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ULTRASONOGRAPHY INVESTIGATION OF THE ISOINERTIAL TRAINING EFFECTS ON TIGHT MUSCLES IN FEMALE FOOTBALL PLAYERS

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***Abstract**: It is important to study muscular behavior after different types of sports training. Some studies using electromyography show that muscle activity during eccentric muscle activation is lower than during isometric or concentric contractions. The present study, using ultrasonography, assesses the effect of isoinertial training on the thigh muscles of 16 young female football players, in the acute-post-effort phase and evaluates the transverse and longitudinal dimensions of the thigh muscles. The results observed demonstrate the existence of an adaptability to effort, as a consequence of isoinertial training, more evident in the rectus femoris muscle.*

***Keywords**: muscle, ultrasonography, isoinertial training, sport performance*

1. Introduction

Skeletal muscle is considered to be a nearly constant volume system; therefore, changes in muscle length due to contractions parallel changes in muscle thickness [2], [12].

Monitoring the change in muscle thickness during contractions would be a useful tool to assess muscle contractile properties [22]. According to studies, relative changes in muscle contractile parameters are associated with skeletal muscle atrophy [5], [20], with the percentage of muscle fiber types [6], [7], with general and local muscle fatigue [4], [12], and generated muscle force [11], [23]. Among the non-invasive methods for evaluating muscle functions that can be used, we list: surface electromyography (EMGS), mechanomyography (MMG), and ultrasound imaging. When a hypothetical healthy muscle undergoes a concentric contraction from a true resting state, an increase in thickness and a decrease in length are generally observed, however, if the muscle is hypertonic (e.g., increased muscle tone secondary to pain), a similar contraction will result in a smaller change in thickness and length. The isoinertial training method (ITm) has been used over time to improve muscle tropism [13], [18] neuromuscular functions [14], muscle strength [10], and sprint time [9]. Its effectiveness occurs through the development of adapted resistance and an

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optimal, individualized eccentric overload [19]. ITm is based on the resistance generated by a device that applies personalized eccentric overloads, simulating according to Tesch the mechanism of a "yo-yo" through the rotating component that generates an iso-inertial force with the adjustment of the overload at each repetition. The resistance force (in the eccentric phase) is proportional to that generated by the concentric effort, thus unlimited linear loads appear, superior to those in traditional methods. According to specialized studies, isoinertial technology represents an important tool for rehabilitation and injury prevention, which allows the development of force in concentric and eccentric regimes [4], post-application an increase in power and speed occurs at the muscle level, enhanced by the reduction of the moment of inertia [17]. Eccentric contractions, initially avoided due to the risk of injury, have begun to be introduced into strength training as a method of protection against injury [5]. A study by Tous et al. [16] claims that this type of training increases the size, strength, and elasticity of the muscle fiber, which makes the muscle-tendon structure respond favorably to eccentric exercises, having a protective effect on the connective tissue; this plays an important role in improving strength sports activities, thus being successfully integrated into athletics or maintenance, prevention, and rehabilitation programs after sports injuries [17].

2. Materials and Methods

The study started from the premise that IT, performed on the thigh muscles, causes changes in morphological parameters that can be objectively demonstrated by ultrasound. Although the popularity of this training is growing, there are gaps in the understanding of the neurophysiological mechanisms and short-term morphological adaptations. The physiological and molecular basis underlying the effects of isoinertial training, based on eccentric contraction, is represented by the preferential regulation of the activity of transcriptional pathways in fast-twitch muscle fibers, which seem to be affected. From a mechanical point of view, during an eccentric contraction, the muscle elongates against the applied external force, which exceeds the muscle force. The immediate effects consist of the phosphorylation of myosin light chains, which leads to an increase in force and the rate of development of muscle force. From a clinical point of view, ultrasound is used to assess tissue condition, but also to appreciate the effect of concentric and eccentric muscle contractions. Ultrasonography provides 1) quantitative data such as the dimensions of the muscle cross-section, and 2) qualitative data through muscle echogenicity, evaluated on a grayscale, according to which black means hypoechogenic and white represents hyperechogenicity. Based on a series of results of our documentation, regarding isoinertial training, we asked ourselves the question regarding the ultrasound aspects that accompany isoinertial exercises, from a qualitative but also dimensional point of view.

2.1. Research hypothesis

We started from the hypothesis that isoinertial training techniques can determine changes in the muscle cross-section.

2.2. Purpose and objectives

What we set out to do was to objectify the existence of a link between isoinertial training and the size of the muscle's cross-section and muscle strength by quantifying the parameters of the thigh muscles by ultrasound, immediately after applying isoinertial exercises. The objective of the study is to quantify the effects of isoinertial training in the acute-post-exertional phase and to evaluate the transverse and longitudinal dimensions of the thigh muscles by ultrasound.

The study was conducted between October 1, 2019, and December 2021 on 16 girls, members of the football team in League 1 of the Universitatea Craiova Club. The inclusion criteria in this study were that they had been playing football for at least 1 year, had constant participation in training, and were willing to be included in an isoinertial training program. Athletes who had suffered injuries in the last year were unable to participate in testing or practice other sports besides soccer were excluded. Anthropometric characteristics (height, weight, body mass index, BMI) are presented in Table 1.

Table 1

Anthropometric characteristics of the studied group

Item	Age [years]	Weight [Kg]	Height [cm]	BMI [Kg/m2]
average value	14.75	53.94	162.63	20.31
standard deviation	1.25	10.16	7.17	3.10

The subjects were evaluated using the ultrasound analysis method, which was performed before and after the isoinertial training. The ultrasound scans were performed using the VINNO 6 Color Doppler equipment, using the X4-12L linear multifrequency probe, settings - Gain: 45 dB, Dynamic Range: 72, the examination is performed in B mode, with presets that corresponded to the examined area. The examination was performed at the level of the rectus femoris and biceps femoris muscles, bilaterally. The skin was degreased before the ultrasound examination, and the area of maximum muscle relief was chosen as the examination area, after applying the gel locally (Aquasonic 100 ultrasound transmission gel). The subject was positioned in the supine position for the assessment of the rectus femoris muscle and in the prone position for the biceps femoris muscle. At the level of the rectus femoris muscle, the examination area corresponded to half the distance between the anterior superior iliac spine and the upper edge of the patella.

Fig. 1. *Cross-sectional examination of the rectus femoris and biceps femoris muscles*

The ultrasonographic evaluation was performed in the transverse section for both muscles (Figure 2 a, b, c) and additionally in the longitudinal section for the rectus femoris muscle. For each examined area, three measurements were recorded and then the parameters were averaged.

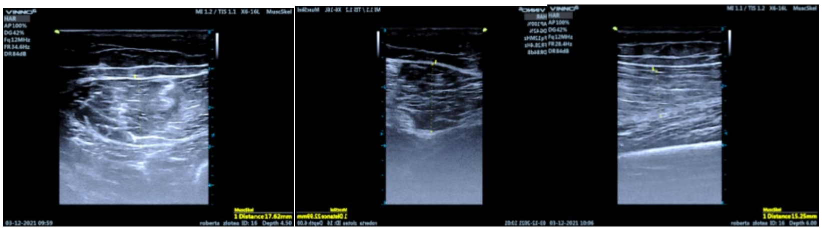

Fig. 2 a,b,c. *Ultrasound images from left to right - transverse section of the rectus femoris muscle, transverse section of the biceps femoris muscle, longitudinal section of the rectus femoris muscle*

3. Results and Discussion

The results obtained aim to present the evolution in terms of the morphology of the muscles evaluated by ultrasound, immediately after the application of an isoinertial type training, the so-called post-acute phase. The recorded values are presented through descriptive statistics in Tables.

Table 2

Ultrasound dimensions of the rectus femoris muscle

Items	Right				Left			
	Transversal [mm] Drept femural		Longitudinal [mm] Rectus femoris		Transversal [mm] Rectus femoris		Longitudinal [mm] Rectus femoris	
	before workout	after workout	before workout	after workout	before workout	after workout	before workout	after workout
Minimum	15.70	18.99	6.73	12.70	11.97	14.36	9.23	12.01
Maximum	25.43	29.89	18.72	20.94	19.08	27.01	15.32	18.78
Media	19.70	22.039	13.899	16.172	15.40	18.90	12.27	14.66
Std. deviation	2.37	2.98	2.89	2.79	1.75	2.85	1.73	2.20
Cohen d-test	0.865		0.80		1.48		1.21	
Coefficient of variation	0.12	0.135	0.21	0.17	0.11	0.15	0.14	0.15

It is observed, from the data presented in Table 1, an increase in the values of the ultrasound dimensions, approximately at the same level for both measured dimensions, which signifies the existence of an increase in muscle volume.

An increase in dimensions is observed, more pronounced in the diameter of the cross-section, and compared to the evolution in the right lower limb, the increases are greater, which represents a response that can be based on the existence of a left/right asymmetry, which requires a more complete evaluation.

Table 3

Ultrasound dimensions of the right and left biceps femoris muscle

Items	**Transversal [mm] Biceps femoris right**		**Transversal [mm] Biceps femoris left**	
	before workout	**after workout**	**before workout**	**after workout**
Minimum	14.57	19.54	16.99	16.88
Maximum	29.39	29.42	28.22	26.84
Media	21.34	23.79	20.47	21.53
Std. deviation	3.29	2.72	3.23	2.93
Cohen d-test	0.81		0.34	
Coefficient of variation	0.15	0.11	0.16	0.14

At the biceps femoris muscle level, the ultrasound quantification was performed only in the transverse section, since the evaluation in the longitudinal section is irrelevant for this muscle. The data in Table 3 highlight increases in the value of the transverse section dimension, but this increase is relatively small in the left biceps femoris, highlighting once again the existence of a left/right asymmetry.

The results obtained demonstrate the existence of adaptability to the effort, as a result of isoinertial training, more evident at the level of the rectus femoris muscle, an aspect that can extend to the level of the quadriceps muscle, even if the ultrasound measurements were performed only on the rectus femoris muscle. The same aspect is observed in the case of the biceps femoris muscle. Also, the statistical analysis shows once again the existence of a left/right muscle imbalance from a morphological point of view, which justifies the need for a deeper analysis of symmetry and coordination, other characteristics that define sports capabilities and performance.

Although this study focused exclusively on morphological changes in some muscle groups, the results highlight an acute response and especially a potentiation of muscle activation immediately after the interruption of the training session. Isoinertial training modifies the transverse and longitudinal dimensions of the muscles. We observe a tendency to increase muscle volume and, implicitly, muscle strength, an aspect also highlighted by a series of other studies that reported neuromuscular adaptations produced after isoinertial training. These adaptations also involve the recruitment of more synchronized motor units, reflected in symmetry and coordination [3], [8]. A synthesis study conducted by Abe et al. [1] confirmed the relationship between muscle volume, cross-sectional area, and muscle strength in the quadriceps muscle, in different types of training, and that cross-sectional area and muscle volume can be considered predictors of muscle strength and power. Similarly, Watanabe et al. [24] found a positive correlation between cross-sectional area and muscle strength by analyzing the relationship between the cross-sectional diameter of the quadriceps muscle, echogenicity, and maximum isometric contraction. Selva et al. [17] showed an ultrasound effect of increasing muscle strength very closely related to the cross-sectional area of the rectus femoris muscle (significance level being $p<0.05$). Discussions and articles regarding the relationship between muscular architectural parameters assessed by ultrasonography and muscular functional potential, although they exist, have not fully elucidated the issue, especially if we discuss isoinertial trained eccentric contraction.

4. Conclusions

Ultrasound investigation is a valuable tool, it allows monitoring the effects of training aimed at increasing muscular strength, through the information provided related to the cross-sectional diameter of the trained muscle groups. Ultrasound performed on the rectus femoris muscle shows an increase in size, more pronounced in the cross-sectional diameter, and comparatively, in the left rectus femoris muscle compared to the evolution in the right lower limb, the increases are greater, which represents an answer that can be based on the existence of a left/right asymmetry, which requires a more complete evaluation. Especially in young athletes, it is necessary to introduce different and more challenging training methods that can stimulate kinetic energy and increase the complex efficiency of skills during the football match. The changes in the dimensions of the cross-sectional and longitudinal diameters, in the case of the rectus femoris muscle and the cross-sectional area for the biceps femoris muscle, in the direction of growth, demonstrate that in the post-"acute" period, post-exertion, a minimal muscle activation occurs, which over time can generate morphological changes consisting in an increase in muscle volume.

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This result confirms the hypothesis that isoinertial training techniques cause changes in the cross-sectional area at the muscle level.

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