50 to 80% of 1RM (34.2 ± 5.9 to 35.6 ± 6.3 cm., 3.8%; $p < .05$). In the current study, an increment of 4.1% occurred in CM.J after 6 weeks (46.1 ± 5.4 to 48.0 ± 5.5), and an increment of 5.8% after 12 weeks (46.1 ± 5.4 to 48.8 ± 7.3; figure 2A). These results agree with those observed by ourselves in 2014 and 2016 where there was an increase in vertical jump height of 5 and 7%, respectively (Sánchez-Moreno et al. 2014; García-Asencio et al. 2016). In addition, JS height increment 2,7% after six weeks, and 6.0% after 12 weeks (figure 2A). Similar improvements were observed in the height of the JS in the 2014 and 2016 studies (5,7% and 9,7%, respectively) whereas lower body strength was observed to be increment by 3.6% after 12 weeks (figure 2B) only in the actual study. The comparison of the results of these studies suggest that high loads do not produce better results on vertical jump performance, since in our study a load equivalent to 60% of the 1RM (~1 $m \cdot s^{-1}$) in the FS was not exceeded, and jumping exercises were performed with light loads.

Our findings are consistent with those observed by González-Badillo et al. (2015) and Gorostiaga, Izquierdo, Ruesta, Iribarren, González-Badillo & Ibáñez (2004) in which were observed increases in vertical jump height and lower body strength after perform a traditionally called «*explosive strength training*» characterized it by high-velocity contractions with low loads in young soccer players. It has been proposed that heavy RT improves high-force portions of the force-velocity curve, whereas light and moderate loads RT improves high-velocity portions of the force-velocity curve (Moss, Refsnes, Abildgaard, Nicolaysen & Jensen, 1997). The use of heavier loads will drastically reduce movement velocity, which may have a negative impact on gross motor skills that require a high degree of movement velocity such as jumping. Recently has been proposed that the magnitude of velocity of movement experienced during RT appears to influence functional and structural muscle adaptations, observed that low velocity may be detrimental for improving explosive strength (Pareja-Blanco et al. 2016). This is particularly relevant for many athletes for whom resistance training is focused on improving dynamic performance in the most efficient way. Ours results seem to indicate that RT with moderate loads and high-velocity contractions may be enough to improve lower body strength when it is evaluated at low and moderate loads (up to the load that was displaced at a velocity of 1 $m \cdot s^{-1}$, approximately 60% of 1RM in the full back squat exercise) and vertical jump height. In addition, the athletes in the current study, contrary to those used by Gonzalez-Badillo et al. (2016) and Gorostiaga et al. (2004), were previously exposed to RT, and unloaded jumps are performed regularly during practice and competition therefore had lowest potential for adaptability. Nevertheless, even in well-trained elite male volleyball players, there was a 6% improvement in the unloaded CM.J. This result suggests that an appropriate training load was used with the current sample of volleyball players.

Thus, several critical implications for coaches may be derived from this investigation to optimize the training process in professional male volleyball players. First, RT with moderate loads and lifting the load at maximal voluntary velocity involves an intense stimulus within the normal volleyball training program that produces improvements in tasks critical to volleyball performance. Finally, since the strength training applied in this study has a short duration and produces low fatigue levels, it can be easily integrated twice a week in the morning before the normal technical-tactical field volleyball training.

Conclusions

Our results suggest that the use of moderate loads could be enough to improve the vertical jump performance, since in our study a load equivalent to 60% of 1RM in the FS was not exceeded and jumping exercises were performed with moderate loads. These results suggest that the specificity of training, which in this case is expressed by the proximity of the velocities of execution of the training exercises to the velocity of execution of the vertical jump, seems to be determinant for the performance. Further studies are required to determine the appropriate combination of loads and time training to allow further improvement and to sustain these improvements throughout the competitive phase.

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