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Jump height of volleyball players across the league season

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C Statistical Analysis
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Abstract

Background & Study Aim: Volleyball is a sport that requires movements commonly regarded as dynamic with one of the most important factors in this discipline being jump height. The schedule of the league season, with its most important matches, heavily influences the jump height of the players. Of particular interest was the difference in jump height before the beginning of the season and at its final stage. The study aimed was knowledge about the jump height of volleyball players before the season and in the final phase of the league games and possible changes in the level of motor coordination associated with jumping.

Material & Methods: The study involved 12 men aged between 18 and 23 years training in the minor-league volleyball team of the Sports Club of the Academic Sports Association at the University of Warmia and Mazury in Olsztyn, Poland. Each time a participant made two standing jumps. The first jump was a counter movement jump (CMJ). The second one was a counter movement jump with arms swing (CMJ+B). The study was divided into two parts, before and during the final phase of the season. A motion sensor (WIVA® system) was used to analyse the jump.

Results: No statistically significant differences were found for the CMJ trials. Unlike CMJ+B, where statistically significant differences were found for one of the most important indicators for volleyball players, i.e. explosive power (p=0.0414), and also in a indicator called coordination % (p = 0.002) which is decisive for performance in volleyball.

Conclusions: The juxtaposition of CMJ+B and coordination % indicators, which showed statistically significant differences, is indicative of a significant improvement in the physical fitness of the examined volleyball players and may be important for success in volleyball. It confirms the directly proportional relationship between the manifestation of muscle strength and neuromuscular coordination.

Keywords: centre of gravity • coordination • explosive power • kinematic chain • various motor skills

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Centre of gravity – *noun* **1.** the point at which a body can be balanced. Abbreviation **CG** **2.** the point through which the force of gravity acts [20].

Training session – *noun* a period of time during which an athlete trains, either alone, with a trainer or with their team [20].

Technique – specific procedures to move one's body to perform the task that needs to be accomplished [21].

Tactics – decisions and actions of players in the contest to gain an advantage over the opposing players [21]

Motor skills – *plural noun* the ability of a person to make movements to achieve a goal, with stages including processing the information in the brain, transmitting neural signals and coordinating the relevant muscles to achieve the desired effect [20].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [20].

Biomechanical analysis – *noun* the assessment of the proper use of techniques in sport and exercise biomechanics [20].

INTRODUCTION

There are various motor skills, mainly jump height (JH), velocity, endurance, strength, agility and coordination that determine the sporting achievements of volleyball players. Some authors believe that in addition to these, the longitudinal development of the skeleton (muscle tissue, adipose tissue, ossification of bone tissue, arm length) may be the most important feature in volleyball [1, 2].

Volleyball is a sport requiring movements commonly regarded as dynamic, such as jumps, ball strokes and short movements of the whole body. Attack and blocking are the key actions in the game needed to achieve victory [3, 4].

The schedule of the league season, with its most important matches, heavily influences the jump height of the players. The differences in jump height were analysed before the beginning of the season and at its final stage. Such a comparison makes it possible to determine the changes in jump height.

Analyses based on the measurement of motor skills are a common method used to diagnose the development of skills and to improve the sporting level. Therefore, in addition to pre-season training to improve fitness, it is important to study changes occurring during the league season. However, it is difficult to carry out such research among rivals during the league season [5].

Since talents are usually identified at an age of dynamic growth and development, many factors should be studied, including the role of biological maturity for jumping results [6].

Good performance in vertical jumps is not only important for success in sports games but is also related to other important physical skills such as sprint running or agility. Common scaling models based on the assumption of geometric similarity revealed that while the jump height may be independent of body size, the muscle strength increases proportionally to body weight. One of the most frequently examined factors that may contribute to an increase in jump efficiency is the muscle strength of the lower limbs [7].

The vertical jump is an important part of preparatory exercises in most sport disciplines, such as volleyball and basketball, where JH growth and ability to increase power are presented as key success factors [8-10].

A plyometric training program can potentially improve jumping performance and reduce the risk of injury [11].

The jump height depends on the maximum velocity that the centre of gravity reaches when the feet lose contact with the ground. Obviously, during the flight itself, nothing can be done to stay longer in the air. The positive function of the body, causing acceleration during the upright movement of the knee joint, provides the driving force. This acceleration is determined by the force of the extensors which, during this activity, is provided by the kinematic chain. A uniform take-off angle (e.g. 90^{o}) means that the muscle tension is the same for all subjects, as knee joints are straight during take-off. In this case, the jump height is proportional to muscle tension [12].

The study aimed was knowledge about the jump height of volleyball players before the season and in the final phase of the league games and possible changes in the level of motor coordination associated with jumping.

MATERIAL AND METHODS

Participants

Twelve men aged 18-23 (Table 1), in the minor-league volleyball team of the Sports Club of the Academic Sports Association at the University of Warmia and Mazury in Olsztyn, Poland took part in the study. All of them had up-to-date medical examinations, allowing them to participate in the measurements.

Table 1. Characteristics of the 12 volleyball players

Statistic indicator	Age [years]	Body height [cm]	Body weight [kg]	BMI
Mean	19.91	191.29	81.33	22.40
SD	1.62	6.97	9.32	8.85

Consent to this research was granted by the Commission for Scientific Research Ethics at the University of Warmia and Mazury in Olsztyn, Poland (Decision no. 9/2018).

Study design

The research took place in October 2019 and March 2020 at the Sports Hall in Kortowo in Olsztyn according to a specified research procedure (Figure 1). Between the first and the second test rounds, the competitors were subjected to a training program with five sessions a week for two hours each. Twice a week there were training sessions focused on strength development, and the remaining three sessions were of technical and tactical nature with the use of balls. The calendar of games included 24 league matches (including 6 matches in friendly tournaments).

The research tools used in this work in the initial phase included measurement of the body's composition with *Inbody270* analyser, a device which allows making measurements using 20, 100 kHz impedance and 200 uA current, using an 8-point tetrapolar system of touch electrodes (2 left foot electrodes, 2 right foot electrodes,

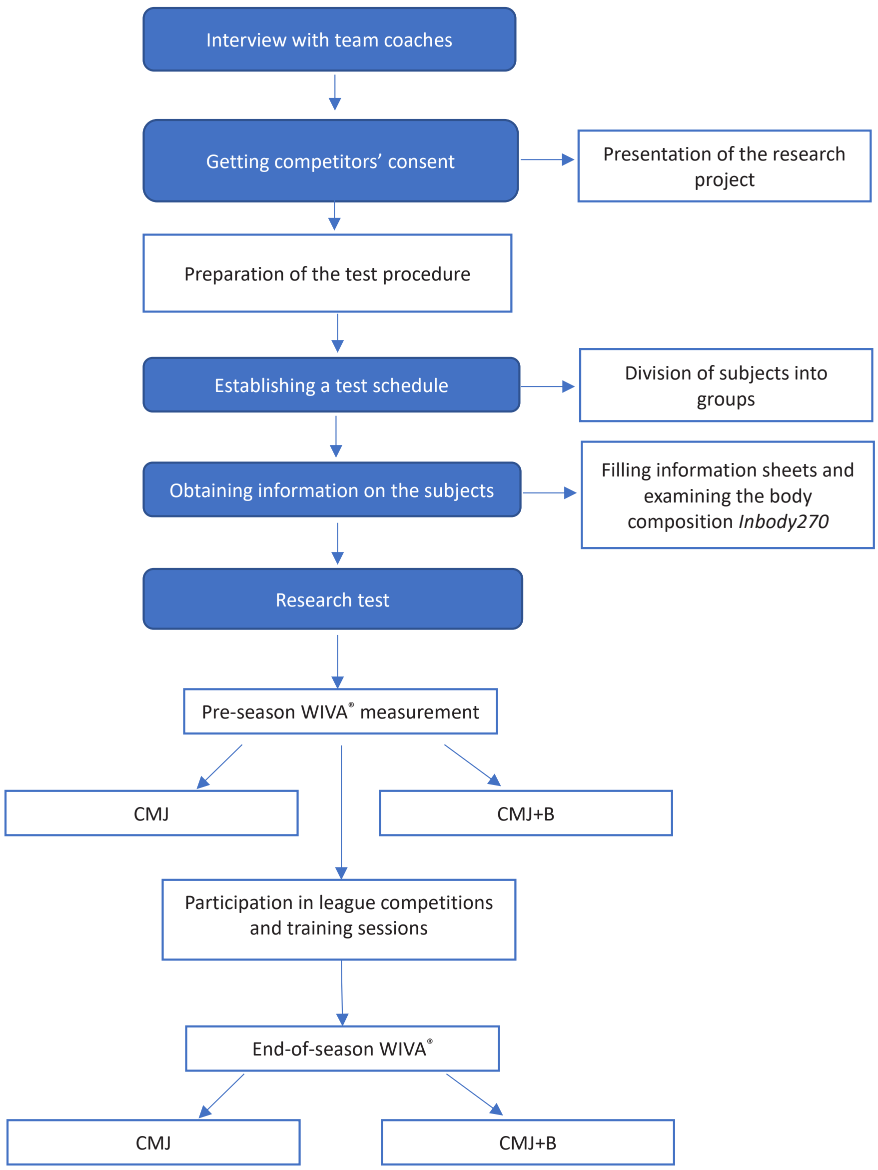

Figure 1. The test procedure.

2 left-hand electrodes, 2 right-hand electrodes). The subject placed his feet and hands according to the researcher's instructions. The test took 15 seconds.

During the actual test phase, a motion sensor (*WIVA® system)* was used, which, among other things, can be used to analyse jump height. It is used to examine different types of jumps. It includes a wireless sensor with a Bluetooth connection and a flexible wristband to stabilize the sensor. It is also possible to connect it to a computer using a Bluetooth connection. By combining data from an accelerometer, magnetometer and gyroscope, the system used in this study offers the most accurate sensory method of motion detection. Each of the sensors used fills in the gaps in signals from other sensors. In this way, it is possible to perform measurement tasks depending on the sensor's position. Before starting the test, the measuring sensor should be placed in a special fastening strip at the height of the L5 vertebra. The sensor should be placed in a maximum vertical position with the connection facing upwards. To prevent signal oscillations, the belt should be tightly fitted to the subject's body (Figure 2).

Testing procedure

The research started after a short warm-up in the gym. The room temperature was 22-23^{0}C. Each time, the test participant made three standing jumps. Prior to performing the actual three jumps, the participant made several warm-up attempts. First, the counter movement jump (CMJ), i.e. without arm swing was measured. At subject discretion, the time for one jump, and the corresponding measurement was 5 to 60 seconds.

The second round included counter movement jump with arms swing (CMJ+B). Each time, only the best of the three jumps was taken into account for evaluation. During the measurement, indexes such as maximum height, explosive power, concentric power, concentric work and coordination were analysed.

In this study, changes in the jumping indicators were assessed, influenced by six-month volleyball training, before the season and in its final phase. One of the most important performance indexes in volleyball is a indicator called "% coordination". It shows the extent to which the player has developed coordination in movements of the whole body.

Figure 2. Correct positioning of the WIVA® System on the subject's spine.

Statistical analysis

For statistical analysis, the normality of data with the **Shapiro-Wilk Test** was first tested**.** The results obtained for some parameters showed that since the data is not normally distributed, non-parametric tests were used for further statistical analysis (Wilcoxon signed-rank test). The **Mann-Whitney-Wilcoxon test** (also known as the **Mann-Whitney test**, or sometimes the **Wilcoxon rank-sum test** for two samples, or simply the **Wilcoxon test** for two samples). Because measurement results in the test population were not normally distributed, a non-parametric test was applied.

M – arithmetic mean for $a_1, a_2, ..., a_n$ as defined by the following formulas

$(a_1 + a_2 + ... + a_n) /n$

SD (±) – standard deviation, square root of the variance of a random variable *X*:

$$\sigma(X) = \sqrt{D^2 X}$$

one of the most frequently used measures of dispersion of a random variable around its expected value *EX*; its empirical equivalent is mean deviation s. from the sample, being the root square of the sample variance.

min – minimum value occurring in the sample

max – maximum value occurring in the sample

Me - **Median** (also known as a middle value, average value, or second quartile) – in statistics it is the value of a characteristic in ordered series, with an equal number of observations found above and below it. The median is a quantile of the order of 1/2, i.e. the second quartile.

Q_1 and Q_3 – **Quartile** – quantile of order 1/4 (*first quartile*, *lower quartile*), 1/2 (*second quartile*, *median*), or 3/4 (*third quartile*, *upper quartile*). It is one of the measures of position. 25% of observations lie in the first quartile, the second quartile divides the population into two equal parts, and

Table 2. CMJ before and after the season.

Volunteers & statistic indicators	Before season				After season			
	I Max Height [cm]	I Explosive power [N]	I Concentric power [W]	I Concentric work [J]	II Max Height [cm]	II Explosive power [N]	II Concentric power [W]	II Concentric work [J]
1	51.8	854.2	3237.1	764.9	58.7	879.5	2688.5	528.3
2	52.7	663.2	2357	572	56.4	818.8	2910.2	601.7
3	53.6	929.2	3411.1	737.2	46.9	956.8	3222.7	695.6
4	53.1	950.6	2941.3	503.7	54.7	917.8	2899.3	535.2
5	52	777.5	2070.9	423.7	49.4	778.5	2366.7	448.3
6	48.9	792.7	1982.5	354.7	51.7	775.5	1990.9	411.5
7	51.1	645.7	1770.4	324	49.7	651	2418.4	543.9
8	55.7	838.1	2309	438	55.6	873.7	2894.2	637
9	54.3	1014.7	3583.5	673.6	54.9	1023.7	3771.9	724.6
10	52.9	871.6	1626	339.3	51.9	988.7	2724.3	434.9
11	50.6	844.3	2340.9	401.7	49.2	842.3	2289.1	386.7
12	51.7	883.3	3142.7	776.5	50.7	910.5	3192.4	795.4
M	**52.37**	**838.76**	**2564.37**	**525.78**	**52.48**	**868.07**	**2780.72**	**561.93**
SD	**1.71**	**103.66**	**641.34**	**165.20**	**3.39**	**99.11**	**462.86**	**126.03**
Min	**48.90**	**645.70**	**1626.00**	**324.00**	**46.90**	**651.00**	**1990.90**	**386.70**
max	**55.70**	**1014.70**	**3583.50**	**776.50**	**58.70**	**1023.70**	**3771.90**	**795.40**
Me	**52.35**	**849.25**	**2348.95**	**470.85**	**51.80**	**876.60**	**2809.25**	**539.55**
Q1	**51.55**	**788.90**	**2048.80**	**389.95**	**49.63**	**808.73**	**2405.48**	**444.95**
Q3	**53.23**	**894.78**	**3166.30**	**689.50**	**55.08**	**927.55**	**2980.75**	**651.65**

25% of observations lie above the third quartile (with +/−1 accuracy). The difference between the third and the first quartile is the so-called interquartile range, whereas half of this value is called the semi-interquartile range.

RESULTS

For the counter movement jump (CMJ), no statistically significant differences were found (Table 2). Counter Movement Jump With Arms Swing (CMJ+B) showed statistically significant differences for one of the most important parameters for volleyball players, i.e. explosive power (p = 0.0414). During the league season the players significantly increased their coordination capacity – indicator "% coordination" (p = 0.002) (Table 3).

DISCUSSION

Volleyball is a sport in which jumping plays a major role, which is why these players very often participate in scientific research on jumping height. The study of Chu JH et al. [13] conducted on 20 volleyball players (aged 31 ±8.44 years) is a good example, where the authors showed that maximum vertical jump height (MVJH) is one of the key determinants of jump power when playing volleyball. Upper limb counteraction, knee bend before the jump, and approach distance are the three main factors influencing MVJH. What remains unknown, however, is the weight of each factor. The participants were asked to perform a series of maximum vertical jumps with arm swing. The kinematics and kinetic data were collected using a motion capture system and the MVJH was recorded by a vertical pretender. The peak vertical force (PF), maximum shoulder extension angle (SAng) and angular velocity

Table 3. CMJ+B before and after the season.

Volunteers	Before season					After season				
	I Max Height [cm]	I Jump power [N]	I Concentric power [W]	I Concentric work [J]	% coordination [%]	II Max Height [cm]	II Jump power [N]	II Concentric power [W]	II Concentric work [J]	% coordination [%]
1	58.8	893.4	2388.8	415.7	13.51	59.1	905.6	2225.7	349.2	0.46
2	66.9	788.3	2559.1	503.3	27	63.9	797.3	2718.3	537.3	13
3	66.4	931.3	3235.9	674.3	24	52.3	912.1	3004.3	622.6	5.41
4	57.6	877.1	2533.6	445.3	8	60.8	916	2507.5	390.5	6.1
5	60.5	718.7	1999.1	358.9	16	61.3	756.1	2050.2	350.4	11.97
6	73.4	691.5	373.4	67.7	50	84.9	779.2	853.3	135	33.2
7	54.4	625.3	1757.1	314.5	6	50.8	642.7	2089.4	400.7	1.02
8	64.3	836.9	2601.4	589.5	15	63	884.6	3377.4	786.8	7.39
9	62.6	993.9	2907	488.6	15	63.4	971.5	3109.5	578.4	8.45
10	63.6	931.2	2518.5	371.2	20	62.8	938.5	2381.1	346.7	10.98
11	57.1	829.1	1958.7	295.4	13	52.4	835.8	1969	296.7	3.2
12	61.5	924.1	1874.6	352.3	19	53	965.3	1950.4	362	2.28
M	62.26	836.73	2225.60	406.39	18.88	60.64	**858.73***	2353.01	429.69	**8.62***
SD	4.95	106.92	697.65	148.59	10.98	8.72	94.54	641.61	165.72	8.43
Min	54.40	625.30	373.40	67.70	6.00	50.80	642.70	853.30	135.00	0.46
Max	73.40	993.90	3235.90	674.30	50.00	84.90	971.50	3377.40	786.80	33.20
Me	62.05	857.00	2453.65	393.45	15.50	61.05	895.10	2303.40	376.25	6.75
Q1	58.50	770.90	1937.68	342.85	13.38	52.85	792.78	2029.90	348.58	2.97
Q3	64.83	925.88	2569.68	492.28	21.00	63.10	921.63	2789.80	547.58	11.23

*Significant difference to pre-season (p<0.05).

(SVel) were calculated from both arms, peak knee bending angle (KAng) from both limbs, BMI, and the length of the upper limb (ULL). These eight indicators were treated as MVJH predicators. Coefficients for the final MVJH predictive model were as follows: MVJH = 0.12 (right KAng) + 0.037 (right SAng) − 0.0011 (left SVel) + 0.0069 (right SVel) + 8.2669 (PF) − 0.78 (BMI) + 0.43 (ULL). The regression model has an R squared of 0.609 ($p<0.05$). It was concluded that the analysed model provided weights of various factors for predicting MVJH and the associated prediction accuracy was about 60%.

Vaverka F et al. [14] also analysed the jumping height of volleyball players and like us, they found a positive influence of the arm swing (AS) on the efficiency of the countermovement vertical jump (CMVJ). These studies unequivocally demonstrated a 38% increase in jump height (JH) compared to jumping without AS. The results obtained confirmed that AS does not affect the duration of the preparatory phase or the total duration of the jump, but significantly shortens the braking phase and extends the acceleration phase. Increased jumping performance related to AS is due to a significant increase in impulse during the acceleration phase, which depends on a combination of extended duration and increased average force during this phase. AS does not affect the initial body position at the beginning of the acceleration phase. A key factor due to which AS effectively contributes to jumping performance is the start of the upward hand swing shortly after the beginning of the jump acceleration phase. The very small variation in the time at which AS starts (CV = 4%) is indicative of a high and consistent level of AS use by professional volleyball players. The authors confirmed that proper integration of AS in the start phase can be considered an optimal model of AS use to improve CMVJ performance. Moreover, the current results also show that research on the jumping techniques employed by male volleyball players can help improve their performance and increase maximum JH.

Hughes G et al. [15], arrived at similar conclusions. Their research aimed at assessing the effect of post-activation potentiation (PAP) of the upper limb on vertical jumps. Participants performed three jumps with arm swing (CMJAS), and three jumps with their hands on hips (CMJ). Next, the participants performed 10 arm swings with dumbbells of 15% of the participant's body weight and then again performed jumps with arm swing after 3 (PAP3min), 6 (PAP6mins), and 9 (PAP9mins) minutes of rest. When comparing CMJ to CMJAS they observed a significant difference ($p<0.05$) in jump height, the peak vertical ground reaction force (GRF), and the peak concentric power. However, no significant difference was found when comparing CMJAS with any of the conditions caused by PAP to the upper limbs. This shows that the application of PAP to the upper limbs has no significant impact on the jump height.

The influence of arm swing on the jump height was also analysed by Williams S.J. et al. [16]. Their study assessed the contribution of strong arm swing (AS) during the eccentric and concentric phase of a countermovement jump (CMJ) to determine the effect of (AS) on CMJ performance. Fourteen women performed three test exercises, including CMJ without stretching the arm during the eccentric phase, CMJ without bending arms during the concentric phase and regular CMJ with maximum arm bending and extension. Jump height (JH), power (P) and ground response force (GRF) were evaluated using a force platform. The analysis showed significant differences between test conditions for JH ($p<0.001$) and P ($p<0.001$), but not for GRF ($p>0.05$). This study showed significant differences between the jump conditions. The conditions excluding upward and downward arm swing resulted in jump height being respectively 12.1% and 3.51% lower than regular CMJ. The arm sweep is thus important for both the eccentric and concentric phases of the jump.

Nunes A et al. [17] were also interested in jump height in young people training volleyball. The study aimed to analyse the effect of integrative neuromuscular training (INT) on the countermovement vertical jump height (CVJH) in young volleyball players before and after the eliminatory period. The study involved 32 beginner volleyball players randomly divided into two groups: intervention group – INT (age: 13.1 ±0.4 years; body weight: 55.3 ±12.1 kg; body height: 161.1 ±6.4 cm) and control group – CON (age: 12.8 ±0.7 years; body weight: 51.8 ±13.6 kg; body height: 160.1 ±10.7 cm). Participants were evaluated for somatic puberty (age from peak speed peak) and CVJH performance at four points in time within 20 weeks: baseline, 6 weeks INT, 12 weeks INT, and 8 weeks after INT (withdrawal). To identify possible differences in delta CVJH in both groups the analysis employed repeated measurements, analysis of variance and a Bonferroni post hoc test. The Spearman correlation coefficient was calculated to verify the relationship between the values of the vertical jump tests and the puberty levels found. INT showed a significant improvement in CVJH from baseline to 12 weeks and maintained an increasing trend induced by training after the elimination period (p> 0.001). A significant increase in CVJH was found in the percentage of change (Δ%) from the baseline to 6 weeks (p>0.005), 12 weeks (p>0.001) and the withdrawal moment (p>0.001) in INT compared to CON. The results of this study indicate that INT was able to improve the CVJH performance of novice young volleyball players. Moreover, these changes persisted for the whole of the deconditioning period.

These findings indicate that regular participation in supervised INT may improve jumping performance in young players, and this type of neuromuscular program may be particularly beneficial for young people with limited basic motor skills.

Jumping height was addressed by McGinnis et al. [18] who analysed the countermovement jump (CMJ) using an inertial measurement unit (IMU). The IMU's scalar kinematic trajectories reproduced acceleration, speed and displacement in 252 jumps performed by 14 people. The ability to differentiate the jump performance indicators in different test populations proves the usefulness of this method. Changes in kinematic indicators were visible under various conditions and several changes were significantly related to changes in jump performance (i.e. height). These results, together with the current results, show that in the future it may be possible to employ methods used in natural environments for many purposes, including the assessment and tracking of biomechanical results, fatigue assessment, and jump training.

Rocha JA et al. [19] researched jumping height in a slightly different context. Twenty people practising parkour without any systematic strength training were subjected to tests. They were divided into two groups. The strength training group (SG) did strength training and conventional parkour training, whereas the control group (CG) did conventional parkour training only. Both types of training were performed twice a week. The SG showed a significant increase in the CMJ jump height (p = 0.000194), whereas CG did not show a significant increase (p = 0.138). All SG practitioners showed a percentage increase in CMJ height, with an average difference of 9.9 ±0.9%.

The results presented above confirm that strength training increases vertical jump height in people practicing parkour, which can positively affect their performance in this modality. Therefore, combining strength training with a load protocol for muscle hypertrophy can increase parkour performance. The volleyball players who participated in the current study, apart from volleyball training, also did strength training once a week during the season. As a result, the whole training cycle contributed to increased jump height. Please note that the volleyball players examined in this study also had strength training twice a week, which was emphasized in the description of the research procedure and confirmed that inclusion of targeted strength training boosts jumping height during the season.

CONCLUSIONS

The juxtaposition of CMJ+B and coordination % parameters, which showed statistically significant differences, is indicative of a significant improvement in the physical fitness of the examined volleyball players and may be important for success in volleyball. It confirms the directly proportional relationship between the manifestation of muscle strength and neuromuscular coordination.

REFERENCES

1. Grgantov Z, Milić M, Katić R. Identification af Explosive Power Factors as Predictors of Player Quality in Young Female Volleyball Players. Coll Antropol 2013; 37(2): 61-68
2. Kafkas AS, Cinaru FS, Kafkas ME. The longitudinal development of endurance, sprint, agility, strength and jumping performance within college volleyball players. J Athl Perform Nutr 2018; 5(2): 1-16
3. Rodríguez R, Quiroga ME, Miralles JA et al. Study of the Technical and Tactical Variables Determining Set Win or Loss in Top-Level European Men's Volleyball. J Quant Anal Sports 2011; 7: 113
4. Moreno MS, Asencio CG, Badillo JJ. The effects of short-term resistance program on vertical jump ability in elite male volleyball players during the competition season. Retos (Madrid) 2014; 26: 153-156
5. Trajkovic N, Milanovic Z, Sporis G et al. The effects of 6 weeks of preseason skill-based

conditioning on physical performance in male volleyball players. J Strength Cond Res 2012; 26(6): 1475-1480

6. Nikolaidis PT, Gkoudas K, Afonso J et al. Who jumps the highest? anthropometric and physiological correlations of vertical jump in youth elite female volleyball players. J Sports Med Phys Fit 2017; 57(6): 802-810
7. Ćopić N, Dopsaj M, Ivanović J et al. Body composition and muscle strength predictors of jumping performance: differences between elite female volleyball competitors and non-trained individuals J Strength Cond Res 2014; 28(10): 2709-2716
8. Duthie GM, Young WB, Aitken DA. The Acute Effects of Heavy Loads on Jump squat Performance: An Evaluation of the Complex and Contrast Methods of Power Development. J Strength Cond Res 2002; 16(4): 530-538
9. Wisløff U, Castagna C, Helgerud J et al. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. Br J Sports Med 2004; 38(3): 285-288
10. 8Sarvestan J, Cheraghi M, Sebyani M et al. Relationships between force-time curve variables and jump height during countermovement jumps in young elite volleyball players. Acta Gymnica 2018; 48(1): 9-14
11. Krističević T, Krakan I, Baić M. Effects of short high impact plyometric training on jumping performance in female volleyball players. Acta Kines 2016; 10(Suppl 1): 25-29
12. Babic J, Lenarcic J. Vertical jump: biomechanical analysis and simulation study. In: de Pina Filho AC, editor. Humanoid Robots, New Developments. London: IntechOpen Ltd.; 2007: 551-582
13. Chu JH, Zhang JH, Chan ZY et al. Prediction of maximal vertical jump height with upper-limb countermovement, pre-jump knee-flexion and approaching distance in volleyball players. Abstract Book of the 11th Pan-Pacific Conference On Rehabilitation: Advances In Research And Practice; 2018 Nov 17-18; Hong Kong; the People's Republic of China. Hong Kong: Polytechnic University; 2018: 52
14. Vaverka F, Jandačka D, Zahradník D et al. Effect of an Arm Swing on Countermovement Vertical Jump Performance in Elite Volleyball Players. J Hum Kinet 2016; 53: 41-50
15. Hughes G, Dalmeida M, Johnstone J. The effect of upper limb post-activation potentiation on increases in vertical jump height due to an arm swing. 35th Conference of the International Society of Biomechanics in Sports; 2017 Jun 14-18; Cologne, Germany. Cologne: German Sport University Cologne; 2017: 991-994
16. Williams SJ, Barron TR, Ciepley AJ et al. Kinetic Analysis of the Role of Upper Extremity Segmental Inertia on Vertical Jump Performance. J Exer Physiol online 2017; 20(2): 28-34
17. Nunes AC, Cattuzzo MT, Faigenbaum AD et al. Effects of integrative neuromuscular training and detraining on countermovement jump performance in youth volleyball players. J Strength Cond Res, forthcoming
18. McGinnis RS, Cain SM, Davidson SP et al. Quantifying the effects of load carriage and fatigue under load on sacral kinematics during countermovement vertical jump with IMU-based method. Sports Eng 2016; 19(1): 21-34
19. Rocha JA, Dias da Silva RA, Paulino Oliveira M et al. Chronic effect of strength training on vertical jump performance in parkour practitioners. Arch Budo Sci Martial Art Extreme Sport 2017; 13: 173-178
20. Dictionary of Sport and Exercise Science. Over 5,000 Terms Clearly Defined. London: A & B Black; 2006
21. Martens R. Successful Coaching. 3rd ed. London: Human Kinetics; 2004

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