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## ORIGINAL

### CORRELATION BETWEEN MUSCLE ECHO-INTENSITY AND VERTICAL JUMP IN SCHOOL-AGE CHILDREN

### CORRELACIÓN ENTRE ECO-INTENSIDAD MUSCULAR Y SALTO VERTICAL EN ESCOLARES

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#### ABSTRACT

Objective: to analyse the correlations between the echo-intensity (EI) of the quadriceps muscle measured by a quantitative ultrasound and the vertical jump in school-age children. Methodology: a cross-sectional, comparative and non-randomised study was carried out. An intentional sample composed of 184 schoolchildren aged between 7 and 10 was used. Transversal images of the right quadriceps femoris were obtained by ultrasound to determine the echo intensity of the rectus femoris or anterior, vastus intermedius or crural and vastus lateralis or external. Explosive power was measured by countermovement jump (CMJ) and repeated jumps for fifteen seconds (RJ15). Results: The EI of the evaluated components of the quadriceps correlates significantly with the measurements of the vertical jump type CMJ and RJ15 in boys and girls aged between 7 and 10 (PP15R vs.Dif 1C, Dif 2C, Dif 3C,  $r=0.53-0.59$ ).

**KEY WORDS:** Muscular development, Children, Quadriceps muscle, Ultrasonography.

## RESUMEN

Objetivo: analizar las correlaciones entre la eco-intensidad (EI) del músculo cuádriceps medido por ecografía cuantitativa, y el salto vertical en niños en edad escolar. Metodología: Se realizó un estudio transversal, comparativo y no aleatorio. Se utilizó una muestra intencional compuesta por 184 niños escolares, entre 7 y 10 años. Imágenes transversales fueron obtenidas del cuádriceps femoral derecho por ecografía para determinar la eco-intensidad del recto femoral o anterior, vasto intermedio o crural y vasto lateral o externo. La fuerza explosiva fue medida mediante las pruebas de Salto con contra movimiento (CMJ) y saltos repetidos por quince segundos (RJ15). Resultados: La EI de los componentes evaluados del cuádriceps se correlacionan significativamente con las mediciones derivadas del salto vertical tipo CMJ y RJ15 en niños y niñas entre 7 y 10 años (PP15R vs Dif 1C, Dif 2C, Dif 3C,  $r = 0,53-0,59$ ).

**PALABRAS CLAVE:** Desarrollo muscular, Niños, Músculo cuádriceps, Ultrasonografía.

## INTRODUCTION

Jumping is a complex multi-joint movement, of which the external mechanical power produced, such as the push of the feet against the ground, is frequently used as a measure of the power produced by the knee extensors (1). It is also considered as an indicator of muscular fitness due to its positive association between lean muscle mass, bone mineral content and physical condition (2,3). The countermovement jump CMJ and repeated jumps (RJ) are jumps that require a moderate eccentric activation followed by a high concentric activation. Specifically, the CMJ is the most widely used test to establish levels of muscular strength, since it reflects percentages and maximum peak power of lower limbs (4-6), in addition to having a high intra-test reliability (7). Regarding children, a high correlation was found between the vertical jump height and the data obtained on the force platform. Evidence can be found in some studies such as those carried out by O'Brien et al. (2009), who found a high correlation between jumping power and the quadriceps femoris muscle volume (1). In addition, another study indicated that anthropometric measures of volume such as thigh circumference are positively correlated with vertical jump and long jump in children aged between 7 and 10 (9). A more accurate way to measure the cross-sectional area of the muscle, rather than the perimeter of an anatomical region, is ultrasound, which measures muscle thickness more reliably. This system has a drawback, particularly regarding school-age children, since functional changes in the muscle not always imply an increase in muscle size (10). Thus, the concept of muscle quality measured by ultrasound with EI (echo intensity) arises, in connection with physiological aspects of the evaluated musculoskeletal tissue. A lower EI reflects a better quality of the muscle. In

adults, studies using EI show differences attributed to pathologies, and also related to the level of physical activity. In these cases, the EI decreases with regular exercise (11). The decrease in EI in adults could be due to a decrease in fat content, an increase in carbohydrate content, or both (12). Also, in older people, fibrosis is seen as a possible cause of the increase in EI during ageing (13). There are few studies that evaluate EI related to muscular strength and strength tests in children, thus being the results more contradictory (14). In fact, among young children gender differences have been found in EI, differences which do not exist when comparing muscle size in the cross-sectional area, or muscle thickness (15). Furthermore, the EI measured in both extremities does not distinguish between dominant and non-dominant, and its reliability is related to the size of the area studied (13). Therefore, the results of the studies referred to seem to indicate that EI might be a better tool to evaluate muscles than thickness, and besides, if related to a measure of anaerobic power such as vertical jump, it could also estimate the percentage of fast fibres (16).

In a study carried out using magnetic resonance imaging to compare the anaerobic metabolism of children and adults, it was noticed that the differentiation of the type of fibre occurs relatively at an early age, and, in children aged 6, the histochemical profile of the skeletal muscle is already similar to that of a young adult (17). The RJ15s (repeated jumps for fifteen seconds) were used to determine the percentage of fast fibres when evaluating the anaerobic performance during jumps (16). Recent studies have tested the reliability and validity of repeated CMJ to assess anaerobic performance (18). In fact, a positive relationship was found between anaerobic power performance and the percentage of FT fibres (fast muscle fibres), the percentage of the FT fibre area, and the FT area / ST (slow muscle fibres) area of the human quadriceps (19). However, other findings demonstrated that the ability of the knee extensor muscles per cross-sectional area to produce dynamic force is lower in children than in young adults (15). This highlights the need for different options to evaluate children using images, other than muscle size (which has been proved to be smaller at these ages), and that can be related to functional tests, such as EI. Therefore, in order to study the type of fibres and the predominance of the metabolism (aerobic-anaerobic) in the quadriceps muscle, the aim of this study is to analyse the correlations between the EI of the quadriceps muscle measured by quantitative ultrasound, and the vertical jump in school-age children.

## **MATERIAL AND METHODS**

### *Participants*

The study was made up of an intentional sample of 191 school-age children (113 boys and 78 girls), aged between 7 and 10, belonging to two different sport initiation schools, and to a primary education school in the city of Medellín, Colombia. The exclusion criteria considered were: a cardiovascular disease or metabolic disorder, musculoskeletal injuries, sexual maturity defined by the Tanner scale self-reported other than 1 (20), or the inaccurate performance of the jumps. Seven children (4 boys and 3 girls) were excluded according to these criteria. The children and their parents signed an assent and an informed

consent, respectively. The study protocol was approved by the ethics committee of the university "Politécnico Colombiano Jaime Isaza Cadavid".

### *Design*

The study was cross-sectional, correlational and non-randomised. All participants went to the laboratory of the university Politecnico Colombiano Jaime Isaza Cadavid, or to another suitable room used as a laboratory in the facilities of the San José de las Vegas school and the Lucrecio Jaramillo school, all of them educational institutions in the city of Medellín. (Colombia). The data collection took place between October 2018 and March 2019, when the anthropometric measurements were taken: body mass, height and fat percentage. After that, an ultrasound of the right quadriceps was performed followed by the CMJ and RJ15 jumps. The study variables were the following:

### *Quantitative ultrasound*

The cross-sectional images of the quadriceps femoris in the right limb were obtained using a mode B ultrasound equipment (B-Ultrasonic Diagnostic System, Contec, CMS600P2, Republic of China). A linear transducer (gain: 58, frequency: 7.5 MHz; depth: 6 centimetres), covered with enough water-soluble transmitter gel to avoid the compression of the dermis, was placed in a perpendicular position to the transverse axis of the quadriceps femoris at the midpoint between the anterior superior iliac spine and the superior pole and, between it, and the superior-external angle of the patella for the anterior and lateral images, respectively. The participants were evaluated in the supine position, with at least a 5 minute rest period, and no prior vigorous physical exercise performed that day. Two cross-sectional images were scanned of each midpoint. The frozen image was digitalised and subsequently analysed using the free software ImageJ (National Institute of Health, USA, version IJ 1.46). For a greater reliability of the EI, only cross sections (21) were used. The anterior cross-sectional images were used to measure the EI of the rectus femoris and the vastus intermedius. The lateral cross-sectional images were used to measure the EI of the vastus lateralis and the vastus intermedius in a lateral view. The EI of the different muscles evaluated was quantified using the histogram function in ImageJ. The region of interest was the largest rectangular area of each muscle excluding fascia. The mean of the two images was expressed as a value between 0 (black) and 255 (white). The EI correction was made with the thickness of the subcutaneous cellular tissue proposed by Young and the percentage of fat was measured using the method proposed by the same author for all muscles (22). In addition, as a control strategy, the difference of the fat EI was calculated in the different portions of the evaluated quadriceps corresponding to Dif1C to Dif6C (23). The coefficient of variation of two measurements of ten subjects at different times, the same day was 0.4% for EI.

### *Explosive power*

The explosive power was measured by the CMJ and RJ15 tests. At the beginning of the session, all participants performed a general dynamic warm-

up, concluding with six jumps, with a progressive level of effort. The children performed the CMJ three times, and the best jump was used for statistical analysis. After a two minute rest, they performed the RJ15, which consisted in consecutive CMJ jumps for 15 seconds. Throughout the test, the children were verbally stimulated. In order to ensure the correct execution, each jump was evaluated using a check list, verifying if it complied with the requirements for a correct execution. Those jumps that did not comply were considered non-valid. The jumps were measured on an AXON JUMP® mat (Axon Bioingeniería Deportiva, Buenos Aires, Argentina) with the Axon Jump 4.0 software, which measured the flight time and, also, in the case of RJ, contact time. In all the jumps the children had to keep "their hands on their waist". The RJ was performed to calculate the average power ( $PP = g^2 * Tf * 15 / 4n (15-Tf)$ ) and the percentage of the distribution of FT fibres ( $\% FT = 48.31 + (g^2 * Tf * 15) / 1.04n (15-Tf)$ ) (16). The CMJ power was obtained by the Sayers equation (CMJ Power (W) =  $(51.9 * CMJ \text{ height (cm)}) + (48.9 * \text{body mass (Kg)}) - 2007$ ) (24). The CMJ power per push-off distance was obtained using the equation proposed by Jiménez-Reyes et. al. ( $P = mg ((h / h_{po}^2) + 1) \sqrt{gh} / 2$ ) (25).

### *Anthropometry*

Body mass and height were measured barefooted and wearing sportswear. The percentage of body fat was estimated by the Lohman method, measuring fat folds in two different places: triceps and subscapular region (26). In addition, the push-off distance was measured according to the suggestions by Jiménez-Reyes et. al (25).

### *Statistical analysis*

For the descriptive analysis of the sociodemographic and ultrasound aspects, absolute frequencies, relative frequencies, and summary indicators such as arithmetic mean, standard deviation, median, interquartile range, minimums and maximums were used. The normality criterion of some variables was established using the Jarque-Bera test, and the homoscedasticity criterion using the Levene test. Spearman's correlation coefficient was used to evaluate the correlation between functional tests and ultrasound aspects, and it was represented in a correlation matrix. A value of  $p < 0.05$  was considered statistically significant.

## **RESULTS**

The results of the sociodemographic aspects, the vertical jump, and the ultrasound aspects are presented by mean and standard deviation values in Table 1. As a result of the application of the exclusion criteria, the data of 184 children were analysed (75 girls, age:  $9.41 \pm 0.91$ . 109 boys, age:  $8.97 \pm 1.14$ ).

Table 1. Descriptive statistic.

Variable	Meaning	Girls (n=75)		Boys (n=109)	
		Mean	SD	Mean	SD
Age	Decimal age in years	9.41	0.91	8.97	1.14
Mass	Body mass (Kg)	32.33	6.37	32.27	8.61
Est	Height (cm)	136.09	8.04	134.20	8.18
IMC	Muscle mass (Kg/m <sup>2</sup> )	17.32	2.36	17.75	3.38
PG	% fat	18.21	5.71	16.24	7.11
CMJ	Hight of countermovement jump (cm)	19.94	3.18	20.33	4.28
PCMJ	CMJ power (w)	608.65	347.11	626.04	440.91
PCMJR	CMJ power in relative watts (w/Kg)	17.57	8.65	17.88	10.04
PCMJDE	CMJ power in watts per push-off distance	602.65	190.53	592.99	168.23
PCMJDER	CMJ power per relative push-off distance (w/Kg)	18.72	4.86	18.59	3.84
%FT	% of fast fibres	5.15	7.90	6.21	8.64
PMRJ	RJ average power in 15 seconds (w)	13.14	3.10	14.96	3.48
RFE	Resistance to explosive power	0.89	0.05	0.89	0.04
PP15	Peak power of the best jump in 15 seconds (w)	141.83	29.81	148.75	37.65
PP15R	Relative peak power of the best jump in 15 seconds (w/Kg)	4.44	0.70	4.69	0.86
EIG	EI fat in anterior thigh	142.63	7.49	146.48	9.78
EIRFC	Corrected EI in rectus femoris	169.43	14.44	158.37	18.90
PGRF	% fat in rectus femoris	20.41	1.33	19.39	1.74
EIVIC	EI in the VI anterior thigh	152.39	15.01	143.48	15.84
PGVI	% in the vastus intermedius measured by US	22.55	1.70	21.55	1.79
Dif1C	Difference between EIG and EIRFC	-26.80	17.55	-11.88	24.24
Dif2C	Difference between EIG and EIVIC	-9.76	17.25	3.00	19.75
Dif3C	Difference between EIG and median of EIRFC and EIVIC	-18.28	16.33	-4.44	20.83
EIGL	EI fat in lateral thigh	136.93	7.26	135.40	11.41
EIVLC	Corrected EI in vastus lateralis	171.65	12.93	163.53	17.46
PGVL	% fat in vastus lateralis measured by US	24.76	1.46	23.84	1.98
EIVIEC	Corrected EI in the VI outer thigh	150.77	14.58	139.31	17.72
PGVIE	% fat in the VI outer part measured by US	22.38	1.66	21.08	2.01
Dif4C	Difference between EIG and EI in VL	-34.73	12.27	-28.13	16.89
Dif5C	Difference between EIG and EIVI outer part	-13.85	15.34	-3.91	18.89
Dif6C	Difference between EIG and median of EIVL and VI outer part	-24.29	12.09	-16.02	16.09

Three correlation matrices are presented below (Figures 1, 2 and 3). In each of them, the intensity of the blue colour shows a stronger positive correlation, while the intensity of the red colour shows a stronger negative correlation. Figure 1 shows the correlations between the EI and the percentage of muscle fat in the evaluated components of the quadriceps in the complete sample, with the different variables of the vertical jump. The CMJ variable presents *r* values with the EI variables ranging from -0.32 to -0.46 (EIRFC, PGRF, EIVIC, PGVI, EIVLC, PGVL, EIVIEC), and from 0.25 to 0.47 (Dif1C to Dif6C). The best

correlations were found in the PP15R ranging from -0.42 to -0.50 (EIRFC, PGRF, EIVIC, PGVI, EIVLC, PGVL, EIVIEC), and from 0.37 to 0.59 (Dif1C to Dif6C).

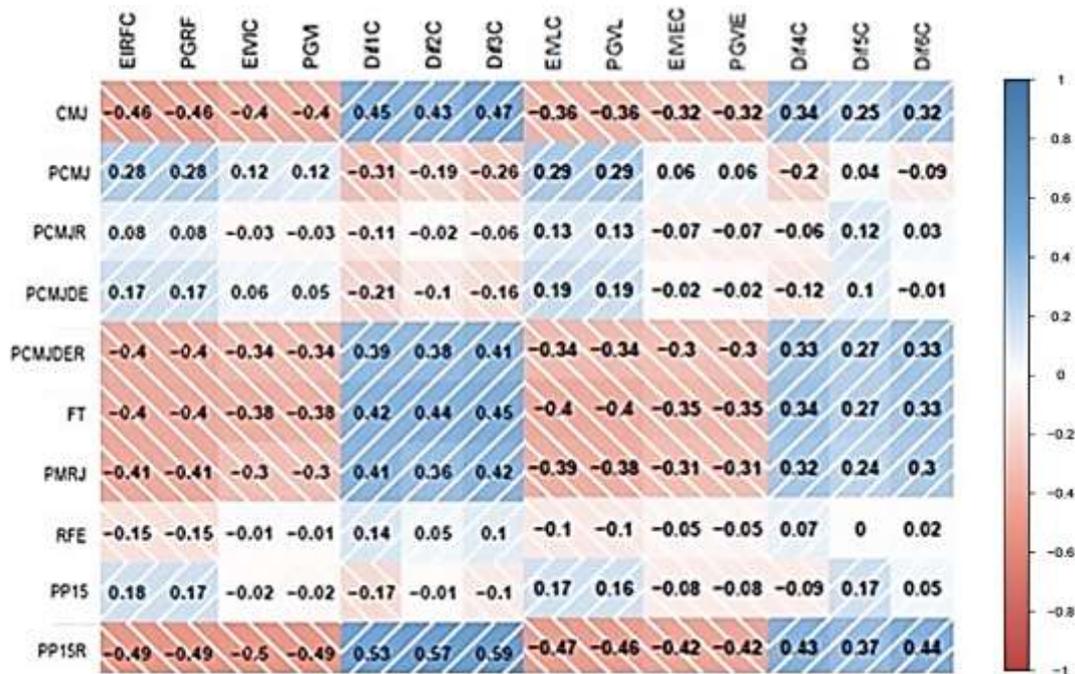


Figure 1. Results of the correlations between EI and the percentage of muscle fat in the evaluated components of the quadriceps in the complete sample.

Figure 2 shows the correlations between the EI and the percentage of muscle fat in the evaluated components of the quadriceps in the group of girls, with the different variables. The FT variable with the EI variables presents  $r$  values ranging from -0.30 to -0.41 (EIRFC, PGRF, EIVIC, PGVI, EIVLC, PGVL, EIVIEC), and from 0.27 to 0.41 (Dif1C to Dif6C). The best correlations were found in the CMJ variable, with  $r$  values between 0.35 and 0.48 (Dif1C, Dif2C, Dif3C).

Figure 3 shows the correlations between the EI and the percentage of muscle fat in the evaluated components of the quadriceps in the group of boys, with the different variables of vertical jump. The best correlations were found in the PP15R variable with the EI variables, with  $r$  values between -0.43 and -0.52 (EIRFC, PGRF, EIVIC, PGVI, EIVLC, PGVL, EIVIEC), and between 0.44 and 0.66 (Dif1C to Dif6C)

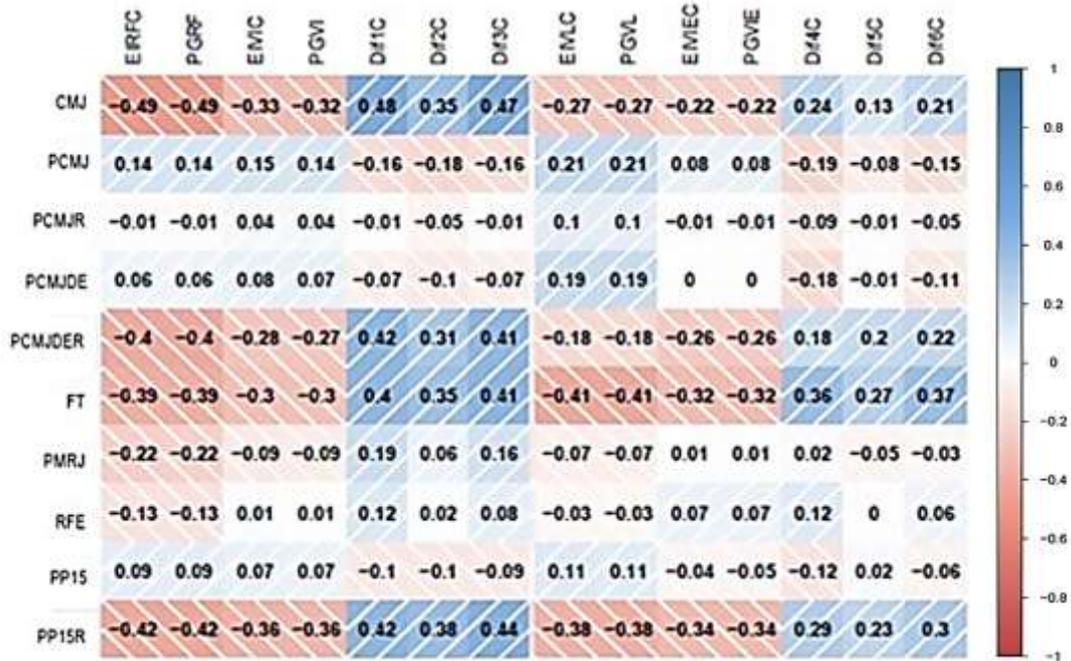


Figure 2. Results of the correlations between EI and the percentage of muscle fat in the evaluated components of the quadriceps in the group of girls.

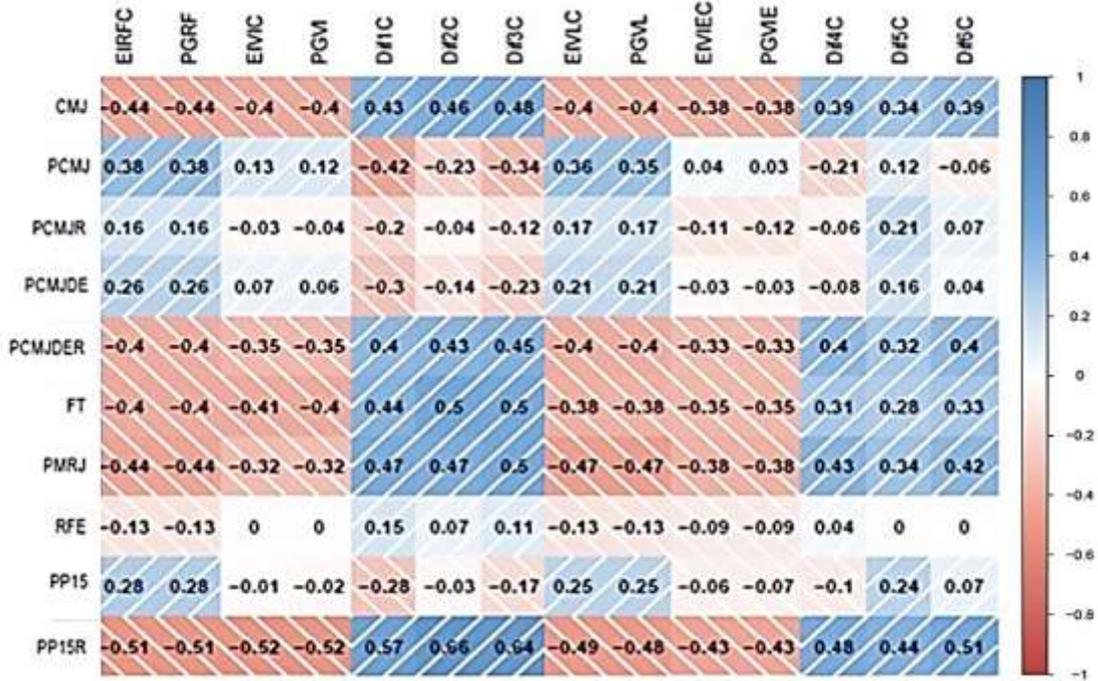


Figure 3. Results of the correlations between EI and the percentage of muscle fat in the evaluated components of the quadriceps in the group of boys.

## DISCUSSION

The field of musculoskeletal ultrasound is new but promising for the overall population, and particularly for school-age children, when it comes to assessing physiological aspects of muscle tissue. In this study, three components of the quadriceps were evaluated, two for being the most widely used by the scientific community (the rectus femoris and the vastus lateralis); and the third one (the vastus intermedius) because it could be evaluated from two different views, both anterior and lateral. The reason to use only a few points in the image is to find a simple way to evaluate the quality of the muscle in children, and, in addition, to serve as a tool to evaluate the changes undergone by children due to the practice of physical activity. Some of the results presented in this work contribute to this, such as the fact that the EI of the vastus intermedius had similar correlations both in the anterior and in the lateral view, with the vertical jump variables, thus revealing little variability in the measurements taken by ultrasound, despite being taken from different anatomical points of the vastus intermedius muscle. This is in line with other studies consulted. Thus, Santos et al. (2017) when evaluating the reproducibility of the ultrasound evaluation of the four components of the quadriceps, revealed a moderate to very high reliability of the EI measurements, with an even higher reliability in the cross-sectional measurements (21). In the same way, Jenkins et al. (2015), in a study on the ultrasound evaluation of the biceps brachii, concluded that the simple transverse image of this muscle for the quantification of muscle thickness and EI is comparable in reliability with a panoramic ultrasound, besides being easier to perform (27).

The best correlation, for both girls and boys, was found between the EI (EIRFC, PGRF, EIVIC, PGVI, EIVLC, PGVL, EIVIEC, Dif1C, Dif2C, Dif3C, Dif4C, Dif5C, Dif6C) and the peak power of the RJ15 (PP15R) when the value was related to body mass, being a little higher in boys than in girls. Boys and girls these ages have the same amount of fat mass in absolute values, but girls have higher values of relative fat mass (% Fat) due to a smaller amount of lean mass compared to boys. Relative fat is 1% higher in girls aged 5, and 6% higher at the age of 10 compared to boys (28), which may explain, at least partially, the differences found. These differences are also explained, in part, because the jump power was higher in boys when compared to girls in absolute terms, although they became more similar in values related to body mass. These results and their possible explanation are in line with those provided by Sahrom et al., who compared both genders in prepuberty (2014) (29). They found a difference in CMJ of a 7% higher in prepubescent boys, but regarding body weight, the average concentric power was similar for both genders.

In this study, only EI was considered as a quantitative ultrasound measure. Muscle thickness was not taken into account because there are no significant differences between girls and boys at these ages. In studies by Kanehista (1995), Welsman (1997) and Özdemir (1995) no differences were found in the transverse section of the muscles evaluated in three different studies, on a sample that included age groups similar to those in this study (15,30,31). A first

study, between dorsi-flexors and planti-flexors; a second one, carried out in Turkey, in the quadriceps of 500 healthy boys and girls; and a third study, which evaluated thigh muscle volume of boys and girls by RM (magnetic resonance). Following this line, the statistical analysis included both genders. Likewise, each subgroup of boys and girls was analysed independently. Only measures inherent to the EI defining the quality of the muscle were analysed, not considering muscle size. In the case of adults, when comparing EI with the measurement of the muscle according to mCSA (muscle cross-sectional area) or muscle thickness, it is observed that the loss of muscle contractile tissue due to ageing is greater than the decrease in muscle size (32). Also in adults, EI showed a significant correlation with age and with muscle thickness and strength (32). The explanation for these correlations in adults is based on the fact that the fatty and fibrous infiltration of the muscle increases with age, generating therefore a greater EI and becoming the muscles weaker as a result. On the other hand, regarding school-age children, the results could be related to the decrease in EI due to an increase in the glycogen content and / or a decrease in the intramuscular fat content. The natural development of anaerobic power entails a significant increase between 6 and 12 years of age, when testosterone levels remain unchanged (33), confirmed by jump height, which doubles between 5 and 13 years of age, similarly in boys and girls (16). This evidence could explain the significant correlations between the EI and the parameters derived from the power of the vertical jump, both in the CMJ and in the RJ15. These correlations are almost the same when the EI is measured in the anterior thigh (RF and VI), evaluated both in general and by gender. In the vastus lateralis the correlations are slightly lower for girls compared to boys. It is also important to mention that the correlations improved when correcting the EI (EIRFC, EIVIC, EIVLC, EIVIEC, Dif1C... DIF6C) as proposed by Young (2017) (22), comparing them with uncorrected correlations. This improvement also appears in another study with adults (34). In this study, the correlations of uncorrected EI (data not shown in the tables presented in the results), with measures of vertical jump, were lower than those found with corrected EI. The corrected EI had better correlations than those found in pre-adolescent children ( $12 \pm 1$  years) in the study carried out by Stock (2017) in which the relationship between vertical jump and ultrasound measurements with corrected EI was also evaluated (35).

Negative correlations are found when the value of the EI of the muscle is compared to various measures derived from the vertical jump, but they are positive when related to the differences between the fat EI and the muscle EI. These correlations were moderate in the global sample, and remained moderate when independently evaluating girls and boys. This means that boys and girls with a better jumping performance have a lower EI, thus implying a better muscle quality. The decrease in EI when related to the increase in vertical jump produces a negative correlation. But, when evaluating the differences between the EI in fat and in muscle (Dif1C... DIF6C), a decrease in the muscle EI, which suggests a better quality, increases the difference, therefore implying that when related to the increase in vertical jump, a positive correlation is found. Therefore, a decrease in EI or an increase in the difference between the EI in subcutaneous fat and in muscle have the same interpretation, that is, a better muscle quality. Other studies have shown these correlations

between vertical jump and EI in young men and women, the mean age being 24.3 for men and 21.5 for women (36). This lower EI is related to a lower fat content in older adults. A study by Stock et al (2017), carried out with children aged between 11 and 14, shows similar correlations to those found in our study between EI and vertical jump height, both in the rectus femoris and in the vastus lateralis (35). But, since this is a borderline age between prepuberty and puberty, it is possible that children who had already begun their pubertal stage were evaluated. In these cases the presence of testosterone is positively related to the strength of leg extensors in adolescents (37). In addition, it coincides with a period of clumsiness (38), which may distort this relationship. This lower EI in school-age children could be explained due to a higher glycogen content, and a lower fat content. This lower fat content was measured in our study as a percentage of muscle fat (PGRF, PGVI, PGVL, PGVIE) as proposed by Young (2016) (11), and it is significantly correlated with vertical jump variables (CMJ, PCMJDER, PMRJ, FT, PPRJ15).

Another element to analyse is that the improvement of strength in children has been considered essentially due to neurological reasons. A study by Behm et. al. (2008) concludes that the improvement of strength owing to training in children can be explained, in part, related to muscle hypertrophy, although it is mainly explained in terms of neural adaptations, such as increased motor unit activation, or other changes such as inter-muscular coordination or neuromuscular training (39). This study has verified that higher levels of anaerobic power in children, evaluated by vertical jump, could be related to a better metabolic condition of the muscles, tending towards anaerobic exercise, since the content of glycogen, which leads to an increase in the content of water, is one of the reasons, if not the most important, to explain the decrease of the EI of the muscle. This means that there are differences in the muscle EI between those performing a good jump compared to those with a poorer performance. In addition, it is important to mention that CMJ in prepubertal adolescents also presents a high correlation with bone mineral density in the lumbar region and in the hip (40), which confirms the association between physical capacity, specifically muscular strength measured by vertical jump, and bone health. This creates an association to explore between muscle quality measured by EI and bone mineral density. The CMJ, and to a greater extent the RJ15, evaluate the ability of the muscle to generate strength with a previous stretching of the muscle. They also evaluate intramuscular coordination and the myotatic reflex, elements that are part of the action of the nervous system (38). These results suggest that those children with a lower muscular EI, independently of gender, performed a better CMJ jump including an eccentric phase, which implies a better intramuscular coordination and use of the elastic component (not evaluated with the EI), and, they can have better metabolic conditions (it can be evaluated with the EI), whether performing a single jump or repeated jumps for 15 seconds. These results may contribute to the control of training at an early age by using the ultrasound evaluation of the EI of the quadriceps as an indicator of the anaerobic metabolism.

## CONCLUSIONS

1. The EI of the components of the quadriceps rectus femoris, the vastus intermedius, and the vastus lateralis significantly correlate with measurements derived from CMJ vertical jump and RJ15 in boys and girls aged between 7 and 10. Measurements include jump height, jump power, and percentage of fast fibres.
2. The results obtained suggest that, in a sample such as the one studied, the schoolchildren who obtain a better jumping result are those with a lower EI, which could be an indicator of a higher glycogen content, and / or a lower content of intramuscular fat.
3. Further studies are necessary to corroborate whether the relationship between EI and vertical jump is due to the glycogen and / or fat content in the muscle.

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