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Can the vertical jump height measure the lower limbs muscle strength?

Gabriele Mascherini[1], Mario Marella[1], Paolo Bosi[2], Marta Radini[2], Paolo Spicuglia[2], Massimo Gulisano[1], Piergiorgio Francia[1,*]

[1] Department of Clinical and Experimental Medicine, University of Florence, School of Human and Health Sciences, Florence, Italy
[2] Laboratory for Motor Science Applied to Medicine, University of Florence, Florence, Italy

Abstract

The vertical jump is frequently used for the functional evaluation of athletes and non-sporting subjects. The jump height is often used as an indicator of lower limbs strength. The aim of this study was to verify the presence of a relationship between the maximum height reached and muscle parameters expressed during the vertical jump. In 22 healthy males practicing recreational physical activity (age, mean ± standard deviation: 22.5±1.2 years; body mass: 72.8±13.2 kg; body height: 177.1±7.0 cm) and in 15 female volley players (age: 16.5±0.4 years; body mass: 64.4± 8.4 kg; body height: 175.5±7.9 cm), Jump Height (cm), Muscle Strength (N/kg) and Power (W/kg) were recorded during the jump tests. In the healthy males group, jump height was correlated with muscle power: $r = 0.33$, $p>0.05$; a higher correlation resulted between muscle strength and power: $r = 0.62$, $p<0.01$. In the female volleyball players group, only the muscle strength and power showed a correlation: $r = 0.54$, $p<0.05$. It is therefore possible to confirm that the jump height reached during a vertical jump does not provide clear information on the strength of the lower limbs. At the same time, an improvement in muscular strength of the lower limbs does not guarantee an increase in jump height. Several parameters should be evaluated at the same time for a correct functional assessment of athletes and healthy non-sporting subjects.

Key words

Accelerometer, motor skills, muscle power, counter movement jump.

Introduction:

Jumping is an activity of many sports, both team and individual. Ziv and Lidor (2010) reported that the maximum height achieved by an athlete in this activity is currently a functional evaluation parameter frequently used by professionals. In particular, athletic trainers use the maximum jump height as an indirect parameter for assessing the strength and muscle power of the lower limbs (Markovic et al, 2004).

During a competitive season, this value is considered by researchers and trainers as means to verify the effectiveness of the training program (Harman et al., 1991). In addition, in youth sports this type of assessment is also used, along with the anthropometric evaluations, for determining athletes' attitudes to certain sports (Moss et al. 2015).

* Corresponding author. E-mail: piergiorgiofrancia@libero.it

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Tests provided by literature for the evaluation of the vertical jump are the Squat Jump (SJ) and the Counter Movement Jump (CMJ). The squat jump (SJ) is defined as a jump that is performed from a squatting position. A counter movement jump (CMJ) is defined as a jump performed by a subject starting in an upright position, who squats down to a pre-determined height and then immediately jumps up from that position. The CMJ is more of a short pre-loading of the muscle-tendons followed by an immediate contraction: this feature makes the CMJ more natural and therefore closer to the activities required during sport (Finni et al., 2010).

Gathercole et al. (2015) underlined that an analytical approach is needed to assess the performance of CMJs. In particular, it is necessary to describe other variables, *e.g.* those of the concentric phase of the jump, such as peak power and strength, in addition to the maximum height achieved.

In fact, it has been demonstrated that there are no correlations between the maximum isometric and dynamic muscle strength of the lower limbs and the jump height in CMJ (Nuzzo et al., 2008).

Devices for this evaluation have been available for a long time with specific characteristics, which allow not only the quantitative evaluation of the jump height but also the qualitative one of the power and muscle strength expressed during all the phases of the vertical jump (Harman et al. 1991). This method should be also applicable to populations with different characteristics such as subjects of different gender, either practicing sport or recreational physical activity (RPA), *i.e.* the activity typically associated with structured and organized activities aimed at wellbeing without competing or participating to sport competitions or training (Ma et al., 2016) or practicing sports compared to sedentary ones.

The aim of this study was to verify the relationship between the jump height and the parameters of muscle strength and power measured during a vertical jump by devices that can be worn in two groups of subjects with different sport habits.

Material and methods

Participants

Twenty-two healthy males practicing recreational physical activity (age, mean ± standard deviation: 22.5±1.2 years; body mass: 72.8±13.2 kg; body height: 177.1±7.0 cm) and 15 females practicing volleyball(age: 16.5±0.4 years; body mass: 64.4± 8.4 kg; body height: 175.5±7.9 cm). None of the participants had pathological or traumatic history at lower limbs. The local ethics committee approved the experimental protocol, and all subjects provided the written informed consent before starting the study protocol.

Testing procedures

The measurements were carried out at the Laboratory of Motor Sciences Applied to Medicine, University of Florence, Italy. All participants were asked to avoid strenuous exercise on the day before the assessments and any additional resistance training in the 72 hours before being tested.

Athletic performance was evaluated by the standard functional performance test, the CMJ test, using the Accelerometer Free Power Jump Next (Sensorize, Rome, Italy).

After 15 minutes warm-up, subjects were expected to reach their maximal jump height within 3 counter movement jumps. This test involves a single jump starting from an upright position with hands on hips and with counter movement. The test consists in the following phases:

- From a standing position the subjects were instructed to maintain their hands on the iliac crest to avoid a different variance resulting from arm swing;
- Subjects squatted to the point they considered an optimal depth (approximately one-third of a full squat);
- Subjects jumped vertically to the maximal height;
- They landed in normal flexion and lasted in a neutral position for 1-2 seconds.

This test allows to determine the height achieved from the center of gravity. Jump height was assessed by measuring the flight time during the CMJ and the highest jump height was used for further evaluations.

Additional parameters evaluated were muscle strength (N/kg) and power (Watt/kg) collected from the acceleration data.

Statistical analysis

Descriptive statistics is given as mean, standard deviation, minimum and maximum value. To establish a relationship between the three variables describing the vertical jump, the Pearson correlation test was used; $p < 0.05$ and $p < 0.01$ were recorded separately and considered as significant..

Data analysis was performed using the Statistical Package for the Social Sciences software version 21 (SPSS Inc, Chicago, IL).

Results

Table 1 shows the mean of the maximum values achieved by males practicing recreational physical activity and performing the vertical jump test (height = 49.5 ± 3.5 cm; strength = 20.3 ± 4.6 N/kg; power = 38.1 ± 5.2).

Relationships between the three variables were the following:

- Jump height vs muscle strength: $r = 0.14$, not significant;
- Jump height vs power: $r = 0.33$, not significant;
- Muscle strength vs power: $r = 0.62$, $p < 0.01$.

While, on one hand, the vertical height increased, on the other the strength and muscle power did not show an equal increase.

Table 2 shows the mean of the maximum values achieved by females volleyball players performing the vertical jump test (height = 44.4 ± 9.2 cm; strength = 12.4 ± 3.7 N/kg; power = 32.1 ± 6.6).

Relationships between the three variables were as follows:

- Jump height vs muscle strength: $r = 0.33$, not significant;
- Jump height vs power: $r = 0.33$, not significant;
- Muscle strength vs power: $r = 0.54$, $p < 0.05$.

Table 1. Average results of height, strength and power during jumping tests performed by healthy male subjects.

Healthy male	Jump height (cm)	Strength (N/kg)	Power (Watt/kg)
Subjects	22	22	22
Mean	49.5	20.3	38.1
St. Dev.	3.5	4.6	5.2
Minimum	43.0	13.4	28.1
Maximum	55.0	29.4	47.2

Table 2. Average results of height, strength and power during jumping tests performed by female volleyball players.

Female volley players	Jump height (cm)	Strength (N/kg)	Power (Watt/kg)
Subjects	15	15	15
Mean	44.4	12.4	32.1
St. Dev.	9.2	3.7	6.6
Minimum	22.6	11.1	21.9
Maximum	55.5	24.6	44.9

In this case also, when the vertical height increased, muscle strength and power did not show an increase.

Discussion

The vertical jump provides information on motor skills (jumping height) and dependant skills (muscle strength). The goal of this study was to verify the presence of a relationship between strength and/or muscle power and the jump height, in addition to determining if height could be not only an indicator of an ability but also of a dependant skill.

Based on the results gained in two distinct groups of subjects we can confirm that the jump height achieved during a vertical jump does not provide information on the strength of the lower limbs. At the same time, an improvement in muscular strength of the lower limbs does not guarantee an increase in jumping height: in fact, the studies carried out by Hatze (1988) on the biomechanics of the CMJ show that the increase in strength and muscle power does not bring about any improvement in skills. This is also due to minor changes that occur during the strength training on the biomechanics of gesture (Hatze, 1988). It is therefore necessary to use strength and muscle power training models, sport-specific, respecting the timing and degrees of freedom of the trained motor skill.

Therefore, since these two aspects of the science of training are not directly linked to each other during a vertical jump, collecting more parameters is needed to carry out a better functional evaluation both in athletes and in healthy non-sporting subjects (Gathercole, 2015).

It is important to use statistically significant indicators both at the beginning of the training period and during the competitive season to correctly set up a training program and verify its ongoing effectiveness

At the same time, it is important to know the limits and reliability of the tests and devices used during functional evaluation of both athletes and healthy non-sporting subjects.

Conductivity carpets and photocells estimate jump height based on the flight time, but cannot provide precise information on strength and muscle power (Dugan et al., 2004).

A direct assessment is therefore necessary for this dependant skill during the vertical jump.

Devices available to directly measure strength/ muscle power are the following:

- Accelerometer, wearable device by recording the acceleration during the phases of the motor gesture,
- Strength platform, by recording the ground reaction force exerted by the foot in contact with the platform.

Scientific literature considers the strength platform a gold standard in the evaluation of the CMJ (Cordova and Armstrong, 1996). However, this method is currently expensive and requires the use of devices difficult to move, hindering the possibility of making multiple evaluations during a competitive season (Cordova and Armstrong, 1996). Other methods for assessing the jumping height are the result of flight time's integration with other parameters closely correlated to the force expressed such as body acceleration during jumping. Therefore, several easily moving, reliable and repeatable methods have been validated to correctly evaluate CMJ by an inertial measurement unit (MacDonald et al., 2016). Recently, smartphones applications using their own accelerometer for this assessment have been produced (Stanton et al., 2017). All this availability of devices needs to be carefully monitored because system errors may arise during the interpretation of the results gained: devices used have to always be the same in case of sequential evaluations because they are not interchangeable (Hilmersson et al., 2015). This is the case of an evaluation at the beginning of the training, followed by one in progress and another at the end.

Conflict of interest:

The authors declare no potential conflict of interest and no financial support.

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