

Influence of Body Mass Index on Mechanical Properties in People With Obesity

Serkan Usgu (✉ serkan.usgu@hku.edu.tr)

Hasan Kalyoncu Üniversitesi: Hasan Kalyoncu Üniversitesi <https://orcid.org/0000-0002-4820-9490>

Engin Ramazanoğlu

Inonu University: Inonu Üniversitesi

Yavuz Yakut

Hasan Kalyoncu Üniversitesi: Hasan Kalyoncu Üniversitesi

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Abstract

Background: The study was to determine influence of body mass index on muscular mechanical properties in people with obesity.

Methods: A total of 300 individuals (mean age: 27.31 ± 7.21 years) were participated. The participants were assigned in groups base on BMI classification (Group 1 (BMI=18.50-24.99 kg/m²), Group 2 (BMI=25.00-29.99 kg/m²), and Group 3 (BMI \geq 30 kg/m²)). The biceps brachii (BB), biceps femoris (BF) were measured bilaterally using the "MyotonPRO" device.

Results: All mechanical properties of the right and left BB muscle, left BF tone and stiffness were found significantly difference between groups ($p < 0.05$). The bilateral BB tone in Group 3 was lower than the other two groups. The right BB stiffness of Group 2 was found to be higher compared to the other two groups ($p < 0.05$). While the right and left BB elasticity was similar in Groups 2 and 3, it was lower compared to Group 1 ($p < 0.05$). The left BF tone and stiffness of Group 3 were found to be significantly higher than Groups 1 and 2 ($p < 0.05$).

The right BB tone showed a weak negative correlation with BMI in females, and for left side in males. A weak positive correlation was found between the right and left BB elasticity and BMI in males and females. The left-right BF tone and left BF stiffness showed a weak positive correlation in males.

Conclusions: The bilateral BB tone and elasticity decreased, and the left BF stiffness increased as BMI increased. Different mechanical properties were observed in sex comparison base on BMI clasification. The BB and BF mechanical properties were affected more in males than females.

Plain English Summary

Obesity is closely related to fat tissue, and it may have direct or indirect effects on physical activity and the musculoskeletal system This study was conducted to determine influence of body mass index on muscular mechanical properties in people with obesity. Our findings showed fat tissue and muscular mechanical properties had weak relation. The muscle firmless and elasticity decreased as fat tissue increased and the mechanical properties were affected more in males than females. The muscular actions and efficiency can adopt to inactivity. Therefore, our study demonstrated the obesity or higher BMI lead to the human body for developing different muscular adaption. The upper and lower extremity muscles acting differently for daily living activities or functions. The increased mechanical load in lower leg cause to rising stiffness of muscles. The upper extremity muscles, which lacks mechanical loading, may adversely affected.

Introduction

Obesity is a significant health problem that is gradually increasing. It can be defined as excessive fat accumulation in a way that can disrupt health, and it predisposes to chronic diseases (1). The calculation of body mass index (BMI) is the simplest indicator of an increase in adipose tissue in the body and the frequently used method (2). According to BMI, individuals are evaluated as underweight (< 18.5 kg/m²), normal (18.5–24.9 kg/m²), overweight (25-29.9 kg/m²), first-degree obese (30-34.9 kg/m²), second-degree obese (35-39.9 kg/m²), and third-degree morbidly obese (≥ 40 kg/m²) (3). A decrease or increase in BMI may be a factor in the formation of chronic diseases (4).

Obesity is closely related to adipose tissue, and it may have direct or indirect effects on physical activity and the musculoskeletal system (5). While the relationship of obesity with cardiovascular diseases and type 2 diabetes draws attention, its effects on the musculoskeletal system are less questioned. Disorders that can affect bone health, such as osteoarthritis or osteoporosis, which threaten joint health due to overload, are the most well-known. There are few studies on the effects of increased BMI on the mechanical properties of muscles or the methods evaluated these properties (6).

Non-invasive elastography, ultrasonographic or myotonometric evaluations are used to evaluate the mechanical properties of muscles (7–9). Myotonometric evaluation which has recently become popular and offers the advantage of use in clinics. The device probe (3 mm in diameter) is placed vertically on the muscle and skin, and the stroke of the probe (0.18 N) causing the oscillations obtained by compressing the subcutaneous tissues (9, 10). The sternocleidomastoid (SCM) and upper trapezius (UT) muscle stiffness and elasticity were examined by myotonometric evaluation in adult females, and it was observed that there was a weak correlation between the UT elasticity and BMI and a moderate correlation between the SCM and UT muscle stiffness and BMI (11). In a study investigating the mechanical properties of the Achilles tendon and gastrocnemius muscle, it was stated that BMI did not affect mechanical properties (12). In a study performed using another technique, elastography, BMI was shown to be related to the upper trapezius stiffness (13), while no relationship was found between mechanical properties and BMI in other studies conducted on different muscles (14, 15). Previous studies were investigated general mechanical properties in healthy individual without wider BMI range. This study was planned to determine influence of body mass index on muscular mechanical properties in people with obesity.

Materials And Methods

Individuals

This study is a prospective observational study. A total of 300 individuals (mean age: 27.31 ± 7.21 years) were participated. Sedentary individuals without any systemic or metabolic disease, without psychological disease or drug use, without any disease that might cause muscle disease or muscle atrophy, who had not undergone musculoskeletal surgery in the last three months, with physical activity levels of ≤ 300 MET min/week according to the international physical activity survey score were included in the study (16). Individuals with rheumatic diseases, a history of fibromyalgia, females in the menstrual cycle period and individuals with a history of pregnancy, those with diseases such as Parkinson's disease, multiple sclerosis, muscular dystrophy that might affect muscle tone

and movements were excluded from the study. It was stated that they should not consume alcohol for at least 24 hours and not engage in strenuous physical activity for at least 48 hours before the test (17).

Individuals were divided into three subcategories according to sexes and BMI range: Group 1 (BMI = 18.50-24.99 kg/m²) (n = 100), Group 2 (BMI = 25.00-29.99 kg/m²) (n = 100), and Group 3 (BMI ≥ 30 kg/m²) (n = 100).

Procedures

The ethics committee approval numbered 2020/101 and dated 16.12.2020 was obtained from the non-invasive research ethics committee of Hasan Kalyoncu University, Faculty of Health Sciences. All participants voluntarily involved and they were informed about the content and purpose of the study and signed the consent form. The physical characteristics and demographic information of the individuals were recorded prior to the test. Weight was evaluated using an electronic scale GSE 450 (GSE Scale Systems, Novi, Michigan), and height was evaluated using a standard stadiometer. BMI was calculated by dividing the weight in kilograms by the square of height in meters.

The tone and viscoelastic properties of the biceps brachii (BB) and biceps femoris (BF) muscles were evaluated bilaterally using a Myoton Pro (Müomeetria Ltd., Tallinn, Estonia) device. This device is known to have good to excellent reliability in healthy individuals (18, 19). It can be used for objective diagnosis and monitoring in soft tissues in terms of validity and inter-user reliability (20, 21).

The BB mechanical properties were evaluated by palpating the lateral end of the acromion and the cubital fossa in the middle from the ¾ of the distance between them with the individual in the resting supine position (22). Concerning the BF, the individual lay in the prone position and was asked to contract the hamstring muscle after placing a pillow under the ankle. The muscle was palpated while the individual was contracting it. Along with the contraction, the most prominent part of the muscle was marked and measured in muscle contraction, as suggested by Gavronski et al. (23). These muscles were preferred since they had been studied previously in many studies (24–25). For each measurement, mean deviation, median and 95% confidence interval were given, and mean values obtained from three consecutive measurements from the reference points were used in statistical analysis.

The Myoton device provides data on three different properties. Tone (f) indicates a passive or resting muscle state without oscillation frequency (Hz), voluntary contraction (26). Stiffness (N/m) indicates resistance to any contraction or external intervention (26). Elasticity (D) is obtained as a logarithmic reduction of the natural oscillation of soft tissues. The increase in the number in the measurement obtained means the decrease in elasticity and is inversely proportional (26). The measurement creates a short-duration (15 ms), low-force (0.40 N) mechanical stimulation that induces damped natural oscillations of the tissues after the constant pre-stimulation (0.18 N) of the probe placed perpendicular to the muscle (3 mm in diameter) and is obtained by recording oscillations using an accelerometer (26).

Statistical Analysis

Descriptive statistics were presented as mean ± standard deviation. The Shapiro-Wilk test was used to check whether the data were normally distributed. The Mann-Whitney U test was used to compare differences between males and females (sex), and the Kruskal-Wallis test was used to compare differences in three groups (according to BMI range) for non-normally distributed data. Post-hoc binary comparisons (after Dunn's correction) were used to determine the source of the difference. The relationship between numerical variables was evaluated by Spearman correlation. As Spearman's rank correlation coefficient, 0.00-0.10 was interpreted as very weak correlation or no correlation, 0.10–0.39 as weak correlation, 0.40–0.69 as moderate correlation, 0.70–0.89 as high correlation, and 0.90–1.00 was interpreted as very strong correlation (27).

Statistical analysis was conducted using Windows version 24.0 for SPSS (IBM Corp. Armonk, NY IBM Corp.), and the value $p < 0.05$ was considered statistically significant. The minimum total number of participants required for each group was determined to be 44 ($\alpha = 0.01$) in order to determine the expectation that there would be a significant difference between three different BMI groups at the large effect level ($f = 0.75$) obtained by referring to the published article with a power of 0.90. G-power program version 3.9.1.7 was used in power analysis (28).

Results

A total of 300 healthy individuals (mean age; 27.31 ± 7.21 years, mean height; 1.69 ± 0.84 m, mean weight; 77.86 ± 14.48 kg), including 150 females (mean age; 26.03 ± 6.89 years) and 150 males (mean age; 28.6 ± 7.33 years) were participated in this study. The 150 male participants; 50 (33.33%) were in Group 1, 50 (33.33%) were in Group 2, and 50 (33.33%) were in Group 3. The 150 female participants; 50 (33.33%) were in Group 1, 50 (33.33%) were in Group 2, and 50 (33.33%) were in Group 3.

Correlation between the BB and BF mechanical properties and BMI

All individuals

A weak negative correlation was found between the right and left BB tone and BMI ($r = -0.177$ - $p = 0.002$, $r = -0.157$ - $p = 0.006$, respectively). A weak positive correlation was revealed between the right and left BB elasticity and BMI ($r = 0.258$ - $p = 0.000$, $r = 0.211$ - $p = 0.000$, respectively). No correlation was determined in the bilateral BB stiffness ($p > 0.05$). A weak positive correlation was found between the left BF stiffness and tone and BMI ($r = 0.164$ - $p = 0.004$, $r = 0.143$ - $p = 0.013$, respectively). No correlation was detected in other mechanical parameters of the BF ($p > 0.05$) (Table 1).

Table 1
The Relationship Between the Mechanical Properties and BMI

		Total (n = 300)	Males (n = 150)	Females (n = 150)
Right BB Tone (Hz)	r	-0.177*	-0.147	-0.212*
	p	0.002	0.072	0.009
Right BB Stiffness (N/m)	r	0.066	0.125	0.020
	p	0.254	0.128	0.810
Right BB Elasticity (log)	r	0.258*	0.285*	0.234*
	p	0.000	0.000	0.004
Left BB Tone (Hz)	r	-0.157*	-0.131	-0.180*
	p	0.006	0.110	0.027
Left BB Stiffness (N/m)	r	0.036	0.079	-0.001
	p	0.538	0.338	0.993
Left BB Elasticity (log)	r	0.211*	0.199*	0.223*
	p	0.000	0.015	0.006
Right BF Tone (Hz)	r	0.105	0.114	0.103
	p	0.069	0.164	0.209
Right BF Stiffness (N/m)	r	0.108	0.134	0.111
	p	0.061	0.103	0.175
Right BF Elasticity (log)	r	0.104	0.141	0.096
	p	0.072	0.086	0.241
Left BF Tone (Hz)	r	0.143*	0.301*	0.071
	p	0.013	0.000	0.390
Left BF Stiffness (N/m)	r	0.164*	0.284*	0.123
	p	0.004	0.000	0.133
Left BF Elasticity (log)	r	0.090	0.096	0.105
	p	0.121	0.244	0.202

r: Spearman's rank correlation *p < 0.05 significant. Abbreviations: BB: biceps brachii, BF: biceps femoris, Hz: Frequency, N/m: newton/meter, log: logarithmic reduction.

Females

A weak positive correlation was found between the right and left BB elasticity and BMI ($r = 0.234$ - $p = 0.004$, $r = -0.223$ - $p = 0.006$, respectively), and a weak negative correlation was revealed with the right and left BB tone ($r = -0.212$ - $p = 0.009$, $r = -0.180$ - $p = 0.027$, respectively). No correlation was detected in the other mechanical properties of the BB and BF ($p > 0.05$) (Table 1).

Males

A weak positive correlation was revealed between the right and left BB elasticity and BMI ($r = 0.285$ - $p = 0.000$, $r = 0.199$ - $p = 0.015$). No correlation was found in the other parameters of the BB ($p > 0.05$).

A weak positive correlation was observed with the left BF stiffness and tone ($r = 0.284$ - $p = 0.000$, $r = 0.301$ - $p = 0.000$, respectively). No correlation was found between the bilateral BF elasticity and BMI ($p > 0.05$) (Table 1).

Comparison Of Mechanical Properties In Bmi Groups

All individuals

A statistical difference was found in all mechanical properties of the right and left BB muscle, left BF tone and stiffness ($p < 0.05$) (Table 2). When advanced statistical methods were used, it was observed that the bilateral BB tone in Group 3 was lower than the other two groups ($p < 0.05$). The right BB stiffness of

Group 2 was found to be higher compared to the other two groups ($p < 0.05$). While the right and left BB elasticity was similar in Groups 2 and 3, and it was higher than Group 1 ($p < 0.05$). The left BF tone and stiffness of Group 3 were found to be significantly higher than Groups 1 and 2 ($p < 0.05$) (Table 3).

Table 2
The comparison of mechanical properties in BMI groups

	Group 1			Group 2			Group 3			p		
	T (n = 100)	M (n = 50)	F (n = 50)	T (n = 100)	M (n = 50)	F (n = 50)	T (n = 100)	M (n = 50)	F (n = 50)	T	M	F
Right												
BB Tone (Hz)	14.32 ± 1.72	14.5 ± 1.85	14.13 ± 1.57	14.4 ± 2.44	15.08 ± 2.94	13.73 ± 1.59	13.61 ± 1.35	13.85 ± 1.19	13.36 ± 1.46	0.006	0.019	0.051
BB Stiffness (N/m)	215.22 ± 42.49	211.9 ± 48.08	218.54 ± 36.24	235.41 ± 48.8	242.16 ± 58.06	228.66 ± 36.72	218.29 ± 34.14	216.64 ± 32.35	219.94 ± 36.09	0.001	0.001	0.214
BB Elast. (log)	1.00 ± 0.22	0.97 ± 0.2	1.04 ± 0.14	1.13 ± 0.24	1.08 ± 0.22	1.18 ± 0.25	1.13 ± 0.26	1.09 ± 0.28	1.17 ± 0.22	0.001	0.010	0.007
BF Tone (Hz)	15.01 ± 2.13	15.81 ± 1.87	14.21 ± 2.09	15.66 ± 2.25	16.79 ± 2.24	14.53 ± 1.59	15.45 ± 2.16	16.31 ± 1.83	14.58 ± 2.14	0.138	0.065	0.427
BF Stiffness (N/m)	243.08 ± 53.4	258.5 ± 48.14	227.66 ± 54.39	260.57 ± 57.55	289.62 ± 60.51	231.52 ± 36.17	258.23 ± 59.85	278 ± 63.87	238.46 ± 48.57	0.090	0.031	0.345
BF Elast. (log)	1.09 ± 0.25	1.19 ± 0.23	1 ± 0.24	1.1 ± 0.27	1.21 ± 0.3	1.00 ± 0.18	1.15 ± 0.27	1.24 ± 0.25	1.07 ± 0.26	0.175	0.493	0.335
Left												
BF Tone (Hz)	14.89 ± 1.98	15.45 ± 1.36	14.32 ± 2.32	15.42 ± 2.04	16.28 ± 1.9	14.57 ± 1.83	15.8 ± 2.56	16.99 ± 2.36	14.60 ± 2.18	0.049	0.003	0.562
BF Stiffness (N/m)	242.38 ± 50.69	254.12 ± 37.54	230.64 ± 59.17	261.01 ± 50.05	286.04 ± 45.95	235.98 ± 40.88	267 ± 56.46	288.34 ± 52.35	245.66 ± 52.63	0.005	0.001	0.215
BF Elast. (log)	1.14 ± 0.24	1.26 ± 0.24	1.03 ± 0.18	1.12 ± 0.26	1.22 ± 0.28	1.03 ± 0.20	1.13 ± 0.27	1.3 ± 0.27	1.08 ± 0.23	0.053	0.127	0.225
BB Tone (Hz)	14.43 ± 1.84	14.8 ± 1.9	14.06 ± 1.72	14.14 ± 1.7	14.39 ± 1.79	13.89 ± 1.59	14.13 ± 1.68	14.17 ± 1.55	13.5 ± 1.46	0.037	0.238	0.140
BB Stiffness (N/m)	221.89 ± 45.81	218.66 ± 48.9	225.12 ± 42.74	229.64 ± 43.25	231.04 ± 46.74	228.24 ± 39.88	229.16 ± 42.81	221.04 ± 36.89	225.44 ± 35.45	0.040	0.036	0.622
BB Elast. (log)	1.04 ± 0.25	0.99 ± 0.24	1.08 ± 0.26	1.12 ± 0.27	1.1 ± 0.31	1.15 ± 0.21	1.12 ± 0.26	1.13 ± 0.29	1.23 ± 0.28	0.001	0.044	0.033

p < 0.05. Abbreviations: T: Total, M: Male, F: Female, BB: biceps brachii, BF: biceps femoris, Hz: Frequency, N/m: newton/meter, log: logarithmic reduction

Table 3
Dunn's multiple comparison test results

All participants	Males												
	Right BB Tone	Right BB Stiffness	Right BB Elasticity	Left BB Tone	Left BB Stiffness	Left BB Elasticity	Left BF Tonus	Left BF Stiffness	Right BB Tone	Right BB Stiffness	Right BB Elasticity	Left BB Stiffness	Left BB Elasticity
BMI	P	P	P	P	P	P	P	P	P	P	P	P	P
Group 2-3	0.006*	0.005*	0.808	0.116	0.074	0.157	0.554	0.733	0.005*	0.011*	0.754	0.089	0.392
Group 1-3	0.006*	0.197	0.001*	0.011*	0.506	0.001*	0.018*	0.003*	0.135	0.119	0.005*	0.409	0.014*
Group 1-2	0.994	0.001*	0.001*	0.328	0.014*	0.026*	0.076	0.008*	0.184	0.001*	0.013*	0.012*	0.108

* p < 0.05. Abbreviations: BB: biceps brachii, BF: biceps femoris, BMI: Body mass index

Males

The statistical differences were found in the right BB all mechanical properties (stiffness, tone, elasticity) and the right BF stiffness, left BB stiffness and elasticity, left BF tone and stiffness base on BMI group comparasion ($p < 0.05$) (Table 2). The right BB tone of Group 3 was found to be lower than the other

two groups ($p < 0.05$). The right and left BB stiffness of Group 2 was determined to be higher than that of Groups 1 and 3 ($p < 0.05$). The left BF tone of Group 3 was higher than that of Group 1 and Group 2 ($p < 0.05$). The right and left BF stiffness increased as BMI increased, and it was found to be higher in Group 2 than Group 1 ($p < 0.05$). The right and left BB elasticity in Group 1 was higher than other two groups ($p < 0.05$) (Table 3).

Females

The statistical differences were found in the right and left BB elasticity ($p < 0.05$) (Table 2). The right BB elasticity was higher in Group 1 compared to the other groups ($p < 0.05$), the BB elasticity in Group 2 was better than in Group 3, but it was not statistically significant in Groups 2 and 3 ($p > 0.05$). Although the left BB elasticity was higher in Group 1 compared to the other groups ($p < 0.05$), no statistical difference was found between Group 1–2 and Group 2–3 ($p > 0.05$) (Table 3).

Discussion

This study was conducted to determine influence of body mass index on muscular mechanical properties in people with obesity. There was found a weak relation between BMI and the mechanical properties of the BB and BF muscles. The bilateral BB tone and elasticity decreased as BMI increased, and the left BF stiffness increased. Different mechanical properties were observed in sex comparison based on BMI classification. The BB and BF mechanical properties were affected more in males than females.

Resting muscle tone is classified into two categories as neural and non-neural. If there is no neural activation, muscle tone contains passive stiffness and viscoelastic properties (22). When all individuals were examined, a weak negative correlation was observed between BMI and the bilateral BB tone. The left BF tone showed a positive correlation. While the left BF tone was positively correlated in males, the bilateral BB tone was found to be weakly negatively correlated in females. This correlation in tone suggests that it is caused by different neural and muscular adaptations that people with obesity can develop in the lower extremity and upper extremity. In a study conducted with 12 people with obesity (BMI > 27) adolescent girls and 12 healthy girls, it was reported that with increased mechanical load in people with obesity, adaptation would occur in muscles and nerves, and as a result, people with obesity might have a larger pennation angle, anatomical cross-sectional area and muscle thickness (29). While this advantage in mechanical loading is observed in the positive direction in the lower extremity depending on the increase in weight, it may explain that it is in the negative direction in the upper extremity. The upper extremity, which lacks mechanical loading, and the reduced inactivity, may bring along a disadvantage that will result in the loss of the cross-sectional area and contractile components. In studies comparing athletes and sedentary individuals, it is stated that sedentary individuals have a smaller cross-sectional area (30). This opposing relationship proves that muscular and neural structures will develop different adaptations in the upper and lower extremities.

In the evaluations we performed in males and females, the right and left BB elasticity showed a similar weak positive correlation in all three groups. In the study in which Kocer et al. evaluated the relationship between the SCM muscle stiffness and elasticity and BMI, it was indicated to be highly correlated with elasticity and moderately correlated with stiffness (31). In a study comparing mechanical properties, it was reported that males with high BMI had lower biceps brachii elasticity than females (28). Interestingly, in our findings, a weak correlation with the bilateral BB elasticity in the upper extremity in all three groups (all individuals, males and females) was not observed in the bilateral BF elasticity in the lower extremity. Furthermore, no correlation was observed in the bilateral BB stiffness. A weak positive correlation was found between the left BF stiffness and BMI only in males. Fat infiltration into skeletal muscles in people with obesity can create higher muscle stiffness and reduce flexibility compared to the people with non-obesity group due to the limitation of range of motion and stable posture (28). Moreover, the increase in adipokines, which regulate the production of metalloproteinases, prostanooids, and cytokines in adipose tissue, can affect stiffness and flexibility in overweight and people with obesity (32). The different elasticity relationship in the lower and upper extremities suggests that it may be caused by changes in adipose tissue according to sex.

When all individuals were compared in the sub-groups according to BMI, decreased bilateral BB tone and elasticity were found in individuals who were first-degree people with obesity (Group 3). The right BB and left BF stiffness of overweight (Group 2) and first-degree people with obesity (Group 3) individuals was higher compared to normal and underweight individuals. Comparisons in males were close to the characteristics we obtained from all the individuals above, while in females, mechanical properties were not affected, except for the bilateral BB elasticity. Along with excessive weight gain, adipocyte hypertrophy, intramuscular adipose tissue infiltration, an increase in fibrous components (a decrease in contractile elements), a decrease in the size and number of muscle fibers can be said to be the causes of decreased elasticity and increased stiffness (33–35). However, at this point, we think that adaptations that develop in daily life according to the mechanical loads on the lower and upper extremities will be the primary cause. Increased BMI can affect stability and may provide a biomechanical advantage by increasing the stiffness and tone of the lower extremity muscles due to excessive trunk oscillations in stance or walking.

An inverse correlation between muscle tone and subcutaneous fat was previously observed in a study on sedentary individuals (22). Therefore, it can be assumed that more thickness of subcutaneous fat may alter the response of muscles, reduce their oscillation and frequency, and thus affect tone. In a study comparing female athletes with sedentary females, it was stated that athletes had low BMI values, which was the reason for the decrease in the percentage of subcutaneous fat and the high muscle tone found (30). The calculation of BMI using height and weight in our study may have limited our study in terms of not measuring subcutaneous fat tissue thickness. At this point, we think that regional fat deposition together with BMI may be important for future studies.

From a practical point of view, the increased tone and muscle stiffness in relation to BMI may lead to a decrease in the risk of falls, injury and overall muscular performance, resulting in a limitation in the ability to perform daily activities (36). In this study, increased BMI changes the mechanical properties of the muscles. The decrease in the muscular performance of people with obesity may indicate why physical activity is reduced or vice versa.

Limitations

Our study provides important information for influencing BMI on the musculoskeletal system. But we had some limitations. Firstly, we used the classical BMI calculation using only height and weight, and we did not evaluate the adipose tissue thickness of the individuals. We could have obtained clearer findings with the thought that there might be individuals with different body compositions. If we could have evaluated whether the muscles were relaxed sufficiently in the resting position by an objective method such as EMG, it could help us better understand the mechanical properties, especially the tone. As it is, the findings of our study will help further investigate the relationship between obesity and the mechanical properties of the musculoskeletal system.

Conclusion

A weak correlation was found between BMI and the mechanical properties of the BB and BF muscles. The bilateral BB tone and elasticity decreased as BMI increased, and the left BF stiffness increased. Different mechanical properties were observed in sex comparison based on BMI classification. The BB and BF mechanical properties were affected more in males than females. In addition to excess weight, increased stiffness and decreased elasticity may have adverse effects on other systems, especially physical activity, ambulation, and musculoskeletal system.

Declarations

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Ethical approval

This study was approved by the Ethics Committee for Non-Invasive Research Studies of Hasan Kalyoncu University Faculty of Health Sciences (approval number 2020/101).

Informed consent

Informed writing consent was obtained from each participants before starting study

Clinical Registry

NCT04721431, 20 January 2021, <https://clinicaltrials.gov/ct2/show/NCT04721431>

Author Contributions

S.U: conception and design, data analysis, manuscript editing and final approval of manuscript, revised the manuscript for intellectual content,

E.R: literature search, data collection and analysis, writing manuscript

YY: statistical analysis, critical review of manuscript,

Conflict of interest

All authors declare that they have no conflict of interest.

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Data Availability

Not applicable.

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Figures

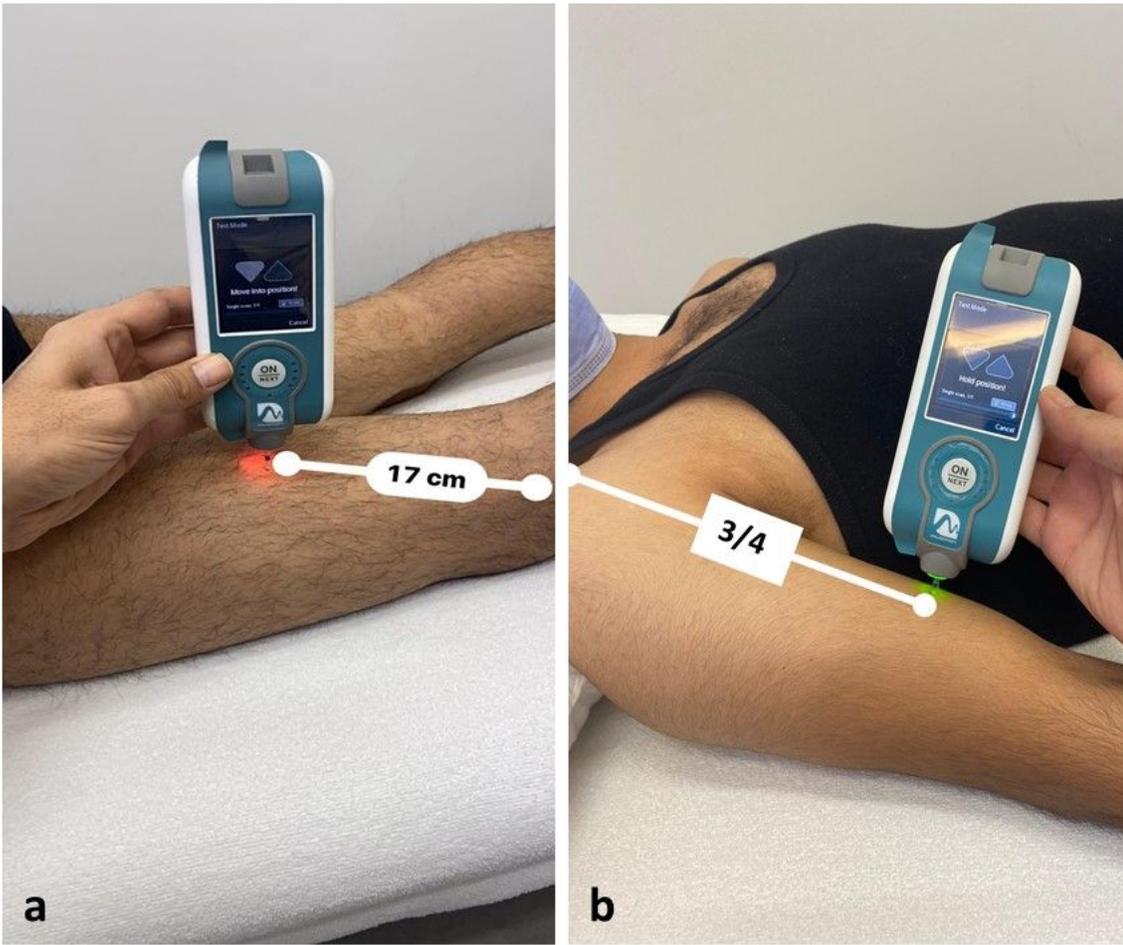


Figure 1

The reference points of muscles for myotonometric assessment. (a) Biceps Femoris, (b) Biceps Brachii.