INCIDENCES OF STIFFNESS ON SQUAT JUMP VARIABLES

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The purpose of this study was to relation level the stiffness of the patellar tendon and three portions of the Achilles tendon; inferior, middle, and superior location with performance variables in the squat jump. The sample was composed of 25 belonging to Chilean elite male handball players. It assesses stiffness tendinous patellar and Achilles tendon using to MyotonPro® device. During the squat jump assessment, two force platforms Pasco and ForceDecks® software for analysis. The main results were RFD 0-50 ms (r=0.611), RFD_N 0-50 ms (r=0.550), RFD 0-100 ms (r=0.615), and RFD_N 0-100 ms (r=0.624) presented a relationship with patellar stiffness, while that Achilles tendon was down relation with peak power in squat jump (r=472). This information can be useful for training handball players. From the results, it can be concluded that the stiffness of the patellar tendon and the Achilles tendon determine some mechanical variables of the SJ, mainly in relation to the RFD in different time windows of early phase.

KEYWORDS: Stiffness; Athletic Performance; Biomechanical Phenomena; Muscle Strength.

INTRODUCTION

Vertical jumps have been widely used to assess the ballistic performance of the lower extremities (Morin et al., 2019), with countermovement jumps (CMJ) and squat jumps (SJ) being commonly used (Hooren et al., 2017). The main difference between the two is that the first presents an eccentric phase, and the second starts from a static position. Different variables, kinetic and kinematic, can be determined from a vertical jump: Jump height, Rate of Force Development (RFD), Torque, Impulse, Power, and angular velocity, among others (Macedo Alfano Moura & Alves Okazaki, 2022), and many are used to control training loads and neuromuscular fatigue (Gathercole et al., 2015). An essential aspect of jump performance is tissue stiffness (Kuitunen et al., 2007), being a determining variable that partly explains the difference in performance between CMJ and SJ jumps, with the CMJ jump being greater due to storage and utilization of elastic energy product of tissue stiffness (Kubo et al., 1999). However, little evidence exists if stiffness is related to variables of an SJ jump.

The purpose of this work is to determine the relationship between the stiffness of the patellar tendon and the calcaneus tendon, with variables of the performance of the SJ.

METHODS

25 elite male handball players (body mass 87.1±10.9 kg; height 180.3±8.5 cm; age 26.3±4.2 years old) participated in this study. The study considered the ethical principles for medical research in humans established in the 2013 Declaration of Helsinki (World Medical Association, 2013). Since the intervention performed was not invasive and posed no risk to participants, the study was not submitted for approval by an institutional ethics committee. The participants' informed consent was obtained to collect the data after explaining the objectives, benefits, and risks of the research through online meetings. The MyotonPro device (MyotonPRO, Myoton Ltd., Tallinn, Estonia) was used to measure the stiffness of the patellar tendon (Midpoint between the inferior border of the patella and the anterior tuberosity of the tibia) and three portions of the Achilles tendon: inferior (6 cm superior to the insertion in the calcaneus), middle (4 cm proximal to the low point) and superior (4 cm proximal to the middle point). Two investigators with two years of experience with the device performed the measurements through 5 simultaneous measurements of the same point (multi-scan), obtaining the average of each tendon. Started with the right calcaneal tendon in this order; inferior, middle, and superior, then with the left in the same way, then the right and left patellar tendons, respectively. Afterward, the athletes performed a 10-minute warm-up consisting of low-intensity cardiovascular exercises and mobility. Finally, each athlete performed 3 SJ jumps on two force platform Pasco PS-2142 (PASCO® Scientific, Roseville, CA) with 1-minute rest between attempts, maintaining 3 seconds in a squat position with knees in flexion of approximately 90º. ForceDecks® software (London, UK) was used to identify kinetic and kinematic variables.

STATISCTICS

The normality of the data was analyzed through the Shapiro-Wilk test, where the assumption of normality for the SJ variables was not assumed ($p<0.05$). Descriptive statistics were expressed as mean and standard deviation. The association between tendon stiffness and SJ variables was analyzed with Spearman's correlation coefficient, using the following thresholds for its qualitative classification: 0.0 to 0.10 trivial; 0.11 to 0.39 weak; 0.40 to 0.69 moderate; 0.70 to 0.89 strong and 0.90 to 1.00 very strong, also used for negative values (Schober & Schwarte, 2018). All the statistics were carried out with the SPSS version 25 software, and the graphs were with the GraphPad version 8 software. A "$p \leq 0.05$" was considered a value of statistical significance.

RESULTS

Table 2 shows the SJ's descriptive statistics and the stiffness variables' correlation coefficients. Moderate positive correlations were found between SPT with RFD 0-50 ms (r=0.611 and p=0.016), RFD_N 0-50 ms (r=0.550 and p=0.034), RFD 0-100ms (r=0.615 and p=0.011) and RFD_N 0-100 ms (r=0.624 and p=0.010) and between stiffness aquiles medium with Peak power (r=0.472 and p=0.017).

Table 2. Descriptive statistic and correlation coefficient between variables.

SJ Variables	Descriptive			Stifness patelar tendon (M ±SD) (555±145 N/m)	Stiffness aquiles inferior tendon (M ±SD) (853±109 N/m)	Stiffness aquiles medium tendon (M ±SD) (766±87 N/m)	Stiffness aquiles superior tendon (M ±SD) (682±100 N/m)
Jump height (cm)	M	30.4	rs	0.161	0.140	0.183	0.253
	±SD	4.02	p	0.441	0.503	0.381	0.223
Peak Power (W)	M	4268	rs	-0.046	0.264	**0.472***	0.327
	±SD	696	p	0.827	0.203	**0.017**	0.111

Peak Power$_N$ (W/kg)	M	49.24	rs	-0.029	0.074	0.020	0.111
	±SD	7.07	p	0.891	0.726	0.926	0.598
Peak velocity (m/s)	M	2.50	rs	-0.039	-0.137	-0.027	0.104
	±SD	0.16	p	0.854	0.513	0.898	0.622
RFD 0-50 ms (N/s)	M	2626	rs	**0.611***	-0.293	-0.161	-0.354
	±SD	1518	p	**0.016**	0.289	0.567	0.196
RFD$_N$ 0-50 ms (N/s/kg)	M	31.5	rs	**0.550***	-0.446	-0.279	-0.425
	±SD	19.0	p	**0.034**	0.095	0.315	0.114
RFD 0-100 ms (N/s)	M	4044	rs	**0.615***	0.000	0.041	-0.006
	±SD	2145	p	**0.011**	1.000	0.880	0.983
RFD$_N$ 0-100 ms (N/s/kg)	M	48.3	rs	**0.624***	-0.191	-0.132	-0.144
	±SD	25.9	p	**0.010**	0.478	0.625	0.594

SJ squat jump; rs correlation coefficient of Spearman; p value; * p<0.05; M mean; SD standard deviation; RFD rate of force development; N normalized by body mass.

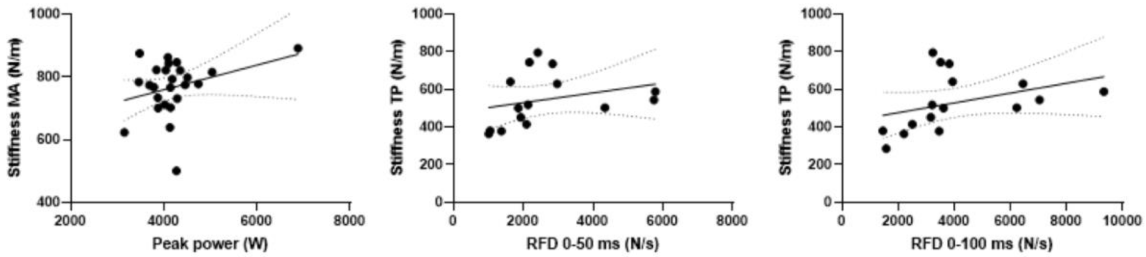

Figure 1- Dispersion graph with regression line between SJ and lower limbs stiffness variables.

DISCUSSION

Passive tendon stiffness was related to RFD and absolute peak power. Due to the speed of force transmission being influenced by the stiffness of the material (Maffiuletti et al., 2016), it is expected that subjects with higher passive tendon stiffness will be able to produce force more quickly (Waugh et al., 2013), related to the above, Longo et al. (2017) demonstrated that the greater the stiffness the electromechanical retardation decreases, the latter being a key factor in the early phase of force production. However, most of the documented studies measure tendon stiffness actively (during contractions) or passively, but through passive stretching (Morse et al., 2008; Waugh et al., 2013), with the measurement performed in this study, it was scarce, so the predictive validity of these measurements has not yet been analyzed. The relationship between the RFD and the SPT could be explained through slack muscle absorption, where a greater rigidity of the tendon unit could cause a faster absorption of this, leading to a movement of less duration (Van Hooren & Bosch, 2016). Van Hooren et al. (2022) found a relationship between the RFD peak during the SJ and jump time, where the subjects with the highest RFD Peak performed the jump in the shortest time, findings that support these assertions. Bojsen-Møller et al. (2005) found relationships between the stiffness of the vastus lateralis and the rate of development of torque (isometric) of knee extension and with the absolute power peak, unlike ours, they also found with the height jump and the normalized power peak, these differences could be associated with the way to normalize the power peak, which was allometric, as well as the fact that I only made the associations only with stiffness normalized in this way and not absolutely. Kubo et al. (1999) did not find any relationship between the tendon stiffness of the vastus lateralis and the jump height in SJ. However, the latter was related to body weight, mentioning that height could be related to muscle volume, where Relationships with muscle mass have already been documented (Konrad & Paternoster, 2022; Pérez-Contreras et al., 2021).

Previous studies showed that the RFD of 200-300 ms in the SJ was inversely explained by 25% of the Achilles tendon length (Earp et al., 2011), demonstrating that passive tissues influence force production. Other musculotendinous architecture parameters, such as the length of the vastus lateralis and gastrocnemius fasciculus or the thickness of the Achilles tendon, did not explain the performance in the SJ, where they only explained the early RFD, during the eccentric phase, in the countermovement jump and drop jump (Earp et al., 2011). Therefore, it could be beneficial to have greater SPT stiffness when applying dynamic concentric force. On the other hand, a relationship was found between the SAM and the absolute power peak, and this could be explained because the power peak is more associated with the speed peak (Linthorne, 2020), which is very close to the takeoff of the athlete, being the ankle joint the one that could generate the greatest power during the final phase of the jump (needs to be verified). However, no association was found with peak speed, which could be related to the force applied at peak speed.

CONCLUSION

From the results, it can be concluded that the stiffness of the patellar tendon and the Achilles tendon determine some mechanical variables of the SJ, mainly in relation to the RFD, which could have practical implications in order to improve jump time through workouts that increase the stiffness of these tendons as well as changes in RFD could be indirect indicators of changes in tendon stiffness.

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