Journal of Physical Education and Sport ® (JPES), Vol. 22 (issue 1), Art 34, pp. 266 - 272, January 2022
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Strength profile in young male and female trail runners

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Published online: January 31, 2022
(Accepted for publication January 15, 2022)
DOI:10.7752/jpes.2022.01034

Abstract:
Strength plays a very important role in the development of athletes and their evolution. With regard to mountain running, different studies have proved the existence of correlations between the strength of certain lower body segments and a better running performance on different slopes or a reduction in energy expenditure. However, there are hardly any studies that analyse the strength profile in young runners. Besides, in the case of trail running, there is no literature in this regard. The aim of this work is to analyse the strength profile of young trail runners, look for possible connections between the results and establish the characteristics and differences in both genders. Data related to jumps (SJ, CMJ, DJ from 40 cmand 15-second multijump) and 1RM in half squat were taken from a total of 18 technified athletes (13 men, 5 women) between 15 and 23 years old. The data showed mean values of 30.1 cm, 26.7 cm, 26.0 cm and 20.0 cm height in CMJ, SJ, DJ and multijump for men, while for women, the values were 24.1 cm, 21.7 cm, 20.3 cm and 18.6 cm respectively. Regarding the calculation of MRI, men moved a total of 110.9 ± 24.1 kg and women 55.8 ± 5.3 kg. In general, were found quite a lot of variation within subjects in terms of explosive strength results. The results generally show mean values below other sports modalities, which may be due to a lack of experience in this type of work. The results of the jump test and 1RM show different significant correlations for the total sample. However, this varies when segmenting the sample by gender, where only the CMJ and 1RM/weight variables significantly correlate in the case of men, although strong and very strong connctions are found between those obtained in various tests.
Key Words*:* **Mountain running, Bosco test, endurance, jump, squat**

Introduction

Strength and endurance training has shown positive results in the physical development of adolescents athletes (Costa et al., 2016). In recent years it has been observed that strength work is gaining importance in the training planning of runners. Despite some discrepancies, several studies have shown that increasing maximal strength has a positive impact on both long distance (Edith Geanine & Romero Frómeta, 2021; Stkren, Helgerud, Maria Stka, & Hoff, 2008) and sprint runners (Cronin, Ogden, Lawton, & Brughelli, 2007).

Ehrström et al., (2018), studied the relationship between the runner's strength profile and its performance in the different situations that we find during a mountain race and affirmed that the classical physiological model of endurance running does not allow the successful identification of physiological predictors for performance in this type of test. However, the predictive power of the model improves when specific factors are incorporated, such as local strength resistance and running efficiency measured on a positive slope.

But when we talk about strength, we can refer to different manifestations of it, such as, for example, maximal strength and explosive strength, among others. The former could be defined as "the capacity of a given muscle or group of muscles to generate maximum muscular force under specific conditions" (Verkhoshansky & Siff, 2004), while explosive strength refers to the manifestation of strength in a period of time such as a jump (Santos-García, Navarro-Valdivielso, Aceña-Rubio, González-Ravé, & Arija-Blázquez, 2008).

For the measurement of strength in its different manifestations there are different methods and tools among which we find the calculation of maximum strength by calculating 1RM, the measurement of isometric strength or the realization of jumps included in the so-called "Bosco test" (Bosco, Luhtanen, & Komi, 1983) among others.

This Bosco test of vertical jumps, due to its ease and safety, as well as its proven ability to estimate the strength of the limbs, is one of the most used (Boyle, 2017), mainly the Drop Jump, the Squat Jump and the Countermovement Jump through which we can analyze values of explosive strength, elastic strength or mechanical power among others. There are several studies that relate jumping capacity with different factors such as fatigue (Balsalobre-Fernández, Tejero-González, & del Campo-Vecino, 2014) or performance in speed and middle distance (Bachero-Mena et al., 2017). Regarding mountain running (Giovanelli, Taboga, Rejc, & Lazzer, 2017) found a significant correlation between SJ performance and lower energy expenditure at speeds of 10-12 km/h.

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The Bosco system has been used in some studies to calculate strength loss during a race (Rousanoglou et al., 2016), but also to analyze the relationship between these jumps and the results in different running tests(Aoki, Katsumata, Hirose, & Kohmura, 2020), finding significant relationship between the CMJ test and different track and field races.

On the other hand, in different sports modalities, it has been studied how maximal strength in Squat exercise (or 1RM) is related to the improvement in speed and power (Baker & Nance, 1999; Balsalobre-Fernández, Santos-Concejero, & Grivas, 2017; Cronin et al., 2007).

But, despite the many studies about strength and its relationship to improvement in endurance sports and its preventive factor. We have not found any study that analyzes different manifestations of strength, establishes correlations between these manifestations and describes a strength profile in trail runners.

For this reason, the following study aims to analyze the strength profile of young trail runners through different jump tests and 1RM squat tests, in order to find if there are relationships between the different exercises and between genders.

Material & methods

Participants

A total of 18 young participants (13 male, 5 female) aged between 15 and 23 years, all belonging to the mountain running technification program and including several runners competing in national events were part of the present study.

Procedure

The days prior to the measurements, the athletes should have rested in their training and attended without having eaten anything in the hours before the body mass and height data were taken. They were allowed to eat something before the strength tests in order to avoid that not eating could affect their performance.

As for descriptive data; height, leg length, hip height, Body mass and % body fat were recorded using a Seca 217 stadiometer to the nearest 1 mm (Hamburg, Germany), a metallic, narrow and inextensible Rosscraf tape measure (precision, 1 mm) and a Tanita BC-601 scale (precision 0.1 kg, Tokyo, Japan).

With regard to the tests, most of the participants had little or no experience in this type of work, so it was necessary to explain and practice each of the tests beforehand to assess and ensure their correct technical execution.

<u>JUMPS</u>

Data were calculated for different static and reactive jumps:

- Squat Jump (SJ): starting from the half squat position. It is used to measure explosive strength
- Countermovement Jump (CMJ): starting from the upright position. It is used to calculate explosive + elastic strength.
- Drop Jump from 40 cm (DJ): from a height of 40 cm the athlete drops with both legs and when touching the ground performs a vertical jump. It is used to assess the reactive strength of the lower limbs.
- Multijump of 15 s (RCMJ15): CMJ type jumps are performed for 15 seconds with little cushioning between each jump. It allows to know the capacity to produce power using the ATP-CP system.

Data concerning these jumps were measured with jumping platform (Chronojump, Bosco Systems®, Barcelona, Spain), validated in (Pueo, Jimenez-Olmedo, Lipińska, Buśko, & Penichet-Tomas, 2018). For the first 3 jumps, each participant performed a pre-take practice to specify to them the execution technique for each jump. Then, three jumps of each modality were recorded for each of the subjects with 5 minutes of rest between jumps.

From the data obtained in the different jumps, the other variables were calculated:

- The elasticity index (EI), which tells us the elastic component that influences the individual's jump by discriminating the difference in height between the CMJ and SJ jumps. This value is calculated from the formula:
    - E.I.=((CMJ-SJ)*100)/SJ and.
- The Q index assesses the reactivity in the DJ jump from a certain height and is obtained from the formula:
    - Q-index= TV/TC
- The values of reactive strength efficiency and mean mechanical power (W average) are obtained from the RCMJ 15 s jump by the following formulas:
    - Reactive strength = (AV/TV)
    - W Average = (TV*test duration*g*2)/(4*No. of jumps*(test duration - TV)

<u>1RM HALF SQUAT</u>

On the other hand, a test to determine the maximum strength of the lower body (1RM) was also performed by means of a half squat (90º), using a 1000 Hz linear encoder (Chronojump, Bosco Systems, Barcelona, Spain), validated in (Vivancos et al., 2014). In this test each subject started with a load lower than his body mass and the load was increased until reaching an execution speed lower than 0.5 m/s, after which the estimation of his 1RM and his 1RM/weight ratio was performed.

Data collection and analysis / Statistical analysis

Data were entered and analyzed by using the IBM SPSS v.22.0 statistical analysis program (IBM, Newark, USA), determining a $p<0.05$ value for significance. Descriptive analyses were performed and coefficients of variation were calculated for each of the jumps. The dependent variables were subjected to normality tests (Kolmogorov-Smirnov). For the comparative analysis between gender and/or category, the data were analyzed by means of t-tests, one-factor ANOVA, with Bonferroni post-hoc analysis. To determine possible associations between the different variables, Pearson's bivariate correlations "r" were calculated, considering the values obtained in the associations as; trivial (0-0,09), week (0,1-0-29) moderate (0,3-0,49) strong (0,5-0,69), very strong (0,7-0,89) almost perfect (0,9-0,99) and perfect (1).

For each of the 3 jumps (SJ, CMJ and DJ), 3 repetitions were performed and the mean of these was calculated, as well as the coefficient of variation, in order to assess whether there were too many differences in the height reached, as this could indicate unreliability in terms of execution. The data showed that in no case did the coefficient of variation exceed 10%. Therefore, since no great variations were observed in the jumps, the highest value obtained by each athlete in each of the different jumps was taken for the following comparisons.

Results

The descriptive analysis of the sample reveals the results shown in Table 1, where we can observe a higher percentage of fat mass in female, as well as a higher height and body mass in male.

Table 1. *Descriptive data of the sample.*

	Male (n=13) Mean	Female (n=5) Mean	Total (n=18) Mean
Age (years)	18.8 ±2.1	18.4 ±2.9	18.7 ±2.3
Size (cm)	173.7 ±6.1	164.8 ±6.2	171.2 ±7.2
Body mass (kg)	62.8 ±8.2	54.9 ±3.2	60.6 ±7.9
% fat	12.3 ±4.4	21.7 ±3.5	14.9 ±6.0

When analyzing the different jump and strength tests, both in general and segmented by gender, the results presented in Table 2 were obtained.It can be seen how the values are higher in male than in female for all variables except for the contact time (TC DJ) and the total number of jumps performed in the 15 s Multijump (RCMJ15), which indicates lower strength values in female than in male.

We found mean height values in CMJ, SJ and DJ for male of 30.1 cm, 26.7 cm and 26.0 cm, although the standard deviation is quite large among the different jumpers, as for female the values obtained are 24.1 cm in CMJ, 21.7 cm in DJ and 20.3 cm in SJ, although the deviations are smaller, which shows less difference in this group.

In the multijump exercise for 15 s, the values were quite similar, with slightly less height in female (18.6 cm) than in male (20.0 cm) and a greater number of jumps in female than in male (22.6 for male and 23.8 for female). The flight and contact times (TV, TC) were similar.

Regarding the squat exercise with load for the calculation of 1RM, it is revealed that the male are able to move an Mean of 110.9±24.1 kg, which corresponds to 1.8±0.3 times their own weight, while the female move an Mean of 55.8±5.3 kg, an approximate equivalent to their own weight. It is here where we find greater significance in the comparison, with a $p<0.001$ value, in comparison with the jumps, where we also find significant differences in CMJ, SJ and some DJ values, but not as large as in the previous test.

Table 2. *Mean values of the different tests performed.*

	Total (N=18)		Female (N=5)		Male (N=13)		
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	*P*
Height CMJ (cm)	28.4	±6.0	24.1	±3.2	30.1	±6.0	0.017*
Height SJ (cm)	25.3	±4.8	21.8	±2.0	26.7	±5.0	0.008*
Height DJ (cm)	24.4	±5.7	20.3	±2.9	25.9	±5.7	0.057
DJ TC (s)	0.2	±0.1	0.3	±0.1	0.2	±0.0	0.007*
DJ TV (s)	0.4	±0.1	0.4	±0.0	0.5	±0.1	0.046*
TC RCMJ15 (s)	5.9	±1.5	5.9	±0.9	5.9	±1.7	0.948
TV RCMJ15 (s)	9.1	±1.4	9.2	±0.8	9.0	±1.5	0.776
Height Av. RCMJ15 (cm)	19.6	±4.0	18.6	±2.2	20.0	±4.5	0.519
Jumps RCMJ15	22.9	±3.5	23.8	±2.3	22.6	±3.9	0.533
1RM (kg)	95.6	±32.6	55.8	±5.3	110.9	±24.1	0.000*
1RM/weight	1.6	±0.5	1.0	±0.1	1.8	±0.4	0.000*

Note: S.D. standard deviation, TC=contact time, TV=flight time, *=$p<0,05$,

Table 3 shows the values of the variables calculated from the different jumps, such as the EI, the Q-index, the efficiency of the Reactive strength and the W Average.

We observe that, although the values are higher in male than in female, there are only significant differences in the "Q-index" (p=0.033). Furthermore, it is important to point out that the variation of results within the group is large, as can be seen from the values corresponding to the S.D., which indicates a considerable variation in the jumping profile of the athletes.

Table 3. *Values calculated on the basis of the jumps performed..*

	Total (N=18)		Female (N=5)		Male (N=13)		
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	*p*
E.I.	12.8	±16.0	10.8	±9.5	13.6	±18.2	0.755
Q-index	117.5	±47.3	80.1	±21.4	131.8	±46.9	0.033
Reactive Strengt	82.8	±33.1	77.3	±18.8	84.9	±37.6	0.579
W Average	5.3	±1.5	5.0	±0.8	5.4	±1.7	0.543

Following these analyses, a one-factor ANOVA test was performed to look for differences between the different categories, in the overall sample and segmented by gender. The data revealed no significant differences between the age groups in any of the variables analyzed. The categories available in the sample were Juvenile (6 male, 3 female), Junior (4 male, 1 female) and Under-23 (3 male, 1 female).

After checking the normality of the jumping and RM variables, Pearson's correlation test was performed in order to search for relationships between them. For the whole sample the data showed that CMJ height correlated with all the other jumps and RM variables, being a strong association in all cases (r between 0.5 and 0.7) and very strong with SJ height (r=0.84). In addition, SJ and DJ heights also showed a significant correlation (p=0.032 and p=0.033) with strong association (r=0.51 and r=0.50 respectively) with the variable 1RM/weight.

It happens that, when segmenting the participants by gender, many of these correlations lose their significance. It can be seen in the following table (Table 4) how, for Male, there is a correspondence (p<0.01) with a very strong association (r=0.80) between the results obtained in the CMJ and SJ jump, and also a correspondence with a strong association (p=0.03 and r=0.60) between the height obtained in CMJ and the 1RM/Weight ratio. It should also be noted that, although there is no significant correlation (p=0.059), there is a large association (r=0.54) between CMJ and RCMJ jumps.

Regarding the female gender (Table 5) the correlations and associations are reduced. It can be seen that there are no significant correlations between any of the variables. In spite of this, we did find variables that, although their correlation is not significant, their association is strong or very strong. This is the case between the CMJ and SJ jumps (p=0.127, and r=0.77) CMJ and DJ (p=0.056 and r=0.87) as well as between the height in the SJ jump and the weight moved in 1RM (p=0.310 and r=0.58).

Table 4. *Pearson's Correlation Results for male.*

		CMJ height	SJ height	DJ height	RCMJ mean height	1RM
CMJ height	*r*					
	p					
SJ height	*r*	0.80*				
	p	0.001				
DJ height	*r*	0.45	0.41			
	p	0.122	0.166			
RCMJ av. height	*r*	0.54**	0.49	0.24		
	p	0.059	0.090	0.422		
1RM	*r*	0.42	0.08	0.36	-0.11	
	p	0.156	0.784	0.226	0.711	
1RM/peso	*r*	0.60*	0.26	0.27	-0.17	0.80*
	p	0.031	0.384	0.371	0.568	0.001

Nota: *r*= Pearson correlation coefficient
* p≤0.05 and r≥0.5
** p>0.05 and r≥0.5

Table 5. *Pearson's Correlation Results for female.*

		CMJ height	SJ height	DJ height	RCMJ av. height	1RM
CMJ height	*r*					
	p					
SJ height	*r*	0.77**				
	p	0.127				
DJ height	*r*	0.87**	0.38			
	p	0.056	0.528			
RCMJ av. height	*r*	0.28	0.18	0.10		
	p	0.649	0.770	0.876		
1RM	*r*	-0.33	-0.58	0.03	-0.13	
	p	0.593	0.310	0.958	0.842	
1RM/peso	*r*	-0.28	-0.50	-0.01	0.18	0.95*
	p	0.646	0.387	0.987	0.768	0.014

Nota: *r*= Pearson correlation coefficient
* $p \leq 0.05$ and $r \geq 0.5$
** $p > 0.05$ and $r \geq 0.5$

Discussion

The aim of this study was to analyze the strength profile of young trail running runners and to look for possible associations between the results of the different tests performed. After the analysis of results we could observe how the heights Means of the jumps in male are 30.1 cm in CMJ, 26.7 cm in SJ, 25.9 cm in DJ and an Mean of 20.0 cm in RCMJ15, these values are quite lower than in other sports such as, in BMX (Robert et al., 2020), where values of between 30 and 50 cm are found for the 3 types of jump, or in volleyball (CMJ=44.4±4.7 cm) (Riggs & Sheppard, 2009) as well as in other studies such as those of Garrido Chamorro, González Lorenzo, Expósito, Sirvent Belando, & García Vercher (2012), where they analyze high-level athletes in various sports, also obtaining higher values for all these jumps, both in male and female. It is possible that these differences are due to the lack of experience in this type of test of the athletes studied, which influences the recruitment of fibres and coordination, since the participants were not, for the most part, familiar with these tests, as well as they did not usually include in their training routine the coordination and/or technique work, in fact studies related to mountain runners in which some of these jumps have been calculated show quite dissimilar data. Baiget et al., (2017) speak of values of 23.6 cm in CMJ and 18.9 cm in RCMJ15 s, Clemente et al., (2021) of 25.6 cm and 21.3 cm respectively , Balducci, Clémençon, Trama, Blache, & Hautier (2017) of 30cm in CMJ and Gatterer et al., (2013) of more than 40 cm in CMJ respectively, being difficult to define the jump profile of this type of runners.

The results have shown an mean body mass of 54.9±3.1 kg in female and 62.8±8.1 kg in male moving in 1RM squat exercise, an mean of 55.8±5.3 kg in female and 110.9±24.1 kg in male, which corresponds to relative strength values 1RM/weight of 1.02±0.04 for women and 1.76±0.43 and men respectively. Based on the studies of Rippetoe & Kilgore (2008), these data indicate an intermediate level of training in female and between intermediate and advanced in male, although according to the studies of Esteve and Cejuela (2010), the levels would change to "medium" for male and "very low" for female.

The correlational analysis of the sample as a whole reports significant results for all the jumps except between SJ and RCMJ with strong or very strong association, but when segmented by gender it is observed that, in the case of female, there are no correlations between any of the jumps, and in the case of the male only between the results in the SJ and CMJ jumps ($p<0.001$ and r=0.80). This correlation also occurs in other studies due to the fact that the CMJ is a jump that has the same phases as the SJ but adding an elastic-explosive phase (Balsalobre-Fernández et al., 2014; Bosco, 2000). The fact of not finding significant correlations may be due to two aspects, on the one hand because the volume of the sample when segmented is somewhat reduced and, on the other hand, due to the lack of experience of the participants, since in the case of women, only 2 of them had performed this type of test (SJ and CMJ) previously and in the case of men approximately half had ever done these same two jumps, which may influence the recruitment of fibres and the consequent results obtained (Linnamo, Strojnik, & Komi, 2001). In fact, it is observed in the results that strong and very strong associations do exist in several tests.

When looking for correlations between the tests of explosive strength (jumps) and maximum strength (1RM) in half squat, it can be seen that, for the general group (N=18) significant results are obtained for the variable 1RM/weight with respect to CMJ, SJ and DJ jumps, as well as between absolute strength (1RM) and CMJ and DJ jumps, all of these correlations having a strong association (r between 0.5 and 0.7).However, when segmented by gender, there is only a significant correlation in the men's group between CMJ height and

1RM/weight values (p=0.03, r=0.597), but not in the case of 1RM. In this sense, the relationship between the weight lifted in squat and jumping capacity does not seem to be entirely clear, since there are studies where low and non-significant correlations have been found between these two actions (J. B. Cronin & Hansen, 2005; Viviescas Bustos, Zapata Lozano, & Mindiola Acevedo, 2018) and others where it seems that it does exist (Wilson, Lyttle, Ostrowski, & Murphy, 1995; Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004). Although all these works speak of absolute load, i.e., 1RM, without taking into consideration the relative load or 1RM/weight as in the case of this work. Therefore, it would be useful to review whether this correlation between relative RM (weight 1RM/body mass) could be more interesting when comparing jumping variables with squat results, as well as to carry out more studies along these lines in order to give greater veracity to the values obtained.

In the case of the female, no correlation was found in this study between the results obtained in the different jumps and the RM variables, which may be due to various factors such as the number of subjects studied (N=5), the differences existing within the group and the lack of experience in this type of training, since none of them performed strength work with loads in their training routine.

Conclusions

Trail running is a sport in which we find different types of terrain and slopes, which makes each race different, it requires different capabilities and adaptations.

Regarding the strength profile of the young runners, we found quite a lot of variation within the subjects in terms of explosive strength results. We can conclude trail runner in the age group analyzed shows a jump profile in the Bosco test below the average in other sports modalities it can be due to a lack of experience in this type of work.

There are significative differences between male and female, being male's values higher than those of female.

Regarding the squat test for the calculation of absolute maximum strength (1RM) and relative (1RM/weight), values of 55.8±5.3 kg were obtained in female and 110.9±24.1 kg in male, which corresponds to 1.02±0.04 and 1.76±0.43 times the body mass in female and male, respectively.

The results of the explosive strength and maximal strength tests show significant correlation for the general sample, but not when segmented by gender, where only the CMJ and 1RM/weight variables correlate significantly in the case of the male.

Future researches should be carried out to better define the profile of these athletes, since, due to the differences between participants and the lack of experience, these values may be interesting as a guide but may vary in the future with a larger sample and more accustomed to this type of work.

Conflicts of interest

All authors declare that they have no conflicts of interest.

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