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# INFLUENCE OF LOWER EXTREMITY BODY COMPOSITION PARAMETERS ON TMG RESPONSE IN KNEE JOINT MUSCLES

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## Introduction

Tensiomyography (TMG) is a method for assessment of contractile characteristics of muscles stimulated by electrical stimulation (Macgregor, Hunter, Orizio, Fairweather, & Ditroilo, 2018; Valenčič & Knez, 1997). This method has proven to be valid, reliable (Križaj, Šimunič, & Žagar 2008; Martín-Rodríguez, Loturco, Hunter, Rodríguez-Ruiz, & Munguia-Izquierdo, 2017; Šimunič, 2012) and is applicable in sports training, injury prevention. physical therapy and rehabilitation (Macgregor et al., 2018; Rey, Lago-Peñas, & Lago-Ballesteros, 2012; Tous-Fajardo, Moras, Rodríguez-Jiménez, Usach, Doutres, & Maffiuletti, 2010).

As with any other method, the validity and reliability of TMG measurements depend on several factors, i.e. many factors influence the response of the muscle to electrical stimuli and parameters of TMG. It has shown that TMG parameters are sensitive to fatigue (Garcia Manso, Rodríguez-Ruiz, Rodríguez-Matoso, de Saa, Sarmiento, & Quiroga, 2011; Garcia Manso et al., 2012), they depend on the type of muscle fibers (Dahmane, Djordjevic, Simunic, Valencic, 2005; Simunic, Degens, Rittweger, Narici, Mekjavic, & Pisot, 2011), mechanical characteristics of muscles (Rey et al., 2012; Tous-Fajardo et al., 2010), muscle force (Toskic, Dopsaj, Stankovic, & Markovic, 2019), electrodes and sensors position (Wilson, Johnson, & Francis, 2018; Simunic, 2019), etc.

Considering that previous studies have shown that muscle response to electrical stimulation depends on the amount of subcutaneous fat (Petrofsky, 2008; Petrofsky, Suh, Gunda, Prowse, & Batt, 2008), it can be assumed that TMG measurements also depend on the proportion of adipose tissue and other parameters of body composition. Unfortunately, the relationship between TMG parameters and body composition has not been extensively investigated to date (Calvo-Lobo, Díez-Vega, García-Mateos, Molina-Martín, Díaz-Ureña, & Rodríguez-Sanz, 2018; Macgregor et al., 2018; Martín-Rodríguez et al., 2017).

In accordance with the aforementioned, the problem of this study is the influence of certain parameters of body composition on the muscle contractions caused by electrical stimulation applied by the TMG method. The aim of this study is to investigate the correlation and influence of certain parameters of lower extremity body composition, that is, lean and fat body mass, on the TMG parameters in the knee joint extensor and flexor muscles. It can be assumed that body composition parameters will have some significant effect on TMG parameters. Based on the results of this study, we can inform about the factors that determine the validity and reliability of TMG measurements, as well as the relationship between body composition parameters and mechanical and contractile muscle properties, which can contribute to the development of sports diagnostics, sports training, physical therapy and rehabilitation and other areas which are related to the human anthropological characteristics.

## Methods

The sample consisted of 60 individuals (30 men - Age = 25.3 ± 3.7 years, TV = 180.9 ± 6.6 cm, TM = 82.3 ± 10.4 kg; and 30 women - Age = 22.5 ± 2.3 years, TV = 169.4 ± 6.04 cm, TM = 60.7 ± 7.2 kg). The subjects were individuals from the group of physically inactive people and students of the Faculty of Sport and Physical Education and the Criminal Police Academy. All subjects were healthy, aware of the purpose and procedures of measurements, and voluntarily agreed to participate in the study. All measurements were conducted in accordance with the ethical principles of the Ethics Committee of the Faculty of Sport and Physical Education, University of Belgrade.

Body composition parameters were measured using bioelectrical impedance (In Body 720, Biospace Co., Ltd). Body composition measurements were performed according to the manufacturer's instructions and based on previous similar research (Bankovic, Dopsaj, Terzic, & Nesic, 2018; Dopsaj et al., 2017; Völgyi, Tylavsky, Lyytikäinen, Suominen, Alén, & Cheng, 2008). The measurements were performed in the morning and the temperature in the room where the tests were performed was between 20 and 25 degrees. The procedure participants had to follow before testing was:

- participans did not intake food for at least 2 hours before the measurement;
- participans did not exercise for 12 hours before the measurement;

- participans did not consume alcohol for 48 hours before the measurement;
- participans did not consume diuretics (coffee, chocolate) 24 hours before the measurement;
- participans did not use the sauna before the measurement;
- participans performed their physiological needs before to the measurement

Participants spent 5 minutes in standing position before the measurement. The subjects were only in their underwear and they were required to remove all metal from themselves if they had one. Prior to measurement, all subjects were familiar with the procedure. Respondents were first asked to stand on the scale and place their hands and feet on contact surfaces. During the measurement, the subjects were asked to stand upright, to be calm and relaxed, i.e. not to clench their arms, legs and torso, to look forward, to breathe normally and not to talk. The measurements took about two minutes.

By the TMG method (TMG-BMC Ltd, Ljubljana) parameters of the main knee joint extensor and flexor muscles of the dominant leg were measured; rectus femoris (RF) and biceps femoris (BF). Respondents lay in a relaxed position on their back or abdomen, depending on the measured muscles (Rey et al., 2012; Toskic, Dopsaj, Koropanovski, & Jeknic, 2016; Toskic et al., 2017; 2019). The angle in knee joint was about 120˚. Before placing the electrodes, the subjects were asked to perform a voluntary contraction to determine the desired muscle by the method of palpation (Toskić et al., 2016; 2017; 2019). After determination, two self-adhesive electrodes were positioned on the central part of the muscle, emitting an electrical impulse, proximal and distal, at a distance of about 5 cm from the desired measuring position (Figure 1).

A sensor was placed between the electrodes, which detects changes in the muscle belly caused by an electrical stimulus and based on which we obtain data on muscle contractile properties. The sensor was positioned relative to the direction of of the fibers and their positioning (Fabok, Dopsaj, Leontijević, & Tomić, 2018). The electrical impulse was achieved by an electrostimulator, 1 ms duration, and the initial pulse was of intensity 25 mA, with increasing intensity by 20 mA to the maximum, that is, until the reaction of the muscles to increase of the amplitude was no longer possible (Toskić et al., 2016; 2017; 2019). The maximum amplitude ranged from 80 to 110 mA. The pause between pulses was about 5 s for muscles to be able to relax. The two best scores are saved, and the average is calculated based on them.

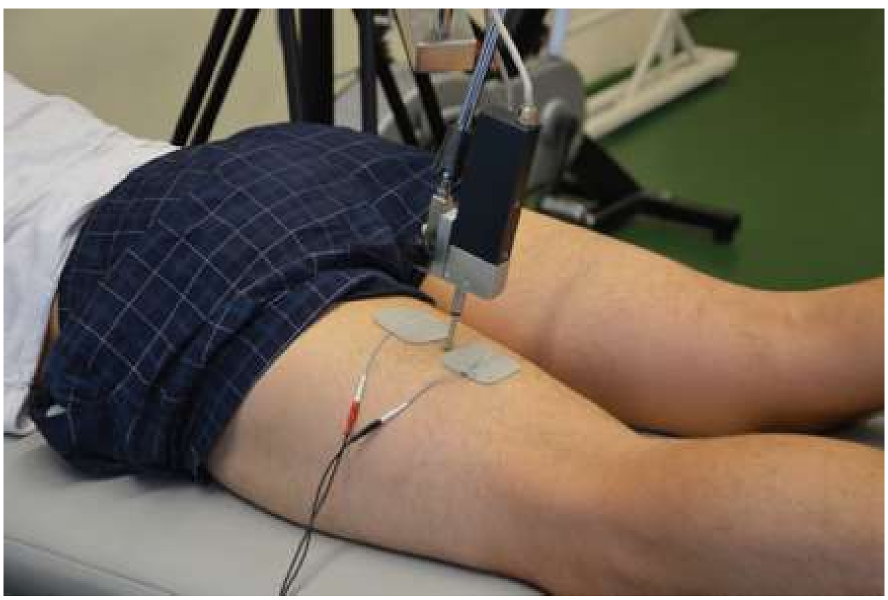

Figure 1. Method of electrode and sensor positioning

All measurements were performed under the same conditions, the subjects were healthy, rested and followed the pre-measurement procedures required of them. All measurements were made by the same experienced individuals in the Methodological Research Laboratory of the Faculty of Sport and Physical Education, University of Belgrade.

The sample of variables consisted of 2 variables for assessment body composition and 4 variables for assessment of muscles contractile properties:

- lean body mass of dominant leg – LBM (kg);
- fat body mass of dominant leg – FM (kg);
- contraction time of rectus femoris muscle – Tc (ms);
- contraction time of biceps femoris muscle – Tc (ms);

- maximal displacement of rectus femoris muscle – Dm (mm);
- maximal displacement of biceps femoris muscle – Dm (mm).

Of the statistical procedures, in the study descriptive statistics (Mean, SD, cV, Min, Max) was applied to describe the measured variables, Pearson's correlation coefficient was calculated, and linear regression analysis was applied to determine the correlation and influence of body composition parameters on TMG parameters. All statistical procedures were conducted in SPSS19 (IBM).

## Results

Table 1 shows descriptive indicators of body composition and TMG parameters. It can be observed that men have higher LBM values (by 40.5%), lower FM values (by 15.7%) longer Tc of RF muscle (by 8.08%), shorter Tc of BF muscle (by 17.2%), higher Dm of RF muscle (by 8.8 %) and lower Dm of BF muscle (by 30.6%) than women. It can also be noticed that the main muscle of the knee joint has lower values of Tc and Dm (16.3%, 3.09%, respectively) than the main muscle of the knee joint flexor. Based on the values of the coefficient of variation (cV), it can be concluded that this group of subjects has lower homogeneity when it comes to the parameters FM (cV = 33.4%), RF Dm (cV = 35.05%) and BF Dm (cV = 38.6%).

Table 1. Descriptive values of body composition and TMG parameters

| | | Mean | SD | cV | Min | Max |
|---|---|---|---|---|---|---|
| **Men** | **LBM (kg)** | 10.4 | 1.2 | 12.2 | 8.6 | 12.7 |
| | **FM (kg)** | 1.9 | 0.8 | 45.03 | 0.8 | 4.2 |
| | **RFtc (ms)** | 32.1 | 5.5 | 17.2 | 23.3 | 46.7 |
| | **RFdm (mm)** | 5.89 | 2.11 | 35.8 | 1.47 | 9.31 |
| | **BFtc (ms)** | 33.1 | 9.1 | 27.6 | 14.9 | 47.5 |
| | **BFdm (mm)** | 5.05 | 2.13 | 42.3 | 0.06 | 9.74 |
| **Women** | **LBM (kg)** | 7.4 | 0.9 | 12.5 | 5.8 | 9.1 |
| | **FM (kg)** | 2.2 | 0.4 | 21.9 | 1.3 | 3.4 |
| | **RFtc (ms)** | 29.7 | 5.2 | 17.6 | 20.1 | 39.9 |
| | **RFdm (mm)** | 5.41 | 1.85 | 34.3 | 1.36 | 9.61 |
| | **BFtc (ms)** | 38.8 | 8.7 | 22.5 | 22.8 | 57.9 |
| | **BFdm (mm)** | 6.60 | 2.30 | 34.9 | 1.51 | 10.63 |

Table 2 and Figures 2, 3, 4 and 5 show the results of correlation and regression analysis, that is, the correlation and influence of body composition parameters on TMG parameters. It can be concluded that there is a statistically significant correlation and influence of LBM parameter on the Dm of BF muscle in men and women ($r = -0.377$, $R^2 = 0.142$, $R^2$ adj. = 0.112, $p = 0.039$; $r = -0.498$, $R^2 = 0.248$. $R^2$ adj. = 0.219, $p = 0.007$, respectively), parameter FM on Dm of BF muscle in men ($p = -0.447$, $R^2 = 0.200$, $R^2$ adj. = 0.171, $p = 0.013$) as well as on Tc of BF muscle in women ($r = 0.384$, $R^2 = 0.148$, $R^2$ adj. = 0.115, $p = 0.043$).

Table 2. Correlation between body composition and TMG parameters

| | | | RFtc | RFdm | BFtc | BFdm |
|---|---|---|---|---|---|---|
| **Men** | **LBM** | **r** | 0.083 | - 0.239 | - 0.075 | **- 0.377*** |
| | | **p** | 0.659 | 0.201 | 0.693 | **0.039** |
| | **FM** | **r** | - 0.284 | - 0.232 | - 0.131 | **-0.447*** |
| | | **p** | 0.127 | 0.215 | 0.487 | **0.013** |
| **Women** | **LBM** | **r** | 0.020 | - 0.271 | 0.067 | **- 0.498**** |
| | | **p** | 0.916 | 0.161 | 0.732 | **0.007** |
| | **FM** | **r** | 0.146 | - 0.152 | **0.384*** | - 0.249 |
| | | **p** | 0.458 | 0.439 | **0.043** | 0.200 |

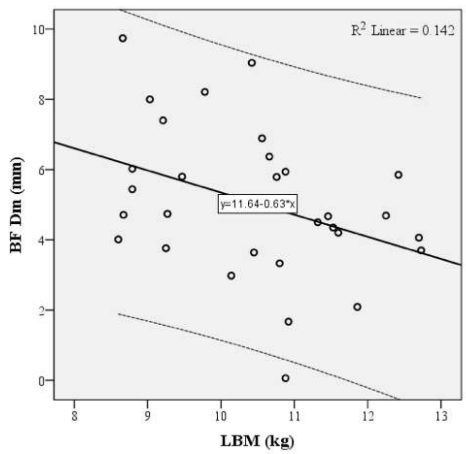


Figure 2. Influence of lean body mass (LBM) of dominant leg on maximal displacement (Dm) of biceps femoris muscle in men

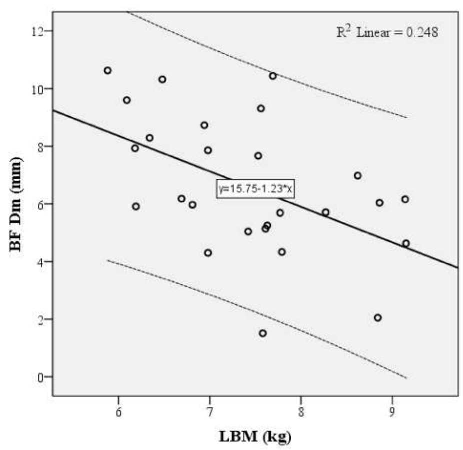


Figure 3. Influence of lean body mass (LBM) of dominant leg on maximal displacement (Dm) of biceps femoris muscle in women

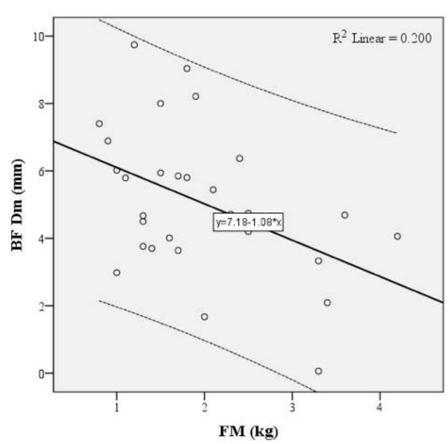


Figure 4. Influence of body fat mass (FM) of dominant leg on maximal displacement (Dm) of biceps femoris muscle in men

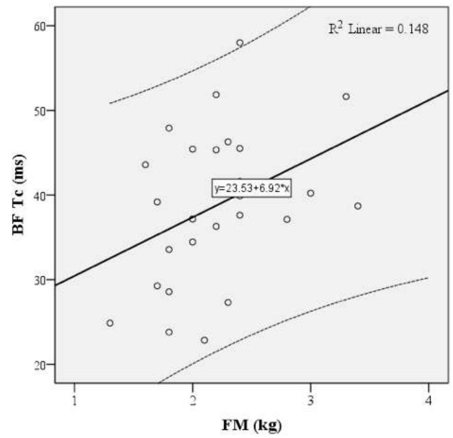


Figure 5. Influence of body fat mass (FM) of dominant leg on contraction time (Tc) of biceps femoris muscle in women

## Discussion

In this study, on the sample of 60 subjects of both sexes, the influence of lower extremity body composition parameters on the TMG response in the knee joint extensor and flexor muscles was examined. Based on the obtained results, it can be concluded that the lean body mass and body fat mass of the dominant leg has a significant influence on the TMG parameters of the main knee joint flexor muscle.

Based on the obtained results, it can be concluded that the lean body mass and fat mass of the dominant leg has a significant influence on the TMG parameters of the main knee joint flexor muscle. Considering that muscle mass in main part of the lower limb lean body mass (Pomeroy, Macintosh, Wells, Cole, & Stock, 2018), and that correlation is negative, it can be concluded that muscle mass has a negative relationship with muscle stiffness and tone, which parameter Dm is assessing (Macgregor et al., 2018; Martín-Rodríguez et al., 2017; Rey et al., 2012). This data points to the fact that individuals with higher muscle mass also have higher muscle stiffness, that is, individuals with lower muscle mass have lower muscle tone, and that an increase in muscle mass leads to an increase in muscle stiffness and tone and vice versa. In men, there was also a significant negative correlation between dominant leg fat mass and muscle stiffness, that is, individuals with a greater amount of lower limb fat mass have higher muscle tone and stiffness of the main knee joint flexor muscle. In women it was shown that the amount of fat tissue in the legs has a significant effect on the time needed for muscle to contract under the influence of electrical stimulation, that is, it has been shown that people with higher values of segmental fat tissue have slower muscle contractions and that the increase in fat tissue leads to a decrease in contraction speed.

These results are somewhat expected. Previous research has shown that there is an association between muscle mass and muscle stiffness (Macgregor et al., 2018; Martín-Rodríguez et al., 2017; Rey et al., 2012), so the statistically significant correlation between lean and fat body mass of dominant leg and maximal displacement is clear and expected. On the other hand, the negative correlation between adipose tissue and muscle stiffness is somewhat unexpected, since it has been shown that muscle stiffness as measured by the TMG method increases to some extent with level of physical activity (Toskić et al., 2016; 2019), so it can be assumed that individuals who regularly engage in physical activity have higher muscle stiffness but also lower adipose tissue values. These results can be attributed to the effect of adipose tissue on muscle contraction caused by electrical stimulation. Namely, as mentioned previously, it has been shown that the amount of subcutaneous adipose tissue has a significant effect on muscle contractions caused by electrical stimulation, that is, on conducting electricity (Petrofsky, 2008; Petrofsky et al., 2008). It can be assumed that even with TMG measurements, the greater amount of fat tissue influences the conductivity of the electrical current to the muscle, and therefore the muscle's response to the electrical current is smaller. In the end, the results of this study showed that lower values of lower limb fat tissue lead to faster contractions of the main knee joint flexor muscle, which was to some extent unknown.

The correlation between body composition and TMG parameters is slightly higher in women ($r = 0.441$, $p = 0.025$, on average) than in men ($r = 0.412$, $p = 0.026$, on average), that is, in women, the influence of muscle mass and fat tissue on muscle stiffness and contraction time is higher than in men. These results can be explained by the existing differences in body composition between men and women (Power & Schulkin, 2008). It can be concluded that significant correlation between lean body mass, fat mass, muscle stiffness, and the contraction time, regarding to muscle groups and measured parameters, was obtained with the main knee joint flexor muscle ($r = 0.426$, $p = 0.025$, on the average), while no statistically significant correlations were obtained with the main knee joint extensor muscle ($r = 0.178$, $p = 0.397$, on average). These results indicate that the expression of muscle stiffness and contraction time of different muscles and muscle groups does not depend on the same factors. Also, it has shown that lean and fat body mass have a more significant influence on muscle stiffness and tone (r = 0.440, p = 0.019, on average) than on muscle contraction time (r = 0.384, p = 0.043, on average), which is expected regarding that the parameter Dm is related to the mechanical characteristics of the muscle (Macgregor et al., 2018; Martín-Rodríguez et al., 2017; Rey et al., 2012), whereas the parameter Tc is related to the type of muscle fibers (Dahamne et al., 2005; Simunic et al., 2011).

The main limitation of this study is the measured parameters of body composition. Future studies should focus on examining the correlation between TMG parameters and other body composition parameters such as subcutaneous, intramuscular, and intermuscular adipose tissue.

## Conclusion

It has been shown that men and women who have higher values of dominant leg muscle mass have higher muscle stiffness and that lower extremity fat values affect muscle stiffness in men and the speed of muscle contraction when it comes to women. In general, it can be concluded that the reaction of the main knee joint flexor muscle to electrical stimulation, as measured by the tensiomyography method, depends to a certain extent on the proportion of adipose tissue and lean body mass i.e. lower extremity muscle mass.

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**Note**

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# UTICAJ PARAMETARA TELESNOG SASTAVA DONJIH EKSTREMITETA NA TMG ODGOVOR KOD MIŠIĆA ZGLOBA KOLENA

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## Uvod

Tenziomiografija (TMG) je metoda za procenu kontraktilnih karakteristika mišića izazvanih električnom stimulacijom (Macgregor, Hunter, Orizio, Fairweather, & Ditroilo, 2018; Valenčič & Knez, 1997). Ova metoda se pokazala kao validna, pouzdana (Križaj, Šimunič, & Žagar 2008; Martín-Rodríguez, Loturco, Hunter, Rodríguez-Ruiz, & Munguia-Izquierdo, 2017; Šimunič, 2012) i ima primenu u sportskom treningu, prevenciji povreda, fizikalnoj terapiji i rehabilitaciji (Macgregor et al., 2018; Rey, Lago-Peñas, & Lago-Ballesteros, 2012; Tous-Fajardo, Moras, Rodríguez-Jiménez, Usach, Doutres, & Maffiuletti, 2010).

Kao i kod svake druge metode, validnost i pouzdanost merenja TMG-om zavisi od brojnih faktora odnosno brojni činioci utiču na reakciju mišića na električne stimulanse i parametre TMG-a. Pokazalo se da su parametri TMG-a osetljivi na zamor (Garcia Manso, Rodríguez-Ruiz, Rodríguez-Matoso, de Saa, Sarmiento, & Quiroga, 2011; Garcia Manso et al., 2012), da zavise od tipa mišićnih vlakana (Dahmane, Đorđevič, Šimunič, Valenčič, 2005; Šimunič, Degens, Rittweger, Narici, Mekjavic, & Pišot, 2011), mehaničkih karakteristika mišića (Rey et al., 2012; Tous-Fajardo et al., 2010), mišićne sile (Toskić, Dopsaj, Stanković, & Marković, 2019), načina postavljanja elektroda i senzora (Wilson, Johnson, & Francis, 2018; Šimunič, 2019) itd.

S obzirom da su određena prethodna istraživanja pokazala da odgovor mišića na električnu stimulaciju zavisi od količine potkožnog masnog tkiva (Petrofsky, 2008; Petrofsky, Suh, Gunda, Prowse, & Batt, 2008), može se pretpostaviti i da merenja TMG-om zavise i od udela masnog tkiva i drugih parametara telesnog sastava u organizmu. Nažalost, do sada nije u velikoj meri istraživana povezanost između parametara TMG-a i telesnog sastava (Calvo-Lobo, Díez-Vega, García-Mateos, Molina-Martín, Díaz-Ureña, & Rodríguez-Sanz, 2018; Macgregor et al., 2018; Martín-Rodríguez et al., 2017).

U skladu sa prethodno navedenim, problem ovog rada je uticaj određenih parametara telesnog sastava na mišićne kontrakcije izazvane električnom stimulacijom primenjenu metodom TMG-a. Cilj rada je da se ispita povezanost i uticaj određenih parametara telesnog sastava donjih ekstremiteta, odnosno bezmasne i masne telesne mase na TMG parametre kod mišića opružača i pregibača zgloba kolena. Može se pretpostaviti da će parametri telesnog sastava imati određeni značajan uticaj na parametre TMG-a. Na osnovu rezultata ovog istraživanja možemo dobiti saznanja o faktorima od kojih zavisi validnost i pouzdanost merenja TMG-om kao i povezanosti između parametara telesnog sastava i mehaničkih i kontraktilnih karkteristika mišića čime se može doprineti razvoju sportske dijagnostike, sportskog treninga, fizikalne terapije i rehabilitacije i drugih oblasti koja su u vezi sa antropološkim karakteristikama čoveka.

## Metode

Uzorak ispitanika je činilo 60 osoba (30 muškaraca – Uzrast = 25.3 ± 3.7 godina, TV = 180.9 ± 6.6 cm, TM = 82.3 ± 10.4 kg; i 30 žena – Uzrast = 22.5 ± 2.3 godina, TV = 169.4 ± 6.04 cm, TM = 60.7 ± 7.2 kg). Ispitanici su bile osobe iz grupe netreniranih, tj. osobe koje ne upražnjavaju svakodnevne fizičke aktivnosti i studenti Fakulteta sporta i fizičkog vaspitanja i Kriminalističko-policijske akademije. Svi ispitanici su bili zdravi, upoznati su sa svrhom i načinom merenja i dobrovoljno su pristali na učešće u istraživanju. Sva merenja su sprovedena u skladu sa etičkim principima Etičke komisije Fakulteta za sport i fizičko vaspitanje Univerziteta u Beogradu.

Parametri telesnog sastava su mereni pomoću bioelektrične impedance (In Body 720, Biospace Co., Ltd). Merenja telesnog sastava su izvršena prema uputstvima proizvođača i na osnovu prethodnih sličnih istraživanja (Bankovic, Dopsaj, Terzic, & Nesic, 2018; Dopsaj et al., 2017; Völgyi, Tylavsky, Lyytikäinen, Suominen, Alén, & Cheng, 2008). Testiranja su izvršena u jutarnjim časovima i temperatura u sobi gde su izvršena testiranja je bila između 20 i 25 stepeni. Procedura koju si ispitanici morali da ispoštuju pre testiranja je:

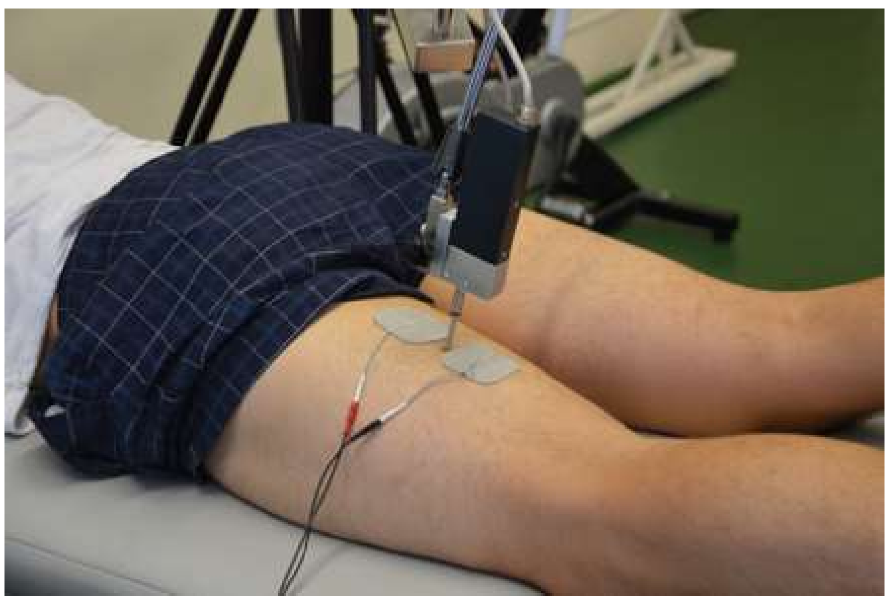
- ispitanici nisu unosili hranu najmanje 2 sata pre merenja;
- ispitanici nisu upražnjavali fizičke aktivnosti 12 sati pre merenja;

- ispitanici nisu konzumirali alkohol 48 sati pre merenja;
- ispitanici nisu konzumirali diuretike (kafa, čokolada) 24 sati pre merenja;
- ispitanici nisu koristili saunu pre merenja;
- ispitanici su izvršili fiziološke potrebe pre merenja.

Ispitanici su proveli 5 minuta u stojećem stavu pre merenja. Za vreme testiranja ispitanici su bili samo u donjem vešu i od njih je zahtevano da skinu sav metal sa sebe ako ga imaju. Pre testiranja su svi ispitanici upoznati sa načinom merenja. Od ispitanika je pre svega zatraženo da stanu na vagu i da postave ruke i noge na kontaktne površine. Za vreme merenja od ispitanika je zatraženo da stanu uspravno, da budu mirni i opušteni odnosno da ne stežu ruke, noge i trup, da gledaju napred, dišu normalno i ne pričaju. Merenja su trajala oko dva minuta.

Metodom TMG-a (TMG-BMC Ltd, Ljubljana) su mereni parametri glavnih mišića opružača i pregibača zgloba kolena dominantne noge; rektus femoris (RF) i biceps femoris (BF). Ispitanici su ležali u relaksiranom položaju na leđima ili stomaku, u zavisnosti od merenih mišića (Rey et al., 2012; Toskić, Dopsaj, Koropanovski, & Jeknić, 2016; Toskić et al., 2017; 2019). Ugao između potkolenice i natkolenice je bio oko 120˚. Od ispitanika je, pre postavljanja elektroda, zatraženo da izvrše voljnu kontrakciju kako bi se metodom palpacije odredio željeni mišić (Toskić et al., 2016; 2017; 2019). Nakon određivanja, na središnji deo mišića su postavljene dve samolepljive elektrode koje emituju električni impuls, proksimalno i distalno, na razmaku od oko 5 cm od željene pozicije za merenje (Slika 1).

Između elektroda je postavljan senzor koji detektuje promene u trbuhu mišića izazvanih električnim stimulansom i na osnovu kojih dobijamo podatke o kontraktilnim karakteristikama mišića. Senzor se postavljao u odnosu na pravac pružanja vlakana i njihovo pozicioniranje (Fabok, Dopsaj, Leontijević, & Tomić, 2018). Električni impuls je ostvarivan pomoću elktrostimulatora, bio je trajanja od 1 ms, i početni impuls je bio intenziteta 25 mA, sa povećavanjem intenziteta za 20 mA do maksimuma, odnosno dok reakcija mišića na povećanje amplitude nije više moguća (Toskić et al., 2016; 2017; 2019). Maksimalna amplituda se kretala od 80 do 110 mA. Pauza između impulsa je bila oko 5 s, kako bi mišić bio u stanju da se relaksira. Dva najbolja rezultata su sačuvana, i na osnovu njih je izračunat prosek.



Slika 1. Način postavljanja elektroda i senzora

Sva merenja su izvršena u istim uslovima, ispitanici su bili zdravi, odmorni i ispoštovali su procedure pre merenja koje su od njih zahtevane. Sva merenja su izvršena od strane istih iskusnih merilaca u Metodološko-istraživačkoj laboratoriji Fakulteta sporta i fizičkog vaspitanja Univerziteta u Beogradu.

Uzorak varijabli je činilo 2 varijable za procenu telesnog sastava i 4 varijable za procenu kontraktilnih karakteristika mišića:

- bezmasna telesna masa dominantne noge – LBM (kg);
- masna telesna masa dominantne noge – FM (kg);
- vreme kontrakcije mišića rektus femoris – Tc (ms);
- vreme kontrakcije mišića biceps femoris – Tc (ms);

- maksimalno vertikalno pomeranje mišića rektus femoris – Dm (mm);
- maksimalno vertikalno pomeranje mišića biceps femoris – Dm (mm).

Od statističkih procedura, u radu je primenjena deskriptivna statistika (Mean, SD, cV, Min, Max) kako bi se opisale merene varijable, izračunat je Pirsonov koeficijent korelacije i primenjena je linearna regresiona analiza kako bi se utvrdila povezanost i uticaj parametara telesnog sastava na TMG parametre. Sva statistička procedura je sprovedena u programu SPSS19 (IBM).

**Rezultati**

Na Tabeli 1 su prikazani deskritpivni pokazatelji parametara telesnog sastava i TMG parametara. Može se uočiti da muškarci imaju veće vrednosti LBM (za 40.5 %), manje veredností FM (za 15.7 %) duže Tc mišića RF (za 8.08 %), kraće Tc mišića BF (za 17.2 %), veće Dm mišića RF (za 8.8 %) i manje Dm mišića BF (za 30.6 %) od žena. Takođe, može se uvideti da glavni mišić opružač zgloba kolena ima manje vrednosti Tc i Dm (za 16.3 %, za 3.09 %, respektivno) od glavnog mišića pregibača zgloba kolena. Na osnovu vrednosti koeficijenta varijacije (cV) može se zaključiti da ova grupa ispitanika ima smanjenu homogenost kada su u pitanju parametri FM (cV = 33.4 %), RF Dm (cV = 35.05 %) i BF Dm (cV = 38.6 %).

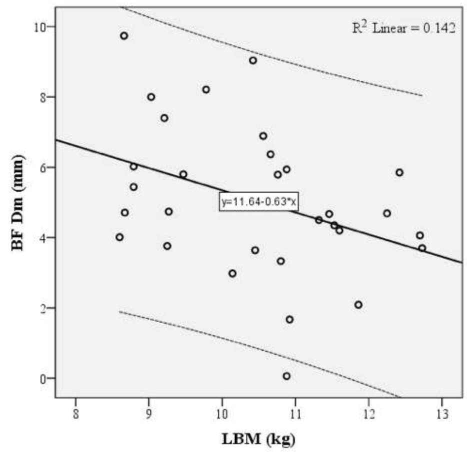
Tabela 1. Deskriptivni pokazatelji telesnog sastava i TMG parametara

| | | Mean | SD | cV | Min | Max |
|---|---|---|---|---|---|---|
| Muškarci | LBM (kg) | 10.4 | 1.2 | 12.2 | 8.6 | 12.7 |
| | FM (kg) | 1.9 | 0.8 | 45.03 | 0.8 | 4.2 |
| | RFtc (ms) | 32.1 | 5.5 | 17.2 | 23.3 | 46.7 |
| | RFdm (mm) | 5.89 | 2.11 | 35.8 | 1.47 | 9.31 |
| | BFtc (ms) | 33.1 | 9.1 | 27.6 | 14.9 | 47.5 |
| | BFdm (mm) | 5.05 | 2.13 | 42.3 | 0.06 | 9.74 |
| Žene | LBM (kg) | 7.4 | 0.9 | 12.5 | 5.8 | 9.1 |
| | FM (kg) | 2.2 | 0.4 | 21.9 | 1.3 | 3.4 |
| | RFtc (ms) | 29.7 | 5.2 | 17.6 | 20.1 | 39.9 |
| | RFdm (mm) | 5.41 | 1.85 | 34.3 | 1.36 | 9.61 |
| | BFtc (ms) | 38.8 | 8.7 | 22.5 | 22.8 | 57.9 |
| | BFdm (mm) | 6.60 | 2.30 | 34.9 | 1.51 | 10.63 |

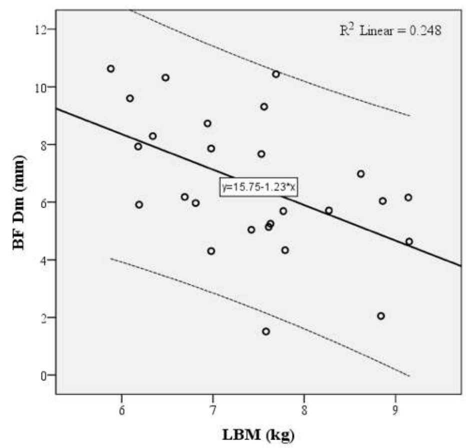
Na Tabeli 2 i Grafikonima 1, 2, 3 i 4 su prikazani rezultati korelacione i regresione analize odnosno povezanosti i uticaja parametara telesnog sastava na TMG parametare. Može se zaključiti da postoji statistički značajna povezanost i uticaj parametara LBM na parametar Dm mišića BF kod muškaraca i žena (r = -0.377, $R^2$ = 0.142, $R^2$ adj. = 0.112, p = 0.039; r = - 0.498, $R^2$ = 0.248, $R^2$ adj. = 0.219, p = 0.007, respektivno) parametra FM na Dm mišića BF kod muškaraca (p = - 0.447, $R^2$ = 0.200, $R^2$ adj. = 0.171, p = 0.013) kao i na Tc mišića BF kod žena (r = 0.384, $R^2$ = 0.148, $R^2$ adj. = 0.115, p = 0.043).

Tabela 2. Povezanost između telesnog sastava i TMG parametara

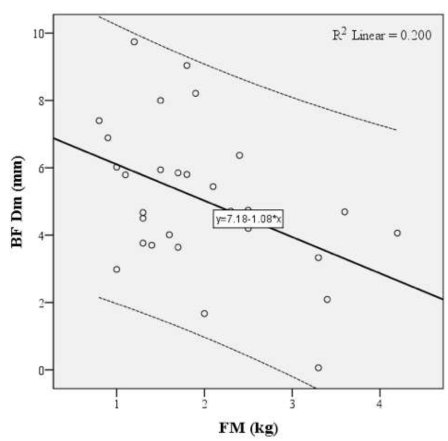
| | | | RFtc | RFdm | BFtc | BFdm |
|---|---|---|---|---|---|---|
| Muškarci | LBM | r | 0.083 | - 0.239 | - 0.075 | **- 0.377*** |
| | | p | 0.659 | 0.201 | 0.693 | **0.039** |
| | FM | r | - 0.284 | - 0.232 | - 0.131 | **-0.447*** |
| | | p | 0.127 | 0.215 | 0.487 | **0.013** |
| Žene | LBM | r | 0.020 | - 0.271 | 0.067 | **- 0.498**** |
| | | p | 0.916 | 0.161 | 0.732 | **0.007** |
| | FM | r | 0.146 | - 0.152 | **0.384*** | - 0.249 |
| | | p | 0.458 | 0.439 | **0.043** | 0.200 |



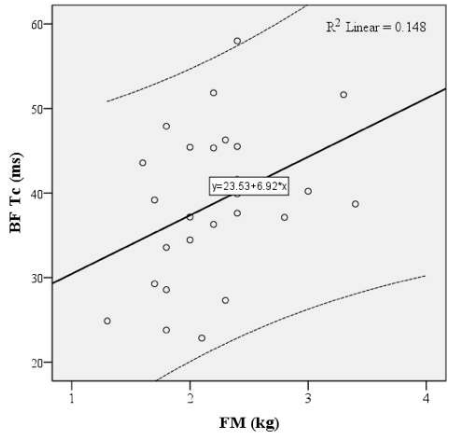

Grafikon 1. Uticaj bezmasne telesne mase dominantne noge (LBM) na maksimalno vertikalno pomeranje (Dm) mišića biceps femoris (BF) kod muškaraca




Grafikon 2. Uticaj bezmasne telesne mase dominantne noge (LBM) na maksimalno vertikalno pomeranje (Dm) mišića biceps femoris (BF) kod žena




Grafikon 3. Uticaj masne telesne mase dominantne noge (FM) na maksimalno vertikalno pomeranje (Dm) mišića biceps




Grafikon 4. Uticaj masne telesne mase dominantne noge (FM) na vreme kontrakcije (Tc) mišića biceps femoris (BF) kod žena

## Diskusija

U ovom radu na uzorku od 60 ispitanika oba pola, ispitivan je uticaj parametara telesnog sastava donjih ekstremiteta na TMG odgovor kod mišića opružača i pregibača zgloba kolena. Na osnovu dobijenih rezultata može se zaključiti da bezmasna telesna masa i masna telesna masa dominantne noge imaju značajan uticaj na TMG parametre glavnog mišića pregibača zgloba kolena.

Na osnovu dobijenih rezultata može se zaključiti da bezmasna telesna masa i masna telesna masa dominantne noge imaju značajan uticaj na TMG parametre glavnog mišića pregibača zgloba kolena. S obzirom da veći deo bezmasne telesne mase donjih ekstremiteta čine mišići (Pomeroy, Macintosh, Wells, Cole, & Stock, 2018), kao i da je povezanost negativna, može se zaključiti da mišićna masa ima negativnu povezanost sa mišinom krutošću odnosno tonusom, što se pokazalo da parametar Dm procenjuje (Macgregor et al., 2018; Martín-Rodríguez et al., 2017, Rey et al., 2012). Ovaj podatak ukazuje na činjenicu da pojedinci koji imaju veću mišićnu masu imaju i kruće mišiće, odnosno da pojedinci sa manjom mišićnom masom imaju manji mišićni tonus, kao i da povećanje u mišićnoj masi dovodi do povećanja krutosti i tonusa mišića i obratno. Kod muškaraca je takođe dobijena značajna negativna povezanost između masne telesne mase dominantne noge i mišićne krutosti, odnosno pojedinci sa većom količinom masnog tkiva donjih ekstremiteta imaju veći tonus i krutost glavnog mišića pregibača zgloba kolena. Kod žena se pokazalo da količina masnog tkiva nogu ima značajan uticaj na vreme potrebno da se mišić kontrahuje pod uticajem električne stimulacije, odnosno pokazalo se da osobe sa većim vrednostima segmentarnog masnog tkiva imaju sporije mišićne kontrakcije, kao i da povećanje masnog tkiva dovodi do smanjenja brzine kontrakcije.
Ovi rezultati su donekle očekivani. Prethodna istraživanja su pokazala da postoji povezanost između mišićne mase i mišićne krutosti (Macgregor et al., 2018; Martín-Rodríguez et al., 2017, Rey et al., 2012), pa je povezanost između bezmasne telesne mase dominantne noge i maksimalnog vertikalnog pomeranja mišića jasna i očekivana. Sa druge strane, negativna povezanost između masnog tkiva i mišićne krutosti je donekle neočekivana, s obzirom da se pokazalo da mišićna krutost merena metodom TMG-a raste do određene mere sa upražnjavanjem fizičkih aktivnosti (Toskić et al., 2016; 2019), pa se može pretpostaviti da pojedinci koji upražnjavaju fizičke aktivnosti imaju kruće mišiće, ali i manje vrednosti masnog tkiva. Ovi rezultati se mogu pripisati uticaju masnog tkiva na mišićnu kontrakciju izazvanu električnom stimulacijom. Naime, kao što je prethodno pomenuto, pokazalo se da količina potkožnog masnog tkiva ima značajan uticaj na mišićne kontrakcije izazvane električnom stimulacijom, odnosno na sprovođenje struje (Petrofsky, 2008; Petrofsky et al., 2008). Može se pretpostaviti da i kod merenja metodom TMG-a veća količina masnog tkiva utiče na provodljivost struje do mišića, pa je samim tim reakcija mišića na električnu struju manja. Na kraju, rezultati ovog istraživanja su pokazali da manje vrednosti masnog tkiva donjih ekstremiteta dovode do bržih kontrakcija glavnog mišića pregibača zgloba kolena, što je donekle bila nepoznanica.

Povezanost između parametara telesnog sastava i TMG parametra je nešto veća kod žena ($r = 0.441$, $p = 0.025$, u proseku) nego kod muškaraca ($r = 0.412$, $p = 0.026$, u proseku), odnosno kod žena je uticaj mišićne mase i masnog tkiva na mišićnu krutost i brzinu kontrakcije veća nego kod muškaraca. Može se pretpostaviti da su posledica ovih rezultata postojeće razlike u telesnom sastavu između muškaraca i žena (Power & Schulkin, 2008). Kada je u pitanju povezanost između bezmasne telesne mase, masne telesne mase, mišićne krutosti i brzine mišićne kontrakcije u odnosu na mišićne grupe i merene parametre, može se zaključiti da je značajna povezanost dobijena samo kod glavnog mišića pregibača zgloba kolena ($r = 0.426$, $p = 0.025$, u proseku), dok kod glavnog mišića opružača kolena nisu dobijene statistički značajne korelacije ($r = 0.178$, $p = 0.397$, u proseku). Ovi rezultati nam ukazuju na činjenicu da ispoljavanje mišićne krutosti i brzine kontrakcije različitih mišića i mišićnih grupa ne zavisi od istih faktora. Takođe, pokazalo se da bezmasna i masna telesna masa imaju veći uticaj na mišićnu krutost i tonus (r = 0.440, p = 0.019, u proseku) nego na brzinu mišićne kontrakcije (r = 0.384, p = 0.043, u proseku), što je i očekivano s obzorom da se pokazalo da parametar Dm ima povezanost sa mehaničkim karakteristikama mišića (Macgregor et al., 2018; Martín-Rodríguez et al., 2017, Rey et al., 2012), dok je prametar Tc povezan sa tipom mišićnih vlakana (Dahamne et al., 2005; Šimunič et al., 2011).

Glavno ograničenje ovog istraživanja jesu mereni parametri telesnog sastava. Buduća istraživanja bi se trebala fokusirati na ispitivanje povezanost između parametara TMG-a i drugih parametara telesnog sastava poput potkožnog, intramuskularno i intermuskularnog masnog tkiva.

## Zaključak

Pokazalo se da muškarci i žene koji imaju veće vrednosti mišićne mase dominantne noge imaju kruće mišiće kao i da vrednosti masnog tkiva donjih ekstremiteta utiču na mišićnu krutost kod muškaraca odnosno brzinu mišićne kontrakcije kada su pitanju žene. Generalno se može zaključiti da reakcija glavnog mišića pregibača zgloba kolena na električnu stimulaciju pimenjenu metodom tenziomiografije do određene mere zavisi od udela masnog tkiva i bezmasne telesne mase odnosno mišićne mase donjih ekstremiteta.

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**Napomena**

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