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Translated from the original in spanish

Original article

Comparison of lower limb power tests by two indirect methods in volleyball players under-18 category

Comparación de pruebas de potencia de miembros inferiores por dos métodos indirectos en voleibolistas categoría sub-18

Comparação dos testes de potência dos membros inferiores por dois métodos indiretos em jogadores de voleibol U18

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ABSTRACT

The vertical jump *test is very interesting as a test* physical in modern volleyball to assess the power of the legs, since in this way the physical trainer can plan a strength-speed program with the intention of improving their physical performance on the game field. Volleyball is a sport that is characterized by short duration and high intensity game actions, alternated by short periods of rest. This suggests the need to develop great power in volleyball female players, fundamentally in the lower limbs, aspects that were evaluated on ten volleyball athletes in the sub-18 category of the National Volleyball School by indirect methods Lewis and Harman, to whom a cross-sectional study was carried out in the stage of general physical preparation. The objective of this work was to compare the power levels of the lower limbs by both *tests* in a period of six weeks. As empirical methods, measurement and indirect *tests were used* to evaluate jumping power. Satisfactory results are obtained in both *tests,* fundamentally after subjecting the athletes to a system of exercises that show the Harman power values with a higher level of information for the coach, since in this it takes into account the action of the gravitational acceleration that must be overcome in the take-off phase. Based on the results, individual suggestions for the training of these athletes were provided.

Keywords: Lower limb; Power; Volleyball; Vertical jump; Lewis *test; Harmann`*s test.

RESUMEN

El *test* de salto vertical es muy interesante como prueba física, en el voleibol moderno, para valorar la potencia de piernas, ya que de esa manera el preparador físico puede planificar un programa de fuerza-velocidad con la intención de mejorar sus prestaciones físicas en el terreno de juego. El voleibol es un deporte que se caracteriza por acciones de juego de corta duración y de gran intensidad, alternadas por cortos períodos de descanso. Esto hace pensar en la necesidad de desarrollar en las voleibolistas una gran potencia, fundamentalmente en los miembros inferiores, aspectos que fue evaluado a diez atletas de voleibol categoría sub-18 de la Escuela Nacional de voleibol por métodos indirectos Lewis y Harman, a las que se les realizó un estudio transversal en la etapa de preparación física general. Este trabajo tuvo como objetivo comparar los niveles de potencia de miembros inferiores por ambos *test* en un periodo de seis semanas. Como métodos empíricos se utilizaron la medición y los *test* indirectos para evaluar la potencia de salto. Se obtienen resultados satisfactorios en ambos *test,* fundamentalmente después de someter a las atletas a un sistema de ejercicios que se muestran con mayor nivel de información para el entrenador los valores de la potencia de Harman, ya que en este tiene en cuenta la acción de la aceleración gravitatoria que debe vencer en la fase de despegue. A partir de los resultados, se brindaron sugerencias individuales para el entrenamiento de dichos atletas.

Palabras clave: Miembro inferior; Potencia; Voleibol; Salto vertical; *Test* de Lewis; *Test* de *Harman*.

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RESUMO

O teste de salto vertical é muito interessante como teste físico, no voleibol moderno, para avaliar a potência das pernas, uma vez que desta forma o treinador físico pode planear um programa de força-velocidade com a intenção de melhorar o desempenho físico no campo de jogo. O voleibol é um desporto caracterizado por ações de jogo curtas e de alta intensidade, alternando com curtos períodos de descanso. Isto sugere a necessidade de os jogadores de voleibol desenvolverem grande poder, fundamentalmente nos membros inferiores, aspectos que foram avaliados em dez atletas de voleibol da categoria U-18 da National Volleyball School, utilizando métodos indiretos de Lewis e Harman, que foram submetidos a um estudo transversal durante a fase geral de preparação física. O objectivo deste estudo era comparar os níveis de potência dos membros inferiores por ambos os testes ao longo de um período de seis semanas. Os métodos empíricos utilizados foram a medição e testes indiretos para avaliar a potência de salto. Foram obtidos resultados satisfatórios em ambos os testes, fundamentalmente depois de submeter os atletas a um sistema de exercícios que mostrou com um maior nível de informação para o treinador os valores da potência de Harman, uma vez que tem em conta a ação da aceleração gravitacional que deve ser superada na fase de descolagem. A partir dos resultados, foram fornecidas sugestões individuais para o treino destes atletas.

Palavras-chave: Membro inferior; Poder; Voleibol; Salto vertical; Teste de Lewis; Teste de Harman.

INTRODUCTION

The jumps exert a positive influence on the extensor and flexor muscles of the legs, fundamental for the achievement of a good jumpability, a good power in the jump, fundamental capacity to obtain good results in the volleyball sport during the spike and block actions where this ability plays an important role. The jumps have the peculiarity that, to obtain the desired objective, additional overloads are not necessarily needed, it must be remembered that the body weight itself, when having to jump against the force of gravity, turns out to be the load, hence the importance of taking it into account account is vitally important.

Volleyball is a sport that is characterized by short duration and high intensity game actions, alternated by short rest periods. The total playing time of a match ranges from 1 to 2 hours. In volleyball, the ball is in play for about a third of the total time. Each point lasts an average of eight seconds. The most striking plays are usually those with greater explosiveness and speed, also the most sought-after players are usually those who jump the most and those who finish off with greater power Formenti, *et al.,* (2020).

How many jumps and how are they performed during a game? According to the statistics carried out for this purpose, about 200 jumps are made during a volleyball game. Then there is no other remedy than to jump, jump and jump, and for this an adequate power of the lower limbs is essentia, Forte, *et al.,* (2019). Jump height is commonly used to measure lower extremity muscle power and upper and lower extremity coordination (Morales, 2021).

The number and typology of instruments to assess lower body power through vertical jump tests is considerable and can be classified into three methods. First, the jump height can be obtained by numerical integration of the ground reaction strengths, measured with the strengths plates. Second, the body's center of gravity can be tracked by biomechanical motion capture to track excursion in jumping performances (Dobbs, *et al*., 2015; Linthorne, 2020). Finally, the time interval between takeoff and landing can be transformed into jump height using basic linear kinematics with timing instruments that measure athletes' flight times.

The *tests* can be defined as measurements made to an athlete, in order to establish the physiological components that contribute to the sports brand, predict said brand, guide their training and evaluate said training. Assessing the conditioning physical capacities of sports performance allows evaluating the training process carried out, knowing in what direction the effects of the preparation process are manifested and proposing individualized intervention strategies, Gjinovci *et al.,* (2017). Currently, there are numerous means or *tests* to assess jumping power, some of them directly and others indirectly. In the former, strength platforms and biopsies can be mentioned within others; for them, special conditions are needed that implicitly carry a certain apparatus. In most cases, these platforms are very laborious and not very economical, in some cases becoming invasive for athletes and, consequently, not widely accepted by athletes and coaches. On the contrary, the second ones, the indirect ones, are easy to execute; they are not invasive, cheap and can be within the reach of coaches, which allow quick and efficient information on how the athlete's preparation is (Bui *et al.,* 2015).

In addition, it will be able to control and keep track of the load of the volleyball players of a manifestation that is related to the specific explosive motor actions of the game. On the other hand, the power indices will inform the athlete's performance through coordination, reactivity and elasticity, as well as if feedback on possible injuries is provided Gonçalve, *et al*., (2019). In sports, it is established that, although sports performance depends on many factors, the ability of an athlete to reach a point as far from the ground as possible in a jump can in many cases determine the difference between success and the failure (Pehar *et al*., 2017). Therefore, the importance of determining power levels through jump tests is seen. A simple evaluation to determine the degree of anaerobic power or explosiveness is the vertical jump test (Hernández, Montoya, 2017). This test assesses the dynamic strength of the lower extremities (the legs). Such an evaluation can be of benefit to a large number of sports activities that involve jumping patterns or similar movements.

The truth is that over time a concept has become fashionable that is based mainly on the use of jumps in their various forms for the development of strength and preferably jumpability in volleyball players, as expressed above refers to the so-called plyometric exercises or simply plyometrics (Silva *et al.*, 2019).

Vertical jump *tests* are relatively easy to perform, they are well standardized in the literature, and sufficient information is available in many sports with which the results can be compared. However, the lack of means sometimes leads to simply measuring the height of the jump and knowing this, several formulas are proposed to indirectly calculate the power (Barris, Button, 2008; Peña, *et al.,* 2017). Mechanical power in jump *tests* can be calculated indirectly from the jump height and body mass of the subjects using different formulas (Sayers *et al*., 1999).

The Lewis formula has been used by many coaches, physical education teachers and researchers, but what power is being measured is not specified. Harman's studies reach the conclusion that the power obtained was the average exerted by gravity on the subject in the fall phase and not the power exerted during the jump start. Thus, this author proposed his own formula to determine the power produced during the impulse phase, which it is assumed for this study due to its characteristics and the need to evaluate power taking into account the take-off, since these athletes have limitations in maintain jump chances as important in the jump for spike, block and jump serve (Amador *et al.,* 2005).

The term power can be defined as the ability to exert maximum strength for the shortest possible time. An individual's ability to perform high-intensity, short-duration exercise is known as anaerobic capacity or fitness. High anaerobic power is important for athletes who rely on the phosphagen and glycolytic systems. Some sports that require activating these systems are jumping events such as volleyball, throwing, and sprinting.

The maximum mechanical power developed by the muscles is an essential element in the performance of many sports, especially volleyball. The power can be measured externally by means of different devices from the developed work or from the strength and speed P (W)= F (N) · v (m/s)]. Thus, in any dynamic exercise (concentric or eccentric), average or instantaneous power values can be measured, but not in isometric exercises (in which there is no displacement, and therefore neither work nor speed of movement), in which the power will be zero.

On the other hand, there are certain laboratory tests that allow establishing the maximum or average power generated by the evaluated individual. Some of such tests are stair-climbing tests (the Margaria-Kalamen power test), strength-velocity tests (isokinetic knee extensions and the Cybex isokinetic cycle ergometer test), cycle ergometer effort tests maximum (Ex: Wingate Anaerobic Tests) and others (Aedo, *et al.*, 2020). Due to the considerations raised above, the following objective is proposed: to compare the power levels of the lower limbs by both *tests* in a period of six weeks.

MATERIALS AND METHODS

They were part of the study ten volleyball players, with an average of 17.3 years, 68.2 kgm of body weight and 179.8 cm. tall, all belonging to the same sub-18 youth team, physically able to perform the tests. The time between the two measurements was 6 weeks, in which a system of exercises was performed to strengthen the muscles of the lower limbs and the trunk fundamentally.

Like empirical methods measurement and indirect *tests were used* to assess jumping power.

The measurement is executed from the completion of a system of exercises that are explained below:

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Six-week exercise system

The objective of this proposal is: to apply a system of exercises that allows the development of jumping power through the application of the vertical jump.

The content of this system includes: jumping exercises are exceptional, which allow developing a great dexterity of movement and, in turn, an endless graduation, either due to its level of technical difficulty or its intensity.

Within the simple classification of jumps are:

- Free jumps, vertical and horizontal.
- Jumps over obstacles (hurdles, boxes, etc.) with 2 legs.
- Jumps from objects (boxes) or plyometrics, in depth, with two legs.

Table 1 is also illustrated. It includes the organization of these exercises (Table 1).

Table 1. - Weekly micro-cycle. Program exercises

No.	Ejercicios	Lunes	Martes	Miércoles	Jueves	Viernes	Sábado
1	Abdominales	X		X		X	
2	Salto al pecho	X		X		X	
3	Puntilla	X		X		X	
4	Cuclillas profunda	X		X		X	
5	Saltos continuos	X		X		X	
6	Carreras	X		X		X	
7	Flexibilidad	X		X		X	

The system exercises are as follows:

1. Abdominals (Strengthens the abdominal muscles).
2. Jump raising the knees to the chest (increased jumpability).
3. Tiptoes (Strengthens the muscles of the lower part and back of the legs that are involved in jumping.
4. Deep Squat (Strengthens the Quadriceps muscles, the knee joint and helps with balance.
5. Continuous jump exercise (jump increment).
6. Speed and Endurance Races (Strengthens the muscles of the lower limbs and increases work capacity).
7. Flexibility.

To perform these exercises, it is recommended that the coach consider the following *Training Principles:*

- Gradual and progressive increase in loads.

- Individualization.

As *methodological indications* of this preparation, it is suggested that coaches follow the instructions derived from this experience. This work was carried out with the under-18 women's volleyball team, but it is applicable to other categories and gender, it lasted 6 weeks. The weekly frequency that can be entered is determined by the volume and, therefore, by the duration of each stimulus. In case of strictly adhering to the ATP-CP system, the stimuli can be administered daily, since in 24 hours it would be fully recovered after the effort. If the load exceeds these times, a stimulus every 48 hours is totally bearable, having perfect awareness of the other stimuli that made up the training session in question.

The number of series and repetitions are subject to all precautions, in addition to the sports history of the player, that is, the years of seniority in the sport in which he is training, even so, the high loads are for highly trained organisms.

The measurement It is applied with the help of the tape measure and various materials that are described below:

- Control sheets.
- Pencils.
- A tabloid to fix the spreadsheets.
- A vertical plate two meters high (graduated in centimeters, located at a height of 1.50 m from the ground and separated 15 cm from the wall).
- A small ladder (arranged perpendicularly to locate a controller that can accurately determine the height reached by the participants, so that the controller's view is approximately horizontal to the units of measurement on the scale).

As part of the procedure the athlete stands about 30 cm. of this plate, with the body lateral to it and makes a first mark (a) with a hand painted with chalk or magnesium (try to reach the maximum height without taking off the heels from the ground) that represents the initial reach. Next, the athlete freely flexes her legs to jump as far as possible and, with her arm outstretched, make a second mark (b), which represents the final reach of the jump. The height of the jump is calculated by subtracting the two distances.

Regarding the *tests* to evaluate jumping power, it can be argued that the first *test* used is called the *Lewis Test.* This *test* was used to determine the level of information between the test (vertical jump) and the criterion (power *test)***.** In the first instance, the Lewis formula (or nomogram) was used. The formula to determine the power generated in the jump is presented Equation 1).

$$\text{Potencia Máxima (kgm} \cdot \text{s-1)} = \sqrt{4.9} \text{ X MC (kg) X} \sqrt{\text{Dn}} \quad (1)$$

Where:
4.9 = Constant value;
MC = Body mass (or weight) of the body in kilograms (kg);
Dn = Net Jump Distance. Difference (distance) between stretch height (standing reach

height, in centimeters) and maximum jump height (vertical jump height, SV, in centimeters).

The second *test* used was the so-called *Harman Test;* in this, the normal acceleration of gravity (9.8 m s-1) is included. This alteration allows the use of standardized power units. In this case, kilograms are converted to newtons, which would generate a unit of power in newton meters per second (N m s-1) or Harman watts (W). The revised formula is described below (Equation 2).

$$\text{Potencia Máxima (N·m · s-1)} = \sqrt{4.9} \text{ X } 9.8 \text{ X MC (kg) X } \sqrt{\text{Dn}} \quad (2)$$

Where:
9.8 = Normal acceleration of gravity (9.8 m s-1).

Statistical processing was based on Descriptive Statistics. Windows 10. The registered statisticians were: mean, minimum, maximum, standard deviation and correlation coefficient.

RESULTS AND DISCUSSION

Within the logic of this research, the results obtained from the empirical methods are integrated: measurement and *tests* to evaluate jumping power. In the course of this exhibition, the data and the interpretation of this analysis will be shown (Table 2).

Table 2. - Vertical jump criteria and lower limb power

Momentos	Primera medición				Segunda medición		
Atletas	Salto vertical(cm)	Potencia Lewis(kgm.s)	Potencia Harman. (N.m.s-1)		Salto vertical(cm)	Potencia Lewis.(kgm.s)	Potencia Harman (N.m.s-1)
1	311	1264,23	123,81	1	322	1370,03	135,26
2	310	1383,07	135,49	2	323	1510,27	148,00
3	326	1531,19	150,05	3	332	1563,13	153,18
4	300	1151,34	112,88	4	315	1282,46	125,68
5	307	1114,07	109,17	5	320	1248,25	122,32
6	300	1240,07	121,52	6	321	1363,26	133,59
7	300	1113,57	109,13	7	315	1278,51	125,29
8	300	1119,78	109,73	8	321	1292,97	126,55
9	300	1288,02	126,22	9	328	1406,46	137,83
10	300	1207,7	118,35	10	323	1378,75	135,11
PRO	306	1241,34	124,65	PRO	321	1369,46	134,18

Source: Under-18 volleyball team.

Table 2 summarizes the criteria for vertical jump and power for lower limbs in the first measurement. A 30 % correspondence between vertical jump and power results is presented. Athletes 1, 2 and 3 stand out, but this is not the case with athlete No. 9, who

presents adequate power in both *tests* and her underestimated jump level is below the average value, which coincides with the findings of (Hernández, 2017).

In the second measurement, there is a 50 % correspondence between the vertical jump and the power results, here the athletes 1,2,3,9 and 10 stand out, whose correspondence is in the two power *tests*.

The results found from the formulas that evaluate jumping power by the indirect method show that the Harman *test* is presented with greater advantages in our study group. These results stabilize even more after having applied the exercise system.

It is considered opportune to state that the values of *D* (difference between the reach and the jump) that, according to the formula, must be worked in centimeters. This difference must be taken to meters since in the same equation that physical magnitudes are related they have to be expressed in the same system of units. This case refers to the Harman *test* that contemplates the gravitational acceleration m/s^2 (Sena, 1979). Although in the research carried out, not many correspondences between the vertical jump and the power values are observed. This reinforces the idea that obtaining a higher flight height in the jump does not necessarily mean having marked a higher power peak. It is based on the assumption from which the calculation formulas are based, since the height of the jump depends on several factors, to point out a few: motor control, intramuscular coordination, multiarticular action, high levels of force, high degrees of power, good technique execution, and others (Amador, Lara, Sánchez, 2005; Dobbs, *et al,* 2015).

Table 3. - Summary of statistical processing

Estadígrafos	Medición	Edad A /M	Peso (kg)	Talla (cm)	Salt. Vertical (cm)	Alcance (cm)	Despegue (cm)	Lewis (kgm.s)	Harman (N.m.s.1)
Promedio	1M	17.3	68,4	179,8	306,1	238	68,1	1241.34	12165,25
	2M	**17,3**	**68,7**	**179,8**	**319.4**	**238**	**81.4**	**1369,33**	**13417,86**
Max	1M	17,8	76,8	187	326	247	80	1531,19	15005,74
	2M	**17.8**	**76,3**	**187**	**332**	**247**	**86,0**	**1563,13**	**15318,72**
Min	1M	17	60,3	171	300	225	53	1113,57	10913,03
	2M	**17**	**62**	**171**	**310**	**225**	**70**	**1248,25**	**12232,87**
D.S	1M	0,26	5,00	4,45	8,32	7.23	8,49	134,68	1319.86
	2M	**0,26**	**4,7**	**4,57**	**5,82**	**7,23**	**6,08**	**109,10**	**1070,48**

Source: Under-18 volleyball team.

Table 3 presents a summary of the parameters, reason for the study, under the statistical analysis from the statistical package Excel for Windows. 10. Here are the averages, the maximum and minimum values and the standard deviation. As already noted, the average values of the chronological and anthropometric parameters did not suffer variations, since they are stable parameters. The reach parameter, which remains stable, is included in this observation, since it depends on the size (Table 3).

The values of the standard deviation in the first measurement present higher values with respect to the second measurement. In the case of the vertical jump, takeoff, Lewis and Harman *test,* its explanation is given by the influence of the Exercise System that was applied during the 6 weeks in the General Physical Preparation stage, in which a greater

homogeneity of the data regarding the average value of the measurements (Morales, *et al.,* 2021).

Table 4. - Pearson correlation system between vertical jump and lower limb power

		POTENCIA LEWIS	POTENCIA HARMAN
Salto vertical	P1	0,60	
	P1		0.67
Salto vertical	P2	0,71	
	P2		0,76

Significance level p<0.05

Source: U-18 volleyball team.

Table 4 presents Pearson's correlation levels at its two moments to determine the level of empirical information (first case when there is a measurable criterion) (Zatsiorski, 1989). This level of information is of great importance for the trainer, since it allows him to select the indicator that is most closely related to the test he wants to evaluate; in this case, the test (vertical jump) and the Lewis test and *Harman test* (Table 4) are taken as the criterion.

In the first measurement or pretest, the correlation took the following values: vertical jump and Lewisr power = 0.60, on the contrary, vertical jump and Harman power r =0.67. In both cases, the statistical relationship was medium, although with a slight improvement in vertical jump and Harman power. In the second moment or post-test, there was a slight improvement in both *tests,* the results coincide with the work of the same author (Henríquez, 2016). Vertical jump and Lewis *test r=0.71 and vertical jump and Harman test* r=0.76. In both cases, the statistical relationship is strong, the results are slightly higher in the second test; show the influence of the exercise system applied in the evaluated period. A greater relationship between the vertical jump and the Harman *test is noted in both moments.* It is deduced in our case that the Harman power *test* presents more information for the trainer, it is considered that the levels of correlation can be influenced by the size of the sample.

This research is particular, compared to other works of a similar object of study, that in this case the Harman *test is used* to measure jumping power, unlike other measurements for this purpose. These assessments contributed directly to the characterization of the Volleyball athlete and, as a consequence, a better personalization of the training exercises is generated. This is not the case in other works where the measurements use the Lewis *test more* among other methods and media (Álvarez-Zúñiga, Moreno-Leiva, Arias-Poblete, 2019; Vásquez-Bonilla, *et al.,* 2019; Sánchez-Rojas, *et al.,* 2020; Véliz, *et al.,* 2020; Jiménez, 2021).

CONCLUSIONS

The parameters of age, weight and height of the measurements showed a stable behavior, since the time between pre-test and post-test was very short, in 6 weeks in this category no changes are appreciated.

The higher jump does not necessarily mean obtaining a higher power peak as we have observed in the study at both times. It is considered that this may be influenced by the weight of the athletes, the size of the sample and some coordination factors. The system of exercises proposed to be developed in the 6 weeks contributed to the improvement of performance.

Seeing the great oscillations in power calculated by Lewis and Harman with the formulas that appear in the bibliography, it is believed interesting to study as a possible line of the future.

The jump indicators and the results in the power *tests* by the indirect method had favorable changes after applying the exercise system. Due to the study carried out with the vertical jump and the power *tests* (Sayers, 1999), taking into account the characteristics of each of them, the *Harman Test* provides a higher level of information for the coach, thus demonstrating its suitability.

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