

Research article

NEUROMUSCULAR CHARACTERISTICS OF THE BICEPS FEMORIS MUSCLE IN THE TOP SERBIAN SOCCER PLAYERS MEASURED BY THE TENSIOMYOGRAPHY METHOD: A QUANTITATIVE MODEL

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Abstract. *The main aim of this study was to define the quantitative neuromuscular characteristics of the Biceps Femoris muscle (BF) as the knee joint flexor, i.e. the major synergist of the caudal body in all specific movement tasks of a football player, measured by the tensiomyography (TMG) method. The secondary aim of the study was to compare all TMG-BF characteristics in relation to bilateral dimorphism, as well as to compare dominant and non-dominant legs. The research was conducted on a sample which included 54 professional players aged 23.0 ± 4.4 years; body height: 182.6 ± 15.1 cm; body mass: 81.2 ± 15.1 kg; BMI: 23.3 ± 1.2 kg/cm². TMG variables were measured on the muscles during a transition training phase (mid-season and end of the season). The results have shown that the average Tc - 32.19 ± 7.64 and 33.21 ± 8.88 ms, Td - 25.56 ± 3.58 and 25.44 ± 3.20 ms, and Dm - 7.39 ± 1.87 and 7.52 ± 2.50 mm, for the dominant and non-dominant leg, respectively. The results have indicated that there was no statistically significant difference between the examined TMG variables of the dominant and non-dominant leg (Wilks' lambda Value = 0.979, F=0.300, p=0.952, Part. $I^2 = 0.021$). It may be stated that there are no differences in the manifestation of neuromuscular characteristics in healthy elite football players regardless of their dominant leg. A high level of preparedness in football in addition to a completely healthy status of the body and locomotor system result in a complete neuromuscular contractile symmetry BF of both legs.*

Key words: *Tensiomyography, Football, Biceps Femoris, Muscle, Dominant leg*

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INTRODUCTION

In modern society, football represents the most widespread and most popular activity in the field of sports, both on a professional and amateur level (Andersen, Larsen, Tenga, Engebretsen, & Bahr, 2003), with a constant demand for performance improvement (Ostojić, 2000). According to the conducted research by Wallace & Norton (2014), the requirements in top-level football have greatly increased over the previous period, and this especially relates to the intensity of the play itself, the strain that players are exposed to during the play and the speed at which some football skills are performed during a game, both with and without the ball. Therefore, in order to meet the requirements of the game, a modern player must possess an exceptional level of integral preparedness, i.e., harmonized physical, functional, technical and tactical as well as psychological preparedness.

The nature of the football game implies that players demonstrate various forms of movement and technique elements during their performance. The results of previous studies have shown that a player spends up to 96% the time of active play moving without the ball (walking, running, jumping, turning, stopping, etc.) (Wallace & Norton, 2014), and that the dominant technical element that a player performs with a ball is hitting the ball (passes, shots on goal, centers, goalie's long pass, etc.) (Janković & Leontijević, 2008). The situations when a player performs sprints, jumps, or technical elements with the ball at the maximum intensity are regarded as the moments when most of the hamstring injuries have been recorded (Arnason et al., 2004; Arnason, Gudmundsson, Dahl, & Johannsson, 1996; Hawkins & Fuller, 1999; Woods et al., 2004). As the frequency of the aforesaid elements of the modern football game increases with an emerging trend of general intensification of the play itself, the frequency of situations that involve an increasing risk of possible injuries to the hamstring muscles, i.e., BF muscles also increases, as considered from an epidemiological point of view (Fried & Lloyd, 1992).

EMG analysis of the hamstring during sprints indicated the highest activity of BF muscle was observed in the stage of a forward swing when the movement is realized by an eccentric contraction of the hamstring muscles, as well as during contact with the surface when the muscle is in a transient phase of the muscular contraction i.e. stretch-shortening cycle (SSC) (Jonhagen, Ericson, Nemeth, & Eriksson, 1996). Also, by analyzing the ball hits, it was found that the BF muscle significantly increases the activity up to 50% of the overall time before contact with the ball (Kellis, Katis, & Gissis, 2004).

TMG is a non-invasive method that evaluates the contractile properties of the skeletal muscles (Šimunić, 2012). This measurement method has showed a high reliability and sensitivity to detecting changes in muscular reactions (Križaj, Šimunić, & Zagar, 2008; Rey et al., 2012b) and it has also been found to possess a high reliability to measure the following variables: contraction time (Tc), half-relaxation time (Tr), delay time (Td), sustain time (Ts), and maximum radial displacement of the muscle belly (Dm) in muscles vastus medialis, vastus lateralis, rectus femoris, and BF (Rey, Lago-Peñas, & Lago-Ballesteros, 2012a; Rey, Lago-Peñas, Lago-Ballesteros, & Casáis, 2012b; Carrasco, Sanudo, de Hoyo, Pradas, & Da Silva, 2011; Tous-Fajardo et al., 2010). Thus, the information about muscle stiffness, contraction time, dominance and type of the muscle fiber, as well as about a potential risk that is present during the performance of a specific sports activity is obtained (Rey et al., 2012a; Alentorn-Geli et al., 2015).

The application of a TMG measuring device is widespread in sport, therefore, it has been used in determining the muscular characteristics of athletes engaged in volleyball (Dopsaj,

Ivanović, & Čopić, 2014; Rodríguez-Ruiz et al., 2012), triathlon (García-Manso et al., 2011a), cycling (García-García, Cancela-Carral, Martínez-Trigo, & Serrano-Gómez, 2013), kayak (García-García, Cancela-Carral, & Huelin-Trillo, 2015), professional dance (Zagorc, Šimunič, Pišot, & Oreb, 2010), football (Rey et al., 2012b; Rusu et al., 2013; Alvarez-Diaz et al., 2014), etc.

In football players, the studies mostly examined the contractile properties of muscles when exposed to cold water after loading (García-Manso et al., 2011b), during recovery (Rey et al., 2012b), in players at different positions (Rey et al., 2012a), during the recovery of the anterior cruciate ligament (Alentorn-Geli et al., 2015), when assessing the effects of different types of training (Rusu et al., 2013). It has also been found that the TMG analysis is a reliable method for identifying a lateral asymmetry between the dominant and non-dominant leg (Rodríguez-Ruiz et al., 2014).

Taking into account the limitations and different applications of TMG, the main aim of this study was to define and present the quantitative neuromuscular characteristics of the BF muscle, as one of the most important muscles of the lower extremities in football, which plays an important role in all specific football movements, on a sample of the elite Serbian football players. The secondary aim of this study was to compare TMG-BF characteristics in relation to defining the characteristics of bilateral dimorphism in regard to the aspect of the dominant and non-dominant leg. All the data obtained can also serve as the initial diagnostic norms and standards in relation to future research of this type in football.

METHODS

Sample of participants

The conducted research included a sample of a total of 54 professional football players, including 19 players who were members of the Serbian national team (U20) that won the Football World Cup in New Zealand in 2015. All the examined participants are from Serbia (19 defenders, 19 midfielders, 11 attacking and 5 goalkeepers). Most of the players indicated their right leg as the dominant one (41), while only 13 players were left-footed. The sample of the participants possessed the following descriptive characteristics (mean \pm SD): age, 23.0 \pm 4.4 years; body height, 182.6 \pm 15.1 cm; body mass, 81.2 \pm 15.1 kg; body mass index (BMI), 23.3 \pm 1.2 kg/cm². At the time when the testing was carried out, the players had no muscular problems i.e. without injuries during the competition break (summer and winter transition period). All of the players were informed in detail about the test conditions and the possible risks and benefits of this research. The study was approved by the Ethics Committee of the Faculty of Sport and Physical Education of the University of Belgrade (02 No. 484-2).

Study design

The testing was conducted in the "Advance Fitness" diagnostic and training center, as well as at the Faculty of Sport and Physical Education, i.e. at the Methodical Research Laboratory from 2015 to 2018. All the participants were professional players with a relatively similar competition schedule (autumn and spring season period) who appeared in the Serbian National Super League, as well as in various football clubs throughout Europe (England, Spain, Germany, Portugal, Austria, Croatia, Belgium, Norway and Hungary). On

the day when the testing was carried out, the participants were engaged in no physical activity, i.e. had no training sessions.

Testing procedure

The TMG System (TMG-BMC Ltd., Ljubljana, Slovenia) equipped with a Trans-TekwGK40 sensor (GK 40, Panoptik d.o.o., Ljubljana, Slovenia) was applied to measure the neuromechanical properties of the BF muscle. An involuntary muscle stimulation was provoked by the 5x5cm muscle reaction self-adhesive electrodes (TMG electrodes, TMG-BMC d.o.o. Ljubljana, Slovenia) that were placed according to the manufacturer's recommendation, i.e. at a distance of 50-60mm from the digital sensor (Wilson, Johnson & Francis, 2018).

The testing protocol was determined according to Rey et al. (2012^a). During the testing, the participants were in a prone position, with their ankles placed on a foam cushion of a specific TMG design which was used to fix the position of the knee joint at an angle of 165° (Figure 1). Due to the individual anatomical differences, the sensor was positioned individually by palpation in each participant, and in accordance with the previously published protocol (Valenčič & Đorđević, 2001). The monophasic electrical stimulation with an initial stimulus intensity of 30mA was applied. Each subsequent stimulus was increased by 10mA until the maximum value of the muscle belly displacement (Dm) was reached, i.e. until the moment when there were no evident changes in the observed variables in relation to an increase in the electrical stimulation. A rest of 10 seconds was used between each stimulus in order to relax the muscle, i.e. to avoid the effect of potentiation between the stimuli (Križaj et al., 2008). The measurements were carried out by experienced examiners whereby one was responsible for managing the intensity and frequency of the applied stimulus and the other was responsible for positioning the electrodes and the sensors by which the testing was performed.

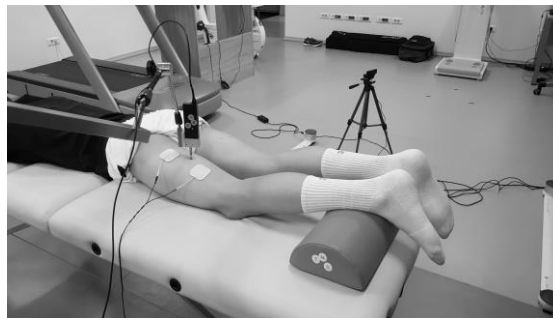


Fig. 1 Tensiomyography assessment of the biceps femoris muscle

Sample of variables

For the purposes of this study, the following variables were used to describe the functional involuntary contractile property of the examined muscle:

1. Tc – time of contraction, for dominant (Dom) and non Dominant (NonDom), expressed in milliseconds (ms), represents the time between 10% and 90% of the maximum vertical muscle movement.
2. Td – delay time, for Dom and NonDom expressed in ms, the time required to reach 10% of the maximum muscle belly displacement.

3. $T_c + T_d$ – total time contraction, for Dom and NonDom expressed in ms, represents the overall contraction time required for the complete muscle belly displacement.
4. T_r – relaxation time, for Dom and NonDom expressed in ms, represents the time required to reduce the muscle contraction, after an electrical stimulus, from 90% to 50% of the overall maximum muscle belly displacement.
5. T_s – sustain time, for Dom and NonDom expressed in ms, represents the time from 50% of the muscle contraction to 50% of its relaxation.
6. D_m – maximal displacement, for Dom and NonDom expressed in mm, represents the overall displacement (shortening) of the muscle by an involuntary stimulation.
7. V_c – contraction velocity, for Dom and NonDom expressed in mm/ms, calculated as a ratio between D_m and T_c+T_d (Loturco et al., 2016).

Statistical analysis

All the data obtained by the testing were analyzed by the application of descriptive statistical analysis, whereby the following were calculated: parameters of central tendency - arithmetic mean; parameters of data dispersion - standard deviation (SD), coefficient of variation (cV%), absolute and relative error in the measurement (Std. Err & Std. Err. %). The equality of data distribution was tested using a nonparametric Kolmogorov-Smirnov Test (K-S Z). In addition, a multivariate analysis of variance (MANOVA) as well as a univariate analysis of variance (ANOVA) were applied in order to determine the differences in the measured variables of the dominant and non-dominant leg. The statistical significance was defined at the level of probability of 95% i.e. $p = 0.05$ (Hair, Black, Babin, Anderson, & Tatham, 2006). All the data was processed using the statistical data processing software SPSS 20 (SPSS Inc., Chicago, IL, USA).

RESULTS

Table 1 presents the results of descriptive statistics (Mean±SD) of the examined variables (T_c , T_d , T_c+T_d , T_r , D_m , V_c and T_s) including the distribution parameters for the Dom and NonDom leg for the BF muscle. It can be noted that the homogeneity of the results is low, which indicates a high level of standardization of the measurement procedure. All the variables have the shape of a normal distribution at a statistically significant level, except for the variable T_r of the dominant leg (cV = 51.59%, K-S=1.621, $p=0.010$).

Table 2 shows the results of the multivariate analysis of variance (MANOVA), as well as the results of the univariate analysis of variance (ANOVA). It was found that, both at general and partial level, there are no statistically significant differences in the examined TMG variables in relation to the dominant and non-dominant leg regarding the studied sample of the football players (Wilks' lambda Value = 0.979, $F=0.300$, $p=0.952$, Part. $\eta^2 = 0.021$).

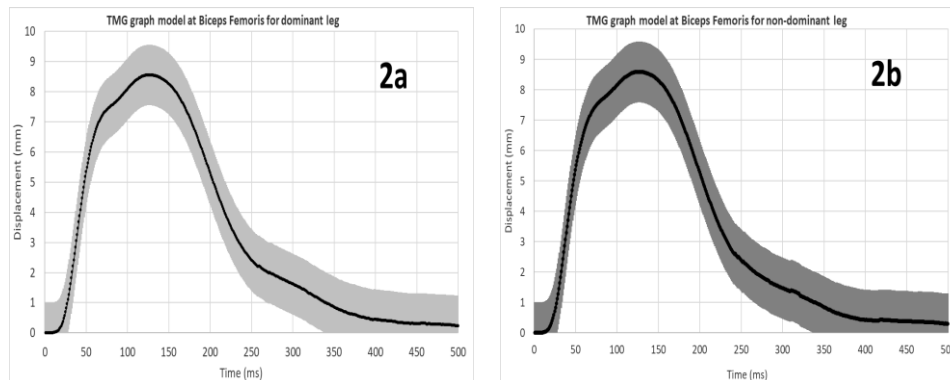
Figures 2a & 2b show the calculated dependency Time - Displacement as the defined quantitative neuromuscular models for the BF of both legs. The presented models provide the information on the initial standard of the neuromuscular status of the tested muscle groups and represent the first stage in defining the final TMG-BF model of the Serbian elite football players, in order to optimize the training technology in football.

Table 1 Descriptive statistics of the studied variables with parameters of distribution

TMG variables		Mean	SD	cV (%)	Std. Err. (aps)	Std. Err. % (Rel)	K-S Z	p value
Dominant Leg Bic. Femoris	Tc_Dom (ms)	32.19	7.64	23.73	1.04	3.23	1.192	0.116
	Td_Dom (ms)	25.56	3.58	14.01	0.49	1.92	0.976	0.296
	Tc + Td_Dom (ms)	57.74	9.50	16.45	1.30	2.25	0.649	0.794
	Tr_Dom (ms)	45.69	23.57	51.59	3.20	7.00	1.621	0.010
	Dm_Dom (mm)	7.39	1.87	25.30	0.25	3.38	0.931	0.351
	Vc_Dom (mm/ms)	0.129	0.029	22.48	.004	3.10	0.629	0.824
	Ts_Dom (ms)	185.79	33.78	18.18	4.60	2.48	0.750	0.627
Non Dominant Leg Bic. Femoris	Tc_Non Dom (ms)	33.21	8.88	26.74	1.21	3.64	0.574	0.897
	Td_Non Dom (ms)	25.44	3.20	12.58	0.44	1.73	0.720	0.677
	Tc + Td_Non Dom (ms)	58.66	10.51	17.92	1.43	2.44	0.646	0.798
	Tr_Non Dom (ms)	44.60	21.13	47.38	2.88	6.46	0.928	0.356
	Dm_Non Dom (mm)	7.52	2.50	33.24	0.34	4.52	0.537	0.936
	Vc_Non Dom (mm/ms)	0.129	0.040	31.01	0.005	3.88	0.776	0.584
	Ts_Non Dom (ms)	180.80	26.70	14.77	3.63	2.01	0.607	0.855

Table 2 Results of the MANOVA – Multivariate test and ANOVA – Univariate test

Multivariate Test					
	Value	F	p value	Part. η^2	Observed Power
Wilks' Lambda	0.979	0.300	0.952	0.021	0.136
Univariate Test					
Dependent Variable	Sum of Squares	F	p value	Part. η^2	Observed Power
Tc	28.05	0.409	0.524	0.004	0.097
Td	0.32	0.028	0.867	0.000	0.053
Tc+Td	22.30	0.222	0.638	0.002	0.075
Tr	31.73	0.063	0.802	0.001	0.057
Dm	0.51	0.105	0.747	0.001	0.062
Vc	9.26	0.000	0.998	0.000	0.050
Ts	671.80	0.725	0.396	0.007	0.135

**Fig. 2a & 2b** Models of Tensiomyography graphs at Biceps femoris dominant and non-dominant leg

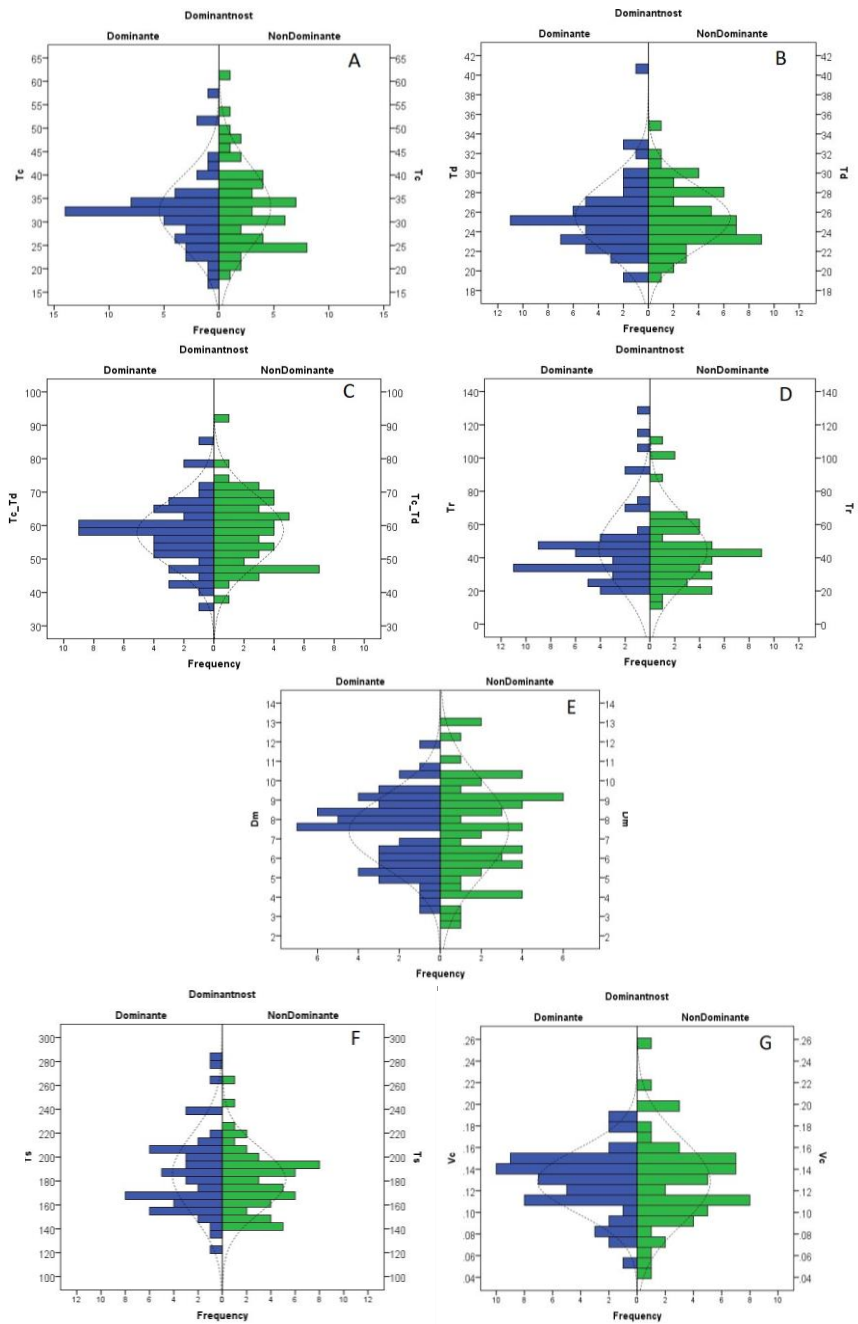


Fig. 3 Presentation of the population distributions of the results of the examined variables (Contraction time (Tc) (A), delay time (Td) (B), total time contraction (Tc+Td) (C), half relaxation time (Tr) (D), maximal radial displacement (Dm) (E), sustain time (Ts) (F), contraction velocity (Vc) (G)), in relation to the dominant and non-dominant leg

Figure 3 shows the population distributions of the results of the examined variables of the Dom and NonDom leg. According to the presented comparative distributions, in case of the dominant leg variable Dm (E), a centralization tendency in the rigidity of the examined muscle as a system relative to the NonDom leg can be observed, which may indicate a leptokurtic distribution shape, i.e. a higher standard grouping of the given ability in the Dom leg compared to the NonDom one, where it may be noticed that a variation of the distribution of the measured muscle property is much greater, i.e. the distribution has a platycurtic distribution. Similar distribution characteristics can be recorded in the variables Vc (G) as well as the variables Tc_Td (C).

DISCUSSION

The main aim of this study was to define the differences and the quantitative neuromuscular characteristics of the BF muscle regarded as one of the most important muscles of the lower extremities, which plays an important role in football in performing sprints, jumps, passes and other movement activities, measured by the method of TMG on a sample of the Serbian elite football players. The secondary aim of the study was to define the level of bilateral dimorphism of the examined variables and to carry out an external validation of the results obtained on a population of elite Serbian footballers in relation to the existing professional standards from leading European football countries.

According to the obtained results, it has been shown that there are no statistical differences found in healthy footballers from Serbia when it comes to neuromuscular characteristics regardless of leg dominance. In other words, there is no bilateral dimorphism, as a measure of difference or lack of a specific property, found between the dominant and non-dominant leg. This, most likely, points to the fact that the tested players were well-trained according to the type of lateral symmetry and that the measured neuromuscular muscle functions were harmonized in both legs. However, it can be noted that a slightly altered distribution and less homogeneity were observed in the variable Tr of the Dom and NonDom leg, which can be recognized as information about a possible chronicity of the fatigue phenomenon which is identified by an increasing value of the variable (Križaj et al., 2008).

The modern football game abounds in game elements such as jumps, sprints and passes, which indicates an increase in the general intensification of physical and motor strains during the play itself. Also, from an epidemiological point of view, it has been determined that as the intensity of the play increases, the frequency of situations involving a risk of possible hamstring muscle injuries is also increased (Fried & Lloyd, 1992). Furthermore, a role of the BF muscle that, in hitting the ball, increases the activity up to 50% of the overall time prior to a contact with the ball is especially emphasized (Kellis et al., 2004). Benitez Jimenez, Fernandez, Montero, & Romacho (2013) in their research have concluded that the parameters which should be specifically focused on when using the TMG are variables Dm and Tc. This increase of Dm reduces muscle stiffness, affecting the loss of strength and explosive ability, while lower values of Dm suggest an increase in stiffness or muscle tone (Kokkonen, Nelson, & Cornwell, 1998; Križaj et al., 2008; Rey et al., 2012b). Tc values of over 30ms clearly indicate a possible presence of slow muscle fibers in the muscle (Dahmane, Valenčić, Knez, & Erzen, 2001), whereas the relationship between the variable Tc and the properties of the muscle fiber structure in sprinters is at a high statistically significant level (Dahmane, Đorđević, Smerdu, 2006).

Generally, the two variables are the most reliable and most stable parameters for monitoring the functional state of neuromuscular characteristics of the contractile property of the measured muscle, while the less sensitive parameters are Tr and Ts (Križaj et al., 2008; Šimunič, 2012; Tous-Fajardo et al., 2010; Ditroilo, Smith, Fairweather, & Hunter, 2013).

The results of this study have shown that no statistically significant difference was found between the measured TMG variables of the BF of the Dom and Non-Dom leg (Table 2, Wilks' Lambda Value = 0.979, $p = 0.952$), nor was a partial statistically significant difference determined between the individual variables (Table 2, $V_c - p = 0.998$ do $T_s - p = 0.396$). However, although the differences have not been determined, it should be pointed out that the variables Ts and Tc have shown a slightly higher level of sensitivity in relation to defining the potential differences in the studied area (Tabela 2, $T_s - \text{Part. } \eta^2 = 0.007$ i.e. 7%, and $T_c - \text{Part. } \eta^2 = 0.004$ i.e., 4%), therefore, more attention should be paid to it in future research.

The results obtained in the conducted research coincide with the majority of the results from the previous studies conducted on a sample of international football players (Alvarez-Diaz et al., 2014; García-García, Serrano-Gómez, & Cuba-Dorado, 2014; García-García, Serrano-Gómez, Hernández-Mendo, & Morales-Sánchez, 2017; Gil et al., 2015) in which the authors have also concluded that there are no statistically significant differences in the measured TMG variables BF of the Dom and NonDom leg. Also, very similar descriptive results of the examined variables were obtained on a sample of futsal (Sánchez-Sánchez et al., 2018), volleyball players (Rodríguez-Ruiz et al., 2012) and cyclists (García-García et al., 2013) in regard to the studied BF muscle.

In their research of the BF muscle, Alvarez-Diaz et al. (2014) found a statistically significant difference only for the variable Ts (214.4±81.6 vs. 195.3±64 ms, for Dom and NonDom leg, respectively). These values are higher in relation to the results of our study from the aspect of the examined variables (Table 1, 185.79±33.78 vs. 180.80±26.70 ms, i.e. 15.40% vs. 8.13% lower values, for Dom and NonDom leg, respectively), which may suggest a higher level of fatigue of the participants during the testing in the aforementioned study. In a study conducted by García-García et al. (2017) the mean values (dominant and non-dominant leg), of the Tc variable, were 34.5±6.6 ms, and for variable Dm they were 7.0±1.7 mm, which is higher by Tc and lower by Dm in relation to our study. One of the possible reasons for the mentioned findings and differences in relation to the results of this study can be explained by an interpretation of testing the sample of football players of a different level of competition, application of tests in a different training period, as well as the size and structure of the sample.

García-Manso et al. (2011^a) examined the average TMG values of the BF muscle parameters for both legs in the triathlon athletes before and after a competitive activity. The results obtained were higher for all the observed variables before the performance of the competitive activity, compared to the results obtained in our research (triathlon athletes = 65.1 ± 22.1 ms, 10.8 ± 3.5 mm, 44.1 ± 5.4 ms, 436.8 ± 68.1 ms, 124.6 ± 33.8 ms, i.e. higher by 99.10%, 44.77%, 72.94%, 138.30%, 175.97%, respectively for Tc, Dm, Td, Ts, Tr). Such great differences are most likely an overall consequence of several factors, including the following: triathlon is a sport of endurance which has a different type of training load, according to continuous aerobic endurance, the selection system of triathlon athletes also includes individuals of a different type of muscle fiber compared to football players, there is a different type of fatigue present, etc.

The lower values of the variables Tc and Dm were determined in the cyclists during the competition season (García-García et al., 2013) compared to the results obtained in our study.

Such findings may indicate that it is most likely due to a different type of motor strain, where cyclists show a high level of pedaling rate as well as a higher level of successive contractile activation and co-activation of the leg muscles, in a constant concentric and eccentric muscular mode, which is one of the more pronounced adaptations of the muscular system, which can lead to an increase of the degree of the muscle system stiffness, or an increased muscle tone.

Regarding the results obtained in non-athletes (Toskić, Dopsaj, Koropanovski, & Jeknić, 2016) it has been determined that their values were higher in Tc, and lower in the Dm variable in relation to our study. The results have indicated that there is a greater muscle stiffness determined in the recreational players, as well as a longer time required for the realization of the 90% complete muscle contractions. In other words, a higher muscle tone (lower Dm) and a longer motor response to the overall muscle contraction (higher Tc) were observed. The most probable reason for such findings can be explained by a greater extent of sedentary time spent during the day in addition to the likely insufficient and professionally non-programmed occasional physical activities of the non-athletes.

Due to an insufficient number of relevant studies in Serbia about this, the research, which would include characteristics and differences of the examined TMG variables in relation to the positions in the game, such studies should be carried out in the future, in relation to different ages and sex, as well as in relation to different levels of competition in the football players in the Republic of Serbia.

Additionally, in regard to the further research on this topic, and in order to obtain standards for the given results, it is necessary to define the criteria of the research sample in relation to: the defined training period, i.e. the time period of testing, in relation to different orientation of the training effects, as well as in relation to the cumulative effects of different models and the cycle of training or competition load.

The results obtained in this study can serve as the initial norms and standards in defining the final TMG model of the elite football players from Serbia, which will be of significance in the future during the creation of training load, as well as in the prevention of the risk of injury. The neuromuscular profile of a football player can help coaches and medical staff to identify the initial norms that are relevant in the training, planning and programming as well as during the recovery process in each individual player. Also, in the competition cycle, the results can contribute to the assessment of a specific effect of the training on the muscle itself, by which each training unit can clearly be managed and more precisely directed.

CONCLUSION

The results have shown that there are no statistically significant differences found in healthy elite football players from the Republic of Serbia in regard to the neuromuscular characteristics measured by the method of tensiomyography, for the BF muscle regardless of the leg dominance. These findings have indicated that the players were well-trained according to the type of lateral symmetry and that the function of the muscle itself was harmonized in both the dominant and non-dominant legs. All the data obtained can also be used as the initial diagnostic norms in relation to the future research of this type, which will be of importance and relevance in the practical application in the field of football.

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NEUROMIŠIĆNE KARAKTERISTIKE BICEPS FEMORIS MIŠIĆA KOD VRHUNSKIH SRPSKIH FUDBALERA MERENE METODOM TENZIOMIOGRAFIJE: KVANTITATIVNI MODEL

Glavni cilj ove studije bio je definisanje kvantitativnih neuromišićnih karakteristika mišića Biceps Femorisa (BF) kao pregibača zgloba kolena, odnosno glavnog sinergiste kaudalnog dela tela u svim specifičnim kretnim zadacima fudbalera, utvrđenim primenom tenziometrijske (TMG) metode. Sekundarni cilj studije predstavljao je upoređivanje svih TMG-BF karakteristika prema bilateralnom dimorfizmu, kao i upoređivanje dominantne i nedominantne noge. Istraživanje je sprovedeno na 54 profesionalna igrača starosti 23.0 ± 4.4 godina; visine: 182.6 ± 15.1 cm; mase: 81.2 ± 15.1 kg; BMI: 23.3 ± 1.2 kg/cm². TMG varijable su merene na BF mišiću tokom prelazne faze (polusezona i kraj sezone) treninga. Rezultati su pokazali da je prosečno Tc - 32.19 ± 7.64 i 33.21 ± 8.88 ms, Td - 25.56 ± 3.58 i 25.44 ± 3.20 ms, i Dm - 7.39 ± 1.87 i 7.52 ± 2.50 mm, za dominantnu i nedominantnu nogu, respektivno. Rezultati su pokazali da ne postoji statistički značajna razlika između ispitivanih TMG varijabli dominantne i nedominantne noge (Wilks' lambda Value = 0.979, F=0.300, p=0.952, Part. $\eta^2 = 0.021$). Kod zdravih vrhunskih fudbalera nema nikakvih razlika ispoljavanja neuromišićnih karakteristika BF bez obzira na dominantnost noge. Vrhunska utreniranost u fudbalu u sadejstvu sa potpuno zdravim statusom organizma i lokomotornog aparata uslovljava i potpunu neuromišićno kontraktilnu simetričnost BF obe noge.

Ključne reči: tenziomiografija, fudbal, biceps femoris, mišić, dominantna noga