Comparing the effect of two different exercise types, mini-trampoline and fast-walking to gastrocnemius/soleus muscle elasticity by sonoelastrography

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ABSTRACT

Objectives: Sonoelastography is a newly introduced ultrasound technique that evaluates tissue elasticity and thus provides additional information to that offered by conventional ultrasound images. Here, we compared the effect of ballistic jumping on mini-trampolin with walk exercise to the elasticity of gastrocnemius/soleus muscles with quantitative measurements by sonoelastography.

Methods: Forty volunteer healty male cases between the ages of 20-22 years were included the study. Initially, both exercise groups were subjected to joint warm-up movements for 8 minutes. Twenty of the cases (40 legs) had mini-trampoline (balistic jumping) exercise for 15 minutes. Another 20 cases (40 legs) had 15 minutes fast-walk exercise. Measurements were made immediately before and after the procedure (within 5 minutes) with the sonoelastography.

Results: A statistically significant difference was observed in the gastrocnemius/soleus muscles after exercise in the trampoline group according to sonoelastography strain value (SESV) data separately (p = 0.0001 / p = 0.0001). According to this, when the SESV values evaluated after 15 minutes of jump with the trampoline, we obtained that the elasticity increases and stifness decreases in the calf muscles. In the walking group, no statistically difference was observed in the gastrocnemius/soleus muscles after exercise separately (p = 0.7925 / p = 0.1879).

Conclusions: According to the study, in the trampoline group in general, a decrease in strain values and an increase in elasticityin muscle groups were found; in the walking group, a decrease in muscle elasticity, an increase in stiffness and muscle strain were found eventually. We found that the 15-minutes exercise program on the mini-trampoline is more effective as a heating technique and has more positive effect on muscle elasticity than the 15-minutes walking exercise.

Keywords: sonoelastography, trampoline, walk, exercise, muscle, stifness, strain

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Sonoelastography (SE) is a newly introduced ultrasound technique that evaluates tissue elasticity and thus provides additional information to that offered by conventional ultrasound images [1]. It is a noninvasive method for measuring tissue elasticity whereby a quantitative estimate is obtained of the elasticity of various soft tissues, including muscles, tendons, salivary glands, and abdominal organs. The

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imaging method is based on acoustic radiation force impulses through the tissue to obtain an elastic modulus. The result is a local measurement of the tissue elasticity at each point of interest of an organ. This imaging method is operator independent, reproducible, and quantitative [2-4].

It has been documented that exercises on a mini-trampoline involve a multi-component approach, including muscle coordination, strength and balance training, body stability, and joint flexibility training [5]. Muscle action and coordination in the lower extremities were continuously facilitated by maintaining body balance on an elastic surface. In general, the ability to maintain balance is based on three mechanisms, including increasing the base of support, counter-rotating segments around the center of mass, and applying an external force other than the ground reaction force. In performing the mini-trampoline exercise, the participants were challenged to stabilize their body while keeping the center of mass over the base of the support. They needed to exert muscle force and neuromuscular responses to stiffen their legs in order to overcome the unstable conditions [6].

The effect of different exercise types on muscle elasticity has not been studied sufficiently. To best of our knowledge, there is no study about mini-trampolin exercise's acute effect to gastroknemius/soleus muscle' elasticity, and the comparison of the results with fast-walk exercise by SE. Here, we compared the effect of mini-trampolin exercise with fast-walk exercise to the gastrocnemius/soleus muscles with quantitative measurements by SE.

METHODS

Study Population

Forty volunteer healty male cases between the ages of 20-22 years were included the study. Initially, both exercise groups were subjected to joint warm-up movements for 8 minutes. Twenty of the cases (40 legs) had mini-trampoline (balistic jumping) exercise for 15 mınutes. Another 20 cases (40 legs) had 15 minutes fast-walk exercise. Measurements were made immediately before and after the procedure (within 5 minutes) with the SE.

Sonoelastography

SE is an ultrasound-based technique that determines mechanical properties of the tissue quantitatively, visually, and qualitatively compared with the B-mode analysis (acoustic impedance) or the color Doppler ultrasound (vascular blood flow). The diagnostic difficulties can be overcome by using the SE method, which is increasingly used in the recent years. Strain elastography is the most commonly used measurement technique among several others, and the externally applied pressure causes more deformation in the soft tissues and less deformation in the hard tissues. This information is color-coded on a screen, and the quantitative data are obtained by measurements from the region of interest (ROI) [2-4].

A high-resolution ultrasonography system (Aplio ™ 400 Platinum, Toshiba Medical Systems Corporation, Tochigi, Japan) and a broad band linear probe (PLT-704SBT) were used. When the gastrocnemius / soleus muscles were visualized on a gray scale ultrasonography image of the area symmetrically, bilaterally and separately, elastography was inserted into the apparatus and pressure was applied. The SE strain value (SESV) of the subcutaneous fat tissue in the same image and SESV of the central segments of the muscles were detected using by measurements from ROI. The sonoelastography strain ratio (SESR) of the muscles was calculated by dividing the fat values by the muscle values. All procedures were performed by the same experienced radiologist who was kept uninformed about the clinical diagnosis.

Statistical Analysis

The approval for this study was granted by the Institutional Ethics Committee. Measurements and calculations derived from SE were expressed as mean ± standard deviation. Categorical data were presented as numbers and percentages. The Shapiro–Wilk test was used to examine the fitness of the variables for the normal distribution. Comparisons of the obtained strain rates were made by independent Student's t test. When P value was less than 0.05, the result was considered statistically significant.

RESULTS

Forty male cases (80 legs) between 20-22 years of

Table 1. Descriptive data of the groups

Group		Age (year)	Height (cm)	Weight (kg)
Trampoline	Mean ± SD	21 ± 1.02	174.5 ± 6.13	70 ± 9.19
Walking	Mean ± SD	20.56 ± 1.8	176.5 ± 4.4	68.38 ± 8.45
t		1.34	1.67	0.82
p value		0.18	0.09	0.41

SD = standard deviation

age were included the study. There was no significant difference in age, height and weight between trampoline and walking groups ($p = 0.182$ / $p = 0.097$ / $p = 0.414$). The descriptive data for the groups are summarized in Table 1.

A statistically significant difference was observed in the gastrocnemius / soleus muscles after exercise in the trampoline group according to SESV data ($p = 0.0001$ / $p = 0.0001$) (Table 2). According to this, when the SESV values evaluated after 15 minutes of jump with the trampoline, we obtained that the elasticity increases and stiffness decreases in the calf muscles.

In the walking group, no statistically significant difference was observed in the gastrocnemius/soleus muscles after exercise ($p = 0.7925$ / $p = 0.1879$) (Table 3). According to this, 15 minute fast-walking exercise

Table 2. Pre/post data of SESV values of gastrocnemius/soleus muscles in trampoline group

Trampoline	Mean ± SD	*p value*
Gastroknemius First	0.38 ± 0.23	**0.0001**
Gastroknemius Second	0.15 ± 0.08	
Soleus First	0.59 ± 0.32	**0.0001**
Soleus Second	0.22 ± 0.08	

SESV = sonoelastography strain value, SD = standard deviation

Table 3. Pre/post data of UESV values of gastrocnemius/soleus muscles in walking group

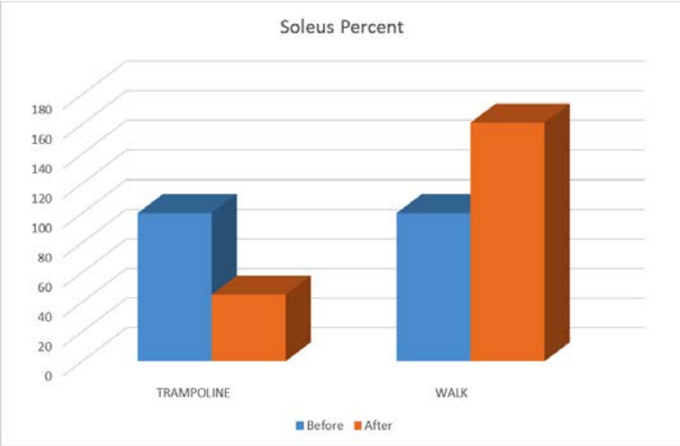
Walking	Mean ± SD	*p value*
Gastroknemius First	0.55 ± 0.38	0.7925
Gastrocnemius Second	0.52 ± 0.61	
Soleus First	0.72 ± 0.58	0.1879
Soleus Second	1.05 ± 1.46	

UESV = ultrasound elastography strain value, SD = standard deviation

Table 4. Changes in SESR values before/after exercise in the gastrocnemius/soleus muscles

Group		Gastrocnemius Percent (n = 40)	Soleus Percent (n = 40)
Trampoline	Mean ± SD	45.05 ± 26.79	46.60 ± 24.29
	Median	39.69	43.93
	Minimum	8.57	17.48
	Maximum	80.00	86.11
Walking	Mean ± SD	161.80 ± 251.74	188.90 ± 270.66
	Median	59.38	84.57
	Minimum	3.23	3.57
	Maximum	962.50	935.85
t		2.9167	3.3118
p value		**0.0046**	**0.0014**

SESR = sonoelastography strain ratio, SD = standard deviation



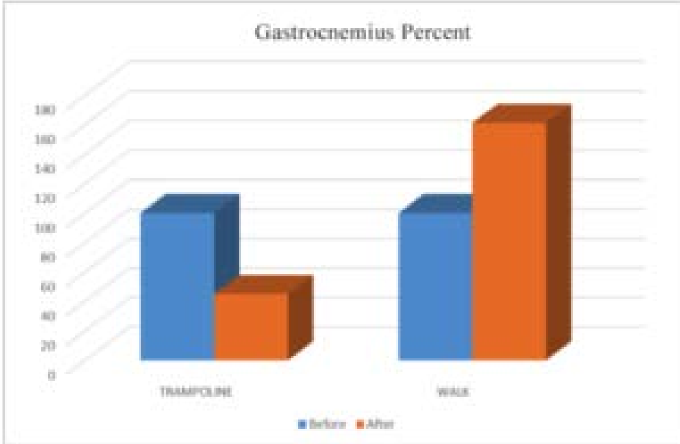


Figure 1. Graphical presentation of percent changes in SESRs in gastrocnemius/soleus muscles in trampoline and walk groups

did not cause any significant change in SESV valuesand did not affect muscle elasticity / stiffness positively.

When the percentages of SESR values before and after exercise were examined; the percent change in the both gastrocnemius/soleus muscle groups was significantly different at the trampoline group (p = 0.0046 / p = 0.0014) (Table 4). According to this, in the trampoline group in general, a decrease in strainvalues, an increase in elasticityatcalf muscles were found; in the walking group, a decrease in muscle elasticity, an increase in stiffness and muscle strain were found (Figure 1).

DISCUSSION

Fast-walking exercise was not found to have a positive effect on calf muscle elasticity. We found that the 15-minutes exercise program on the mini-trampoline is more effective as a heating technique and has more positive effect on muscle elasticity than the 15-minutes walking exercise.

Studies assessing the effect of exercise on muscle function and stiffness have used different measurement techniques and small cohorts, making it difficult to conclude on the overall efficacy of exercises types on these outcomes. Current data suggest that aerobic exercise training should be used as a primary treatment strategy for improving muscle function [5, 6].

Elasticity imaging is a relatively new ultrasound-based technique for investigating musculoskeletal injury. SE, the most commonly used technique, allows determination of the elastic properties of tissue by applying pressure, which provides a quantitative assessment of muscle tissue as a cheap, practical method [7-9]. Based on current of literature, SE seems to be at least as feasible as ultrasonografi (US) and magnetic rezonance imagination (MRI) for identify clinical muscle-tendon alterations [10].

Green *et al*. [11] used Magnetic Resonance Elastography (MRE), a noninvasive imaging technique, to assess the time-course of passive elasticity changes in the medial gastrocnemius/soleus muscles before and after a bout of eccentric exercise. Study findings by Crawford *et al*. [12] suggest that massage loading following eccentric exercise has a greater effect on reducing muscle stiffness.

Passive joint stiffness is an important quantitative measure of flexibility, but is affected by muscle volume and all of the anatomical structures located within and over the joint. Quantifying passive stretching responses of individual muscles by SE, helps the diagnosis of muscle disorders and aids the evaluation of surgical/rehabilitation treatments [13, 14]. The study by Hirata *et al* [15], showed the significant effectiveness of static stretching on the passive fasciclestiffness. Hirata *et al*. [16] also examined the muscle stiffness responses of the gastrocnemius/soleus during passive dorsiflexion before and after a static stretching by using US shear wave elastography. They indicated that passive muscle stiffness differs among the triceps surae, and that the acute effect of a static stretching is observed only in the stiff muscle. Chino and Takahashi [17], determined muscle elasticity, measured independent of the confounding effects of muscle volume and the other nearby anatomical structures, is associated with passive joint stiffness in the joint position where the muscle is sufficiently lengthened. Chino and Takahashi [18] indicated that variations in the elasticity of other tissues, including medial gastroknemius aponeuroses or the ligaments and joint capsule of the ankle, would be associated with the variations in joint stiffness.

Similar to our study, Yanagisawa *et al*. [19] assessed the feasibility of SE for measuring exercise-induced changes in muscle stiffness and to compare the findings of it with those of a tissue stiffness for semi-quantitative assessment. They made participants to perform an arm-curl exercise. They found the strain ratio and the value obtained using the tissue stiffness significantly decreased, after exercise.

In our study, we observed a significant difference in elasticity and stiffness values in the calf muscle groups after 15 minutes on trampoline jumping exercise by SE. When we looked at the strain percentile changes, we also observed a significant decrease in total muscle strains in the trampoline group. We found jumping exercise with mini-trampoline as effective as a muscle heating technique. It has been observed in the literature that trampoline studies have resulted an increase in muscle strength, speed, jump, anerobic physical capacity, motor performance, balance and proprioception in long term [20-22]. We measured the positive effect of trampoline on muscle elasticity in the acute phase (in 5 minutes). At 15-minutes fast-walking group a decrease in muscle elasticity, an increase in stiffness and strain were found. Fast-walking exercise was found to be an ineffective heating method compared to trampoline.

SE has to be viewed as an experimental technique without sufficient supporting evidence to be used as a routine examination equivalent to US and MRI in musculoskeletal analysis. The usefulness of SE can be expected to increase rapidly in the musculoskeletal field, as soon as we learn to interpret elastographic artifacts as well as to take advantage of the new information provided by SE [23, 24].

Limitations

Small sample size and that ultrasound elastography standards have not been established yet in the literature are the limitations of the study.

CONCLUSION

Elasticity imaging is a relatively new ultrasound-based technique for investigating musculoskeletal injury. SE, the most commonly used technique, allows determination of the elastic properties of tissue by applying pressure, which provides a quantitative assessment of muscle tissue as a cheap, practical method. Heating with trampoline exercise is an effective, reliable method that generally increases elasticity and reduces stifness in calf muscles. The trampoline-jumping exercise was found to be superior to the fast-walking exercise in acute period.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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