THE USE OF ELECTROMYOGRAM IN FOOTBALL SYSTEMATIC REVIEW

PRIMENA ELEKTROMIOGRAFA U FUDBALU PREGLEDNO ISTRAŽIVANJE

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REVIEW SCIENTIFIC PAPER
doi: 10.5550/sgia.201601.en.kissv
UDC: 612:796.332
Received : 04.11.2020.
Approved: 12.11.2020.
Sportlogia 2020, 16 (1), 48-66.
E-ISSN 1986-6119

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ABSTRACT

The aim of this systematic review was to indicate and discuss the use of electromyogram in football. For the literature review, following electronic databases were used: Google School, PubMed, Medline and Mendeley for the period from 2005. to 2019. 20 papers were selected for this systematic review based on the established criteria. These studies focused the most on researching the following muscles: m.musculus quadriceps, m.biceps femoris, m.gastrocnemius, m.tibalis anterior and m. gluteus maximus. The review has determined quite a heterogenic choice of topics when it comes to the use of the electromyogram (herein after referred to as: EMG) in football, so the obtained results were grouped based on the similar characteristics. Therefore, the results were categorized according to the following topics: acute effects of the specific football activity, impact of the football strength training, training of kicking on the ball, results based on the difference in sexes, while the rest of the results were sorted in the joint group. Summarizing of the obtained results provides the insight in the multiple possibility for use of EMG in football in order to develop high quality analysis of the neuro-muscle activation of a certain muscle regions of the football players.

Key words: *EMG, electromyogram, muscles, soccer, football*

INTRODUCTION

Even though the first dates related to the EMG date from the 17th and 18th century, Dr. Lambert is considered to be the inventor or "father" of the EMG, as in the beginning of the 60s of the last century, together with his colleague Schmidt, he developed a machine to analyze electric impulses which was relatively user friendly (Reaz, Hussain, & Mohd-Yasin, 2006). Further development was enabled with the development of the computer technologies in the last 20 years, which enabled EMG system to be developed in today's form and functionality. Electromyography represents an electro physiological method of registering the action potentials of muscle motor units and of researching the conductivity of sensor and motor peripheral nerves (Ðuriæ, & Mihaljev-Martinov, 1998). In other words, EMG represents a record of the special and temporal forms of the electric activity in the activated motor units, and has been considered the golden standard for a long time now when it comes to researching of neuromuscular functions (Farina, Merletti, & Enoka, 2004; Kinugasa, & Akima, 2005). General characteristics of the surface EMG, namely its amplitude and strength spectra, depend on the characteristics of the muscle fibers membrane, as well as on the time of the muscle potential activity. This way, the surface EMG reflects both peripheral and central characteristics of the neuromuscular system (Farina, et al., 2004). The improvement of the EMG devices for detection of the electric potentials of performed willing complex movements and the evolution of the methodological approaches to data collection, as well as the computer analysis of patterns, are responsible for higher and higher use of EMG in bioengineering, rehabilitation, sports, as well as in the fields of biomechanics, physiology, zoology and ergonomics (Clarys et al., 1988). Monitoring performances of the elite athletes is vital to achieving better competition results (Hernandez, Estrada, Garcia, Sierra, & Nazeran, 2010). Kinesiological electromyography researches can be summed up in a following way: studies related to the normal muscle function during the selected moves and postures; studies of the muscle activity in complex sports, studies related to rehabilitation and athletes' recovery; studies researching the isometric contractions with the increase of muscle tension; studies researching functional anatomic muscle activity (validation of the classical anatomical functions); studies of coordination and synchronization (kinematic chain); studies related to the specifics and efficiency of a certain training methods; studies researching muscle durability and the impact of fatigue; studies researching relation between electromyography and human muscle strength etc. (Clarys, 2000).

It is well known that EMG is mostly used in medicine and related areas, which explains why the majority of electromyography related studies is connected to the medicine. Nevertheless, contemporary sports, especially in the last 2 to 3 decades has been "leaning on" the medicine and related areas, leading to realizing the benefits from the EMG in sports as well, and finally leading to the multiple use of EMG in sports. Based on these findings, it can be assumed that football can obtain benefits from the research in the area. Therefore, the aim of this systematic review is to indicate the impact of use of EMG in football.

METHODOLOGY

Resources and strategy

For the literature review, the following electronic databases were used: Google Scholar, PubMed, Medline and Mendeley for the period from 2005. to 2019. The following key words were used for the research: EMG, electromyogram, football, soccer. Research strategy was customized for each electronic base in order to increase sensitivity. All titles and abstracts were reviewed, as well as the reference lists from the previous systematic reviews and original researches. Relevant studied were selected based on the following criteria:

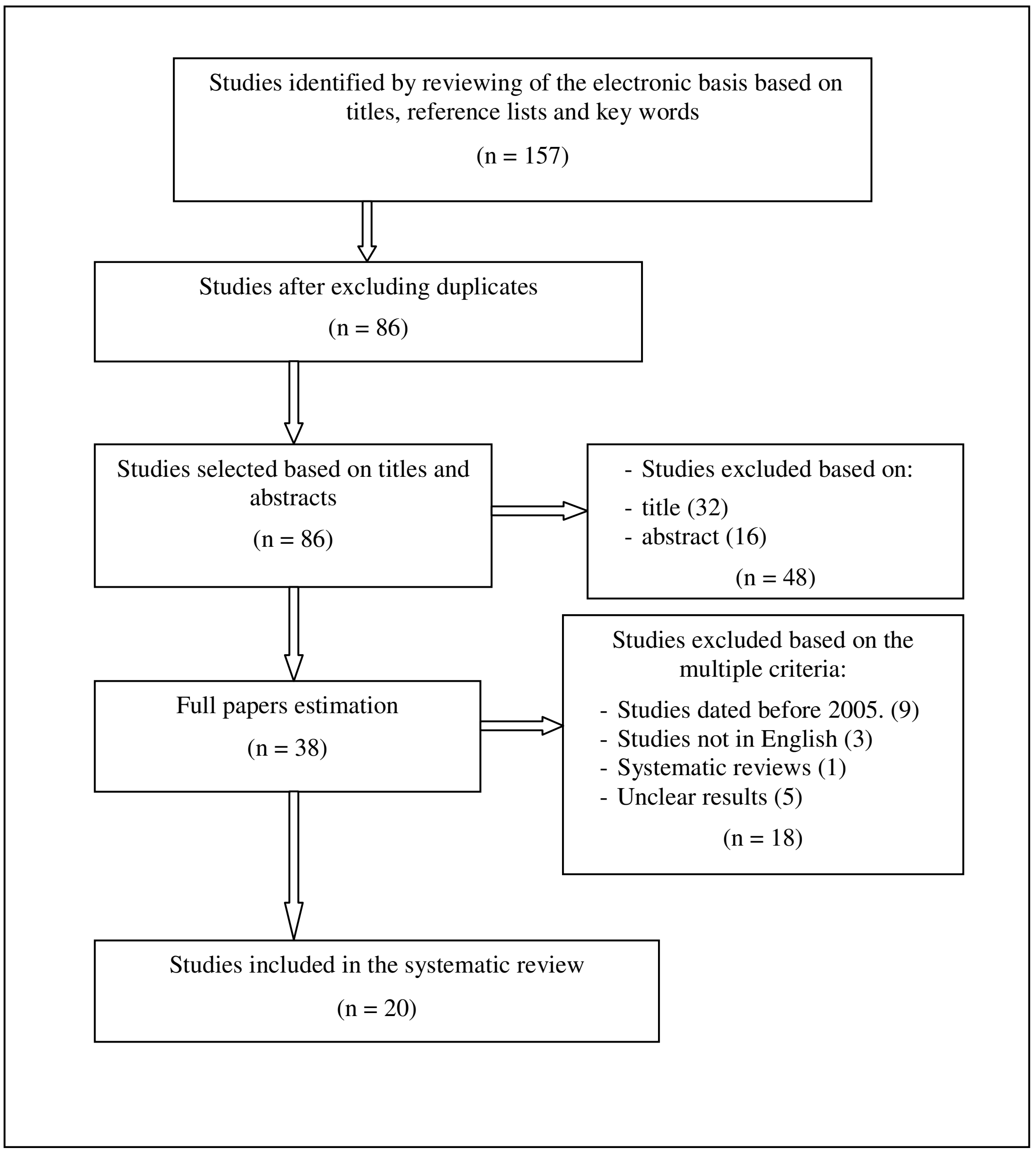
Criteria for including the study:

- Studies that included research of muscle potential of football players using EMG
- Studies in English
- Studies published between 2005. and 2019.
- Studies that are not full papers

Criteria for excluding a study:

- Studies written in languages other than English
- Studies dated before 2005.
- Studies that are not full papers (only abstract)
- Systematic reviews
- Studies in which obtained results are not presented clearly
- Duplicates

Scheme no. 1: *Diagram of the studies' analysis process*



RESULTS

Table 1. *Systematic review and characteristics of the studies included*

First author and year	Sample	Sex	Age	Sample size (n)	Research topic	Muscles examined	Examined EMG character.	Results	Conclusion
Kaygusuz, et al. (2005)	E1: F E2: B + H CG: SE	M	19,9	30	Effects of various trainings on the neuro muscle activation	GCL GCM APB	AMP AR FR HRT	E1: AMP GCL↑, GCM↑ ($p<0.05$), AMP GCL↑, GCM↑ ($p<0.05$); E2: AMP GCL↑, GCM↑ ($p<0.01$), AMP GCL↑, GCM↑ ($p<0.01$), FR ($p<0.05$), HR ($p<0.05$)	Volleyball and basketball trainings contribute to neuro muscular differences and differences in upper and lower extremities more than football trainings, as both extremities are highly used in these sports
Greig, et al. (2006)	E: F	M	24,7	10	Examination of the response of internment treadmill protocol based on the national analysis of matches played	RF BF	EMG peak total	HR INT↑ ($p<0.01$); RPE INT↑ ($p<0.01$); SS INT↑ ($p<0.01$); BF total INT>SS ($p<0.01$); BF peak INT>SS ($p=0.05$); RF total INT>SS ($p<0.01$); RF peak INT>SS ($p<0.05$);	INT activity profile induces cumulative mechanic load of the muscular skeleton system. Increased injury incidence in final phases of the match can be connected with the disturbed mechanics of movement, and not with the physiological stress.
Manolopoulos, et al. (2006)	E: F CG: F	M	20,8	20	Impacts of combination of strength training with kicking on the ball on the biomechanics of football shoot in amateur	RF BF VM GCM	MVC	TI and MVC CoM↑ ($p<0.05$); LV↓($p<0.05$); AV↑($p<0.05$); EMG BF↑ ($p<0.05$); MVC VM↑ ($p<0.05$); Fmax↑ ($p<0.05$); 10m↑ ($p<0.05$)	Training had no effect on the EMG values, except decrease of the average value of GCM, while the maximum isometric strength and sprint time were significantly increased after the training. Results indicate implementation of the specific football program of strength exercises is especially efficient in improvement of performances of the football shoot.
Rahnmana, et al. (2006)	E: F	M	21,4	10	Electromyography of lower extremities muscles fatigued by the intensity of the football match	RF BF TA GCM	MVC	MVC after 45 and 90' RF↓, BF↓, TA↓ ($p<0.05$)	Results indicate that, after the simulation of the intensity of football game exercises, EMG activity in bigger muscles of lower extremities was lower than before. This decrease indicates that extended exercising impacts muscle activity, even if a working rate is

									maintained.
Brophy, et al. (2010)	E1: F E2: F	M+ FF	19, 6	25	Differences between sexes in activation of lower extremities muscles while kicking on the ball with leg	VM VL GC GMA GME IL HM	MA swing and standing.	Swing IL 123%M>34%FF (p=0.0007); standing VM 124%M>55%FF (p=0.005); GME 113%M>69%FF (p=0.002); GMA 139%M>78%FF (p=0.07)	Differences in sexes in harmonizing lower extremities and muscle activation occur during the football side leg kicks. Decrease activation of the hip arresters and increase activation of the hook receivers in the supporting limb during the football kick can be connected with the increased injury risk of the anterior cruciate ligament.
Hart, et al. (2007)	E1: F E2: F	M+ FF	19, 7	16	Differences between sexes in the GME muscle activation during the long jump in football players	GME GCM VL LHM	MA	GME M 7.16>2.62 FF (p=0.002)	Average GME muscle activity was significantly higher in men than in women, while no differences between sexes related to other muscles.
Oliver, et al. (2008)	E: JF	M	15, 8	10	Changes in parameters related to jump and muscle activation after the specific football exercises	VL BF TA SO	MA	MA during DJ: VL↓, BF↓, TA↓ (p<0.05); SO↑(p<0.05); SJ -1.4 (p<0.05); CMJ -3.0 (p<0.05); DJ -2.3 (p<0.05); MA & CMJ (p=0.07), MA & DJ (p<0.05)	Results indicated that performance in all jumps was decreases after the specific football activities. Decrease of muscle activity was the highest regarding the in depth jump, which indicates the impact of muscle flexibility, and stress on the decreases muscle activity when muscles are fatigued.
Beaulieu, et al. (2009)	E1: PF E2: PF	M+ FF	22, 0	30	Differences between sexes in EMG parameters time-frequency of the unforeseeable maneuvers	RF BF TA GCM VL+M ST	EMG IC TI	EMG M=FF ST, GCM, GCL (P>0.05); IC M>FF for VL (P= 0.011, d= 0.99), VM (P= 0.010, d= 1.01) and during the phase VL (P= 0.002, d= 1.23), RF (P= 0.025, d= 0.86) and VM (P= 0.005, d= 1.13); TI-peak earlier in FF than in M for BF (P= 0.026,d= 0.86); and later for TA (P= 0.003, d= 1.21)	Female athletes adopt a different strategy of the recruitment of motor units, which is especially visible in IC, which results in the higher frequency of the EMG LHM signal. This strategy may explain the differences between the sexes in the injury rate of ACL. Differences in sexes in kinematics of the knee joint were noticed, followed by the exposing of female ACL to higher effort, which can be a results of differences in neuro muscular strategies in stabilization of the knee joint.
Thorlund, et	E: JF	M	17, 6	9	Change of the fast muscle	QD HM	EMG MVC	MVC↓ 10 % (p ≤0.01); RFD↓	Decrease of the fast muscle strength was

al. (2009)					force during the football match		RFD	9% (0 – 200 ms); VL 17%, BF↓ 31% (p ≤0.05)	noticed, which probably negatively impacts performances of explosive activities (namely, acceleration, hitting, sprint) which are a part of football matches.
Cerrah, et al. (2011)	E1: PF E2: F	M	22, 9	31	Activation characteristics of knee muscles of the shooting leg during the shoot compared to the parameters of the isokinetic strength and ball speed	RF BF VM VL GC	MVC 800ms before and 800ms after the shoot	E1< E2 190–380 ms RF (p<0.05); E1>E2 200–620 ms VL (p<0.05); E1<E2 470–580 ms VM (p<0.05); E1>E2 650, 600, 100, 50ms BF (p<0.05); E1<E2 250–400ms GC (p<0.05)	Findings of this study, based on the EMG, indicate that the performance of professional players, compared to amateur players, is not connected to the strength factor, nut to the subtle differences in technique, related to the precision itself.
Amori-Khobasari & Kellis (2013)	E: F	M	18, 8	12	Impact of static and dynamic flexing on the neuro muscle components during the shoot	VM VL RF	MA	E: F dynamic. EMG RF↑ (p=0.015), VL↑ (p=0.004), VM↑ (p=0.049), AV↑ (p<0.001); static EMG RF↓ (p=0.015), VL↓ (p=0.004), VM↓ (p=0.049), ↓ (p<0.001)	Based on the obtained results, it can be suggested that dynamic flexing is more efficient in increasing upper knee muscle activation, as well as related to the angle speed in the knee joint extension during the final phase of shooting of the ball.
Chauhan, et al. (2013)	E: SPF	M	24, 4	15	Muscle architecture prediction based on the isometric contractions	VL RF	MA UP	UP& EMG RF (R^2=0.68, p<0.005); UP & EMG VL (R^2=0.40, p>0.05)	Results indicate strong relation between EMG muscle activation and muscle strength. These findings suggest that EMG base measures can be used for forecasting of the muscle strength and that ultrasound based measures can be useful in forecasting EMG muscle activity, This is interesting, as these two tools of the ultrasound measure different aspects of muscle function.
Katis, et al. (2013)	E: F	M	23, 7	21	Muscle activation of the shooting leg during the precise and unprecise shoots	RF BF TA GC	MA	PR upper TA↑ (p=0.026), BF↑ (p=0.043), GC↑ (p=0.040); lower TA↑ (p=0.041), RF↑ (p=0.041)	Players who demonstrated higher activation of TA and PΦ muscles may be less precise. It has been concluded that the activation of the shooting leg muscles represents a significant mechanism which highly contributes to the precision of the football shoot.

Oliver, et al. (2014)	E: JF	M	15, 8	10	Changes in neuro muscular control leg stiffness after the specific football activities	VL BF TA SO	MA MS	MS (26.6 vs. 24.0 kN·m-1, p > 0.05), CoM dis. (r = 0.90, p < 0.01), GRF (r = 0.58, p > 0.05); MA SO (r = 0.64, p < 0.05), VL (r = 0.98, p < 0.05)	After physical exercises, certain changed in the activation of extensor muscles modulate the change in moving the mass center and in stiffness of the leg muscles. Certain changes which decrease pre activation, stopping activity and, consequently, stiffness in muscles of the leg followed by fatigue can increase the risk of injury.
Serner, et al. (2014)	E: PF	M	21, 4	40	EMG evaluation of the hip adduction exercises in football players	AL GME RA EAO	EMG	AL with 14% on 108% EMG (p<0.0001); in 3 out of 8 exercises (35–48%, p<0.0001); RA with 5% on 48% EMG (p<0.001)	Hip adduction exercises with the elastic band can be dynamic high intensity exercises that can be easily performed in any institution and could, therefore, be relevant for including in future prevention and rehabilitation programs.
Girard, et al. (2015)	E: PF	M	27 ±1	17	Neuro muscle fatigue after the match in mild and hot climate	SO	MA MVC RFD	E: SO↓ -1.5% (p<0.05), PPT↓ -16.5% (p<0.05), F30↓, F50↓, F70↓ (p<0.05)	Changes in maximum willing activation of plantar inflexions were moderate and not different after the match in mild and hot weather conditions.
Campayo-Piernas, et al. (2017)	E1: VIF E2: F C: VIS	M	24, 4	28	Role of eye sight in the instable balance tasks and difference between visually impaired and football players with healthy eye sight	RF PL TA GCL	EMG	PC1=53.96%, PC2=17.41%, PC3=12.77%; PC1 E2 EMG↓ (dg=0.72), K EMG↓ (dg=0.49), PC2 and PC3 no difference between groups	Regarding the neuro muscular behavior, 3 main patters explained 84,15% of total differences in gathered data, namely: PC1-size and shape of the activation amplitude pattern, PC2- relation between flexors and extensors, and PC3-relation between pronation and sub pronation. Improvement of other senses due to the visual imparity does not enable better balance of visually impaired players than healthy football players and visually impaired students when playing with closed eyes. Visually impaired players increase the muscle co activation as a safety strategy, but this behavior is no different from players with healthy eye sight when playing with closed eyes.

Schuerman, et al. (2017)	E: F C: F	M	24.3	51	Examination of the impact of the proximal neuro muscular control on the knee injury prevention	HM GMA TM	MVC	GMA↑ flight phase(P= 0.027); TM↑ flight phase (P=0.042); HM↓ pain with 20% on 6% (P<0.024)	It seems that muscle activity during the explosive running is connected with the hamstrings injury occurrence in football players. Better control of GMA and TM muscle activation during the plying phase in running, is connected with the lower hamstrings injury risk. Present results offer a base for the improvement of rehabilitation and prevention based on evidence, especially by focusing on the increase of the gluteus and abdominal muscles during sports activities.
Privalova, et al. (2019)	E: F	M		12	Testing of function of muscles included in kicking with the leg on the ball	VL VM GCL GCM	AMP FR	VLd>VLl, FR GCd>GCl (p<0.05), AMP GCl>GCd (p<0.05), VL & GM (p<0.05)	Sports training aimed at improving of the leg shooting technique of football players, contributes to forming of functional muscle complexes which participate in the axial rotation lodes and in lateral movement of the knee.
Read, et al. (2019)	E: F	M	28,2	10	Impact of the angle of the knee joint on the muscle activation of the back chain during the isometric test of football players	GMA BF ST GCM	MVC	MVC BF30º>BF90º (31%>22%, p<0.002); GMA (CV% = 36.1 vs. 19.8), GCM (CV% 31 vs.22.6)	90º angle indicated lower variations in performance, especially in gluteus maximus and medial gastrocnemius. Therefore, athletes who use test for the estimation of the leg strength, can give advantage to the 30º angle of the knee joint.

Legend: ACL - Anterior Cruciate Ligament; AL - m.Adductor Longus; AMP – amplitude; APB - m. Abductor Policis Brevis; AR – area underneath the curve potential; ÀV – Angular Velocity; B – Basketball Players; BF - m. Biceps Femoris; CV - Coefficient of Variation; CG – Control Group; CoM dis. - Center of Mass Displacement; DJ - Deep Jump; E (1-2) – Experimental Group; EAO - m. External Abdominal Oblique; EMG – electromyogram; F – Football Players; FF – Female Football Players; FR – Frequency; GCL - m. Gastrocnemius Caput Laterale; GCM - m. Gastrocnemius Caput Mediale; GMA - m.Gluteus Maximus; GME - m. Gluteus Medius; GRF - Ground Reaction Force; H – Handball Players; HM – Hamstrings; H-R - H-Reflex; HRT - Half Relaxation Time; IC - Initial Ground Contact; IL - m. Iliacus; INT – Interminent; JF – Junior Football Players; LHM – Lateral Hamstrings; LV - linear velocity; M – Male; MA – Muscular Activation; MS - Musculus Stiffness; MH - medial hamstrings; MV - M-wave; MVC - Maximal Voluntary Contraction; PC - Principal Component; PF – Professional Football Players; PL - m. Peroneus Longus; PTT - Peak Twich torque/force; QD - m. quadriceps; RA - m. Rectus Abdominis; RF - m. Rectus Femoris; RFD - Rate of Force/Torque Development; RPE - Rating of Perceived Exertion; SE – Sedentary Persons; SO - m. soleus; SPF – Semi - professional Football Players; ST - m. Semitendanosus; TA - m. Tibialis Anterior; TI - Approximation of the EMG Signal's Power; UP - Ultrasound Pennation Angle; TM - Trunk Muscles; VA - Voluntary Activation; VIF - Visually Impaired Football Players; VIS - Visually Impaired Students; VM - m.Vastus Medialis; VL - m. Vastus Lateralis.

DISCUSSION

This systematic review included 20 studies on EMG examination on football players. A total of 387 were included, average of 19 per study. The lowest number of participants was 9, and the highest 51. Examination of muscle activation in football players was mainly related to the lower extremities, and the focus was on the following muscles: m.musculus quadriceps (m.vastus lateralis et medialis 11, rectus femoris 10), m.biceps femoris 12, m.gastrocnemius 11 times, followed by m.tibalis anterior 6 and m. gluteus maximus et medius 6 times. The review has determined quite a heterogenic choice of topics when it comes to the use of the EMG in football players. Some of the studies analyzed acute effects of the football activities, while the others examined the impact on various training programs on muscle activity, as well as the muscle activation while shooting the ball. A lower number of studies examined injuries and causes of injuries, sex differences in muscle activation of football players and so on.

A couple of studies examined the acute effects of football activities. Results indicated that football specific activities caused a reduction in muscle activity (Girard, Nybo, Mohr, & Racinais, 2015; Oliver, Armstrong, & Williams, 2008; Oliver, Croix, Lloyd, & Williams, 2014; Rahnama, Lees, & Reilly, 2006; Thorlund, Aagaard, & Madsen, 2009), force increment rate and a decrease in explosive performance (Oliver, Armstrong, & Williams, 2008; Thorlund, Aagaard, & Madsen, 2009), even though the working rate remained the same (Rahnmana et al., 2006). Thorlund et al. (2009) determined that in the period after the match, a significant decrease in the muscle activation occurs VL for 17% and BF for 31% ($p \leq 0.05$) with an average reduction of QD and HM for 10%, with the decrease of RFD for 9% ($p \leq 0.01$), which negatively impacts the explosive activities. Rahnmana et al. (2006) detected a significantly lower activation of muscles RF, BF and TA after 45 minutes, and especially after 90 minutes football match ($p<0.05$). Differently from the regular match, Oliver et al. (2008) were observing the intermittently specific running that is at the same intensity as in the football match even after 43 minutes of running, the activation was lower in all of the jumps, especially in the in depth jump for muscles VL↓, BF↓, TA↓ ($p<0.05$). Authors determined the negative impact on the movement mechanics as well, leading to the modulation of changes that decrease activation, activity related to the transfer of the mass center and to the stopping of the body (Greig, Mc Naughton, & Lovell, 2006; Oliver et al., 2014). Disturbed mechanics of movements as a consequence has the increase of injury risk in football players (Greig et al., 2006; Oliver et al., 2014). Girard et al. (2015) stipulate that the changes in the maximum willing activation are not different after the competition in mild and hot climate.

The rest of the studies that examined the impact of training were experimental. Football specific strength training led to the increase of the average EMG value in muscles GCM, BF and VM ($p<0.05$), while the maximum isometric strength and sprint time were significantly improved after the training ($p<0.05$) (Manolopoulos, Papadopoulos, & Kellis, 2006). Amiri-Khorasani & Kellis (2013) examined the impact of the dynamic stretching, which proved to be effective in increasing the upper knee muscle activation (VM, VL and RF) and the angle strength in knee joint extension while the ending phase of the shoot. While Serner et al. (2014) stipulated positive impact of training with elastic band on the hip injury prevention. After the hip flexion exercises there was a significant improvement of activation of muscles AL from 14% to 108% EMG ($p<0.0001$) and RA from 5% to 48% EMG ($p<0.001$) and significant improvement in 3 out of 8 exercises (35–48%, $p<0.0001$). The only study that compared football players with other athletes, detected significant increase of impulse amplitude of GCL and GCM muscles and in the group KO+OD and in football players, with the conclusion that in the end volleyball and basketball trainings contribute more to the neuromuscular differences in the upper and lower extremities (Kaygusuz, et al. 2005).

A couple of studies analyzed football shoot level of activation. Football training is aimed at improving the shooting technique as it contributes to development of the functional core muscles that improve football shooting performance (Manolopoulos et al., 2006; Privalova et al., 2019). While striking the ball with both legs, a higher activation of right leg muscle VL was detected compared to the left leg ($p<0.05$), while GC of the right leg had higher frequency, but lower amplitude than the GC of the left leg ($p<0.05$), followed by the established connection between VL & GM muscles ($p<0.05$) (Privalova, et al. 2019). Cerrah et al. (2011) have, by using EMG, established significant differences between professional and amateur athletes in the activation of muscles RF, BF, VM, VL and GC (p<0.05), by proving that the difference was not based on the strength factor, except for the GCM muscle, but on the subtle differences in technique, related to the precision. Katis et al. (2013) stipulate that players who demonstrate higher muscle activation of TA and RF might demonstrate lower precision. Additionally, they noticed that activation of the shooting leg muscles significantly improves the shooting precision. Brophy et al. (2010) detected higher activation of standing leg in men, of VM, GME and GMA (VM 124% >55%, p=0.005; GME 113%>69%, p=0.002; GMA 139%>78% p=0.07) and IL (IL 123%>34%, p=0.0007) muscles of the stroking leg compared to women in sidekicks. This can be related to the higher risk of anterior cruciate ligament injuries in women.

A few studies examined causes of injuries in football players. Schuermans et al. (2017) examined muscle activity during the explosive running and its relation with the hamstrings injuries in football players. They concluded that the higher level of muscle activation of GMA (p= 0.027) and TM (p=0.042) during the flying phase is connected to the lower risk of hamstrings injuries. Greig et al. (2006) examined the causes of a decreased injury incidence in the final match phases and concluded that the main cause was a disturbed mechanic of movement, and not in the physiological stress. Looking at the sex differences, Beaulieu, Lamontagne & Xu (2008) stipulate that female athletes have a different strategy of motor units recruitment. There are significant differences in the lower frequency of EMG in the signal of the LHM muscle, as well as in the exposure of the ACL to higher load. No difference between men and women was found in ST, GCM, GCL muscle activation (P>0.05), higher activation was achieved in men in VL and VM (P=0.01), as well as in the whole duration of activation of VL, RF и VM. Women achieve maximum muscle BF activation significantly faster, and later of TA muscle compared to men. These information could play significant role in explaining ACL injury rate between sexes.

While examining differences between men and women football players in long jump muscle activation, a group of authors noticed that only the activation in the GME muscle (7.16>2.62, p=0.002) was significantly higher in men than in women, while no difference regarding any other muscle was found (Hart, Garrison, Kerrigan, Palmieri-Smith, & Ingersoll, 2007). In his study Beaulieu et al. (2008) found the difference only in the LHM muscle, while Brophy et al. (2010) determined higher activation of VM, GME and GMA muscles of standing leg and IL muscle of striking leg in men. Authors did not look for a connection between previously mentioned parameters and football performance, but mainly researched their impact on occurrence of injuries. Listed sex differences could be related with the higher injury risk. The rest of the studies examined various topics so, for example, Campayo-Piernas, Caballero, Barbado, & Reina, (2017) examined differences between visually impaired football players and those with healthy eye sight. Even though they started the research with the premise that visually impaired players, due to visual limitations, have developed other senses, the study showed that it did not enable them better balance than players with healthy eye sight when playing with their eyes closed. Additionally, they determined 3 main patterns which explain 84.15% of the total number of changes in the neuromuscular behavior, namely PC1 (53.96%) - size and shape of the activation amplitude pattern, PC2 (17.51%) - connection between flexor and extensor, and PC3 (12.77%) – connection between pronation and supination. Chauhan, Hamzeh, & Cuesta-Vargas, (2013) detected strong relation between EMG muscle activity and muscle density. These findings suggest that measures based on EMG can be used for forecasting muscle strength, as well as that measurements based on the ultrasound can be useful for forecasting EMG muscle activation. A group of authors detected, by using the isometric squat test, that higher activation is achieved at the 30º angle flexion of the knee joint than at the 90º angle flexion of the back muscle chain that BF, GMA and GCM (Read, Turner, Clarke, Applebee, & Hughes, 2019).

Analysis of the results obtained so far confirm the thesis of Clarys (2000) that the areas of implementation of EMG in sports are very different. Namely, in previously mentioned cases, a couple of different research areas were segregated: acute effects of the football specific activity, football specific strength exercises, training of kicking on the ball, sex differences and so on. Based on the information provided, multiple use of EMG in football were indicated.

CONCLUSION

This systematic review was aimed at detecting multiple roles of EMG in football. Review included 20 studies that examined football players using EMG. Examination of muscle activation of football players was mostly related to the lower extremities, with the focusing on:

- m.musculus quadriceps
- m.biceps femoris
- m.gastrocnemius
- m.tibalis anterior
- m.gluteus

It was noticed that studies that examined muscle activation using EMG included very heterogenic topics, therefore by achieving various results. Achieved results were grouped by topics.

1) Acute effects of the football specific activities:

- decrease of muscle activity
- decrease of force increment rate
- decrease of explosive performances
- disturbing of the mechanic of movement
- reflecting on the working rate

2) Impact of football strength training led to:

- increase of average EMG value in GCM muscle
- improvement of the maximum isometric strength
- sprint time improvement

3) Training of kicking on the ball impacted:

- increase of football shoot performances
- subtle differences in shooting technique
- players with higher activation of TA and RF proved to be less precise
- no impact of the strength

4) Sex based differences:

- activity of GME was significantly higher in men than in women
- higher activation of VM, GME and GMA of standing leg in men
- higher activation of GMA and TM during the running flying phase in men

5) Other obtained results:

- dynamic stretching impacts the increase of MA and UB upper knee extensors
- exercises with elastic band impact the adductor injury prevention
- volleyball and basketball trainings improve neuro muscle differences more than football training
- visually impaired players do not have better balance than players with the healthy eye sight
- a strong relation between EMG activity and muscle strength was determined

Summarizing the obtained results provides and insight in the multiple purpose of electromyogram in football. Achieved results were grouped in common topics. Certain studies analyzed the acute effects of football activity, others examined the impact of different training techniques on muscle activity, as well as muscle activation while kicking with the leg. Lower number of studies examined causes of injuries, sex differences in muscle activation and so on.

Based on the information provided, multiple use of EMG in football was detected. Moreover, a wide range of EMG use was confirmed, in order to provide clearer insight in the neuro muscle activation of football players.

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THE USE OF ELECTROMYOGRAM IN FOOTBALL SYSTEMATIC REVIEW

SAŽETAK

Cilj ove pregledne studije bio je da ukaže na primenu elektromiografa u fudbalu. Za pretraživanje literature korišćene su sledeće elektronske baze podataka: Google Scholar, PubMed, Medline, Mendeley u periodu od 2005. do 2019. godine. Nakon procedure selekcije radova u odnosu na odgovarajuće kriterijume, odabrano je 20 studija koje odgovaraju potrebama ovog sistematskog preglednog istraživanja. Mišići koji su najviše bili ispitivani su: m.musculus quadriceps, m.biceps femoris, m.gastrocnemius, m.tibalis anterior i m. gluteus maximus. Pregledom je uočen prilično heterogen izbor tema kada je u pitanju uloga EMG u fudbalu, pa su i njihovi ostvareni rezultati grupisani prema određenim karakteristikama. S tim u vezi rezultati su razvrstani prema sledećim temama: akutni efekti specifične fudbalske aktivnosti, uticaj fudbalskog treninga snage, trening udaraca po lopti nogom, rezultati u odnosu na polne razlike i ostale teme koje nije bilo moguće razvrstati u pomenute grupe. Sumiranjem dosadašnjih rezultata stiče se uvid u višestruku primenu EMG u fudbalu sa ciljem što kvalitetnije analize neuro-mišićne aktivacije.

Ključne reči: *EMG, elektromiograf, mišići, fudbal.*

Received : 04.11.2020.
Approved: 12.11.2020.

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