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Relationship of jump height to squat mechanical variables in juvenile athletes

[*Relación de la altura de salto con las variables mecánicas de la sentadilla en deportistas juveniles*]

[*Relação da altura do salto com as variáveis mecânicas do agachamento em atletas juvenis*]

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ABSTRACT

Introduction: jumping and squatting are recurrent movements within the training processes of an athlete, which is why it is necessary to understand the variables that interact in the development of performance objectives.

Objective: to determine the relationship between jump height and the mechanical variables of the squat.

Materials and methods: the methodology used is of a quantitative correlational type, with a cross-sectional design, where 43 juvenile athletes (men = 34, women = 9) were evaluated in the counter-movement jump (CMJ), half squat jump (SJ) and free jump test, along with this, 6 repetitions of squats at maximum speed were performed, where the best possible repetition was considered.

Results: the main results obtained were the significant relationship between the mean propulsive velocity and the CMJ (r =0.75, *p:* 0.00), SJ (r =0.69, *p:* 0.00) and free (r =0.72, *p:* 0.00).

Conclusions: finally, it is concluded that there is a relationship between jumping capacity and the squat execution speed.

Keywords: performance, speed, strength and power.

RESUMEN

Introducción: el salto y la sentadilla son movimientos recurrentes dentro de los procesos de entrenamiento de un deportista, por lo cual, se hace necesario comprender las variables que interactúan en el desarrollo de los objetivos de rendimiento.

Objetivo: determinar la relación de la altura del salto con las variables mecánicas de la sentadilla.

Materiales y métodos: la metodología utilizada es de tipo cuantitativa correlacional, con un diseño transversal, donde se evalúan a 43 deportistas juveniles (hombres = 34, mujeres = 9), en las pruebas de salto en contra movimiento (CMJ), salto de media sentadilla (SJ) y salto libre, junto con esto, se ejecutaron 6 repeticiones de sentadillas a máxima velocidad, donde se consideró la mejor repetición posible.

Resultados: se obtuvieron, como principales resultados, la relación significativa entre la velocidad media propulsiva y el CMJ (*r*=0.75, *p*: 0.00), SJ (*r*=0.69, *p*: 0.00) y libre (*r*=0.72, *p*: 0.00).

Conclusiones: finalmente, se concluye que existe una relación entre la capacidad de salto y la velocidad de ejecución de la sentadilla.

Palabras clave: desempeño, velocidad, fuerza y potencia.

RESUMO

Introdução: o salto e o agachamento são movimentos recorrentes nos processos de treinamento de um atleta, por isso é necessário compreender as variáveis que interagem no desenvolvimento dos objetivos de desempenho.

Objetivo: determinar a relação entre a altura do salto e as variáveis mecânicas do agachamento.

Materiais e métodos: a metodologia utilizada é do tipo correlacional quantitativa, com desenho transversal, onde 43 atletas juvenis (homens = 34, mulheres = 9) são avaliados nos testes de salto com contra-movimento (CMJ), agachamento médio. (SJ) e salto livre, juntamente com isso foram realizadas 6 repetições de agachamento em velocidade máxima, onde foi considerada a melhor repetição possível.

Resultados: como principais resultados, obteve-se a relação significativa entre a velocidade propulsiva média e o CMJ (r=0,75, p: 0,00), SJ (r=0,69, p: 0,00) e livre (r=0,72, p: 0,00).

Conclusões: por fim conclui-se que existe relação entre a capacidade de salto e a velocidade de execução do agachamento.

Palavras-chave: desempenho, velocidade, força e potência.

INTRODUCTION

Within the spectrum of physical training, there is an extensive knowledge on the development of strength, which catalogs it as an important element to obtain a better performance. The squat and the jump are basic exercises for the production and increase

of this quality. Both actions are similar in their execution, but they have different objectives, the squat seeks to overcome a certain weight, while the jump seeks to rise as high as possible, overcoming the resistance of gravity. Therefore, the two exercises have similar components, but their use may have different approaches (Gutiérrez-Dávila, 2009. Likewise, Rojas (2018) points out that both movements are classified as power and strength exercises.

In sport there are technical actions that occur more frequently, where knee and hip flexion-extension patterns are the most recurrent, which, in turn, is linked to jumps and squats (Ródenas, Desantes and Ramírez, 2020), which are defined as influential gestures in an athlete's performance (Köklü *et al.*, 2015).

Particularly, the squat is a multi-joint exercise that generates a great activation of the musculature, which is visualized in the speed of execution, the expiration of a load and the movement technique (Martínez, Acosta, and Ayala, 2022). According to this, it is possible to understand that the aforementioned parameters interpret the performance of a subject before strength situations from a mechanical perspective and what evidences the performance of specific actions (Rodríguez-Rosell *et al.*, 2020). Around this, Gutiérrez (2019) points out that training with squats turns out to be a good option for the increase of an athlete's performance.

Likewise, jumping is established as a strength exercise, since it constitutes a basic gesture in the evaluation of this ability (Portilla-Dorado, Villaquiran -Hurtado, and Molano-Tobar 2019), due to the approximations obtained of power, reactive strength, elastic strength and explosive strength, which will be a reflection of success in the sport (Harper *et al.*, 2020). Along with this, there are relationships between sport-specific components and jumping modalities (Babiloni-López *et al.*, 2022), the most studied being the 90° squat jump (SJ) and the jump with counter movement without arm swing (CMJ), which, although they do not resemble sport techniques, are capable of reproducing in a good way the levels of strength, power or speed of an athlete. In addition, the practicality and accessibility of the measurement make the jumping ideal for testing the strength of a subject (Pleša *et al.*, 2022).

According to the above, it is possible to understand that the squat is a movement related to the jump, due to its symmetrical character and its similarity in the vertical displacement, which leads to a transfer of the exercises (Mullican & Nijem, 2016). Along with this, there is an association between the height reached in the jump and the maximum weight lifted in the squat (Hermassi *et al.*, 2019; Santos-García *et al.*, 2008), however, there is a lack of knowledge about the relationship between jump performance and the mechanical parameters of the squat, so this research, is proposed as a central objective, to determine the relationship between the height of the jump with the mechanical variables of the squat.

MATERIALS AND METHODS

The present research is a quantitative cross-sectional study, with a correlational design between the mechanical variables of the squat and the height of the CMJ, SJ and free jumps.

Participants

The sample consisted of 43 subjects (men = 34, women = 9), belonging to the sports recruitment program of the Universidad Católica del Maule (Catholic University of the Maule, UCM, by its Spanish acronym), Chile. The athletes were part of the disciplines of soccer, volleyball, basketball, handball, athletics and gymnastics.

The selection of the sample is non-probabilistic by convenience, where there was first a review of the subject's sports background, to then be selected for the physical evaluation process.

In the admission processes of the Universidad Católica del Maule, Chile (UCM), there is a program to recruit athletes for admission to the institution. In the protocols established for this purpose, the guidelines and ethical regulations are established, which must be taken into account at the time of proceeding with the evaluations and data management.

For this purpose, each athlete had to sign an informed consent prior to the evaluation, where they declared that they were aware of the characteristics of the tests and the processing of their data. The above is governed by the Helsinki treaty and the regulations of the University.

Instruments

To record the height of the jumps, the height was measured with the DM Jump temporary contact platform and the data was processed with the DM Jump V2.2 Beta software.

For the evaluation of the mechanical variables, a 1019 Hz linear position transducer (Chronojump BoscoSystem, Spain) was used, to obtain the variables of velocity, maximum velocity, power, maximum power, force and maximum force.

Procedure

The jumping evaluations were governed by the protocol proposed by Bosco in the SJ, CMJ and free modalities. The measurement establishes performing the SJ with a 90° knee flexion, with the feet parallel and the hands on the hips. As for the CMJ, it is necessary to start standing with the hands on the hips, and then perform a 90° knee flexion and rise. The free jump has the characteristic of being executed as comfortable as possible. The time between each evaluation was approximately three minutes.

To record the mechanical variables, the evaluation of six squats with 60% of the body weight was carried out, where the subject had to reach a 90° knee flexion, performing as quickly as possible. With this measurement, the variables of mean propulsive velocity (MPV), peak velocity (PV), power, maximum power, strength and maximum force were obtained from the best execution.

Prior to the evaluation, the athletes performed a 10-min warm-up, which consisted of joint movements, stretching, dynamic actions and an adaptation to the technique of each jump. A ten-minute break was taken between each evaluation.

Analysis

The statistical analysis was performed in the SPSS Statistics 22 program. The data were subjected to the Shapiro Wilk normality test and the descriptive statistics of mean and standard deviation were calculated for each parameter. The 95% confidence interval was considered. To correlate the data, Pearson and Spearman statistical tools were used, depending on the normality of each variable. Indices up to "0.39" were considered as a weak correlation, between "0.40 to 0.69" as a moderate correlation, from "0.70 to 0.89" as a strong correlation, while "≥ 0,9" will be considered a very strong correlation

RESULTS AND DISCUSSION

Table 1 shows the study variables, where the basic measurements of age (19.8±1.8), weight (71.7±10.6) and height (170.9±15.2) are found; the performances of the SJ (29.8±7), CMJ (34.7±7.7) and Free jumps (39.8±8.8); and the mechanical capacity in the squat with the variables of MPV (0.9±0.2), PV (1.5±0.3), Power (1149.8±366.7), maximum power (2017.7 ±560.3), strength (1275.1±251) and maximum strength (1902.7±352.5) (Table 1).

Table 1. *- Characterization of the variables*

VARIABLES		**X ± Ds**
	Age (years)	19.8±1.8
Basic Measurements	Weight (Kg)	71.7±10.6
	Size (cm)	170.9±15.2
Jumps	SJ (cm)	29.8±7
	CMJ (cm)	34.7±7.7
	Free (cm)	39.8±8.8
Squat Mechanics	Additional weight (Kg)	40.0±7
	Mean Propulsive Velocity (m/s)	0.9±0.2
	Maximum speed (m/s)	1.5±0.3

Table 2 shows the correlations between jump height and squat mechanical variables. It is observed that mean propulsive velocity is the variable with the greatest influence on jumps (r =0.72; p =0.00), CMJ (r =0.75; p =0.00) and SJ (r = 0.69; p =0.00) respectively (Table 2).

Table 2. *- Correlations between mechanical variables and jump height*

		Mean Propulsive Velocity	Propulsive Velocity	Mean Power	Maximum Power	Medium Strength	Maximum Strength
S.J.	*R*	0.69c	0.67c	0.54d	0.49 d	0.23	0.32d
	P	0.00	0.00	0.00	0.00	0.13	0.04
CMJ	R	0.75b	0.71b	0.63c	0.59d	0.34 d	0.5d
	p	0.00	0.00	0.00	0.00	0.02	0.00
Free	R	0.72b	0.69c	0.62c	0.57	0.36d	0.47d
	P	0.00	0.00	0.00	0.00	0.02	0.00

a= very strong correlation, b= strong correlation, c= moderate correlation, d= weak correlation.

Figure 1 shows the scatter plots of the jump height and mean propulsive velocity variables (Figure 1).

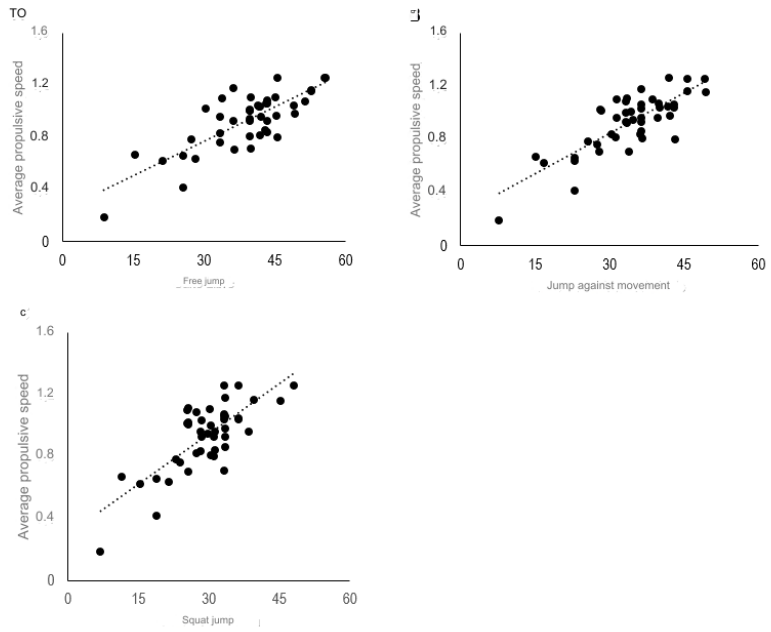

Fig. 1. *- Dispersion of mean propulsive velocity and jumps.*

It is observed that there is a positive relationship between these parameters, which identifies that as the subject possesses more MPV in the squat, they obtain a greater jump height.

This research aims to investigate the relationship between the height of the jump and the mechanical characteristics of the squat. Both variables refer to strength components and are representative not only of an athlete's performance, but can also be predictors of injuries (Abd Rahim *et al.,* 2020; Donohue *et al.,* 2015).

The findings of this study, refer to the relationship between the mean propulsive velocity of the squat and jumps, mainly in the free and CMJ modalities, which would be explained by the involvement of the musculatures to similar movements (Santos- Garcia *et al.,* 2008), since the squat and these types of jumps have a triple flexion-extension of the lower limbs (Gutiérrez-Dávila, 2019), represented by the functioning of the vastus lateralis, vastus medialis and gastrocnemius (Harry *et al.,* 2018). In such a way, it is possible to associate that similar biomechanical patterns will generate a positive relationship, in the same way as those expressed by Scarneo -Miller *et al.* (2019), where he demonstrated that the components of the squat positively influence a functional task, such as jumping, furthermore, Wilson *et al.* (2013) mention that, to achieve an enhancing effect in jumping, patterns similar to the biomechanics of the squat must be generated, because it is classified as one of the multi-joint stimuli that increases performance (Bishop *et al.,* 2017).

According to the previous analysis, the performance of these actions will be influenced by the viscoelastic component of the musculature (Franco- Marquez *et al.,* 2015), since the movement pattern generated in the CMJ and in the free movement causes the activation of the stretch-shortening cycle, which, in turn, allows optimal performance in these ballistic situations (Rojano Ortega, 2021). From this point of view, the elastic resistance of the musculature, contributes to the coordination of muscle fibers that contract rapidly during the descent and ascent phases of the body (Franco-Márquez *et al.,* 2015), represented through high levels of power (Castagna and Castellini, 2013).

In this sense, power, according to González-Badillo, Jiménez-Reyes and Ramírez-Lechuga (2017), indicates it as a dependent variable on jumping performance and is influenced by the improvement of this action (Can, 2018). The above would show the moderate correlations found in this article, however, the literature suggests that the relationships between these variables should be higher, since high levels of jump height project, project higher power values and better performance of the athlete. (Morin and Samozino, 2016). This indicates that the athletes in this article have difficulty in applying force and speed in the movements studied (Behm *et al.*, 2017).

Specifically, jumping is one of the most widely used assessments to determine an athlete's ability (Fort- Vanmeerhaeghe *et al.*, 2020), and it is associated with neuromuscular aspects that facilitate the understanding of high-speed exercises, with maximal power production and strength development (McMahon *et al.*, 2018; Jimenez - Reyes *et al.*, 2016). The evidence indicates that there is an agreement between high values of jump height and actions executed at high speeds (Bustos- Viviescas *et al.*, 2017; Bautista *et al.*, 2021), which is related to the data of the present study, where the CMJ is influenced by the mean propulsive velocity, which agrees with that described by Rodríguez-Rosel *et al.* (2020) that associates CMJ stimuli with increased execution speed, which also, is related to the optimization of specific sport gestures (Linthome, 2020).

Regarding the strength variable, it can be seen that there are weak correlations with the different types of jump. Consequently, these results are justified because the generation of high levels of force requires a longer production time than that of a jump. This analysis is linked to the research of Santos-García *et al.* (2008) where moderate relationships (r = 0.52 and 0.67) are observed between strength and height in the SJ and CMJ. On the other hand, the data reported in the study by McGhie *et al.* (2020) show non-significant relationships between these variables.

In general terms, the mean propulsive velocity is the variable that has the greatest influence on the jumps that have an elastic component in their execution. This characteristic is one of the main limitations of this article, due to the fact that intrinsic parameters of the musculature are unknown.

CONCLUSIONS

The main relationship that exists between jumping capacity and the mechanical variables of the squat in juvenile athletes is the association between mean propulsive velocity and CMJ. However, a more general analysis also links the parameters of peak velocity and free jump as adequate indicators to determine the performance of an athlete.

It is suggested that research similar to the present study be carried out, where each action can be investigated in greater depth, being able to incorporate a force platform and analyze greater mechanical variables.

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Conflict of interest statement:

The authors declare having competing interests.

***Author contribution statement*:**

The authors have participated in the redaction of the manuscript and the documentary review.