Stefan Pandurović¹, Vladimir Pantoš², Biljana Đurić³,
Nikola Topalović⁴, Rada Jeremić⁵, Marina Đelić⁶, Dejan Nešić⁷,
Sanja Mazić⁸

ISPITIVANJE UTICAJA VRSTE SPORTA NA UČESTALOST ELEKTROKARDIOGRAFSKIH PROMENA KOD STUDENATA MEDICINSKOG FAKULTETA KOJI SE BAVE SPORTOM

Sažetak: Kontinuirana fizička aktivnost dovodi do serije adaptivnih promena kardiovaskularnog sistema sportista, zajednički nazvanih sportsko srce. Distinkcija tako nastalih fizioloških promena na EKG-u od patoloških nalaza na miokardu značajna je u prevenciji iznenadne srčane smrti sportista.

Cilj ove studije bio je da ispita uticaj vrste sporta na učestalost elektrokardiografskih promena, između dve grupe ispitanika, od kojih jedni treniraju fudbal a drugi odbojku.

Studija uključuje 47 ispitanika, studenata i studentkinja Medicinskog fakulteta, Univerziteta u Beogradu, podeljenih u dve grupe zavisno od vrste sporta kojim se bave. Prvu grupu čini 29 odbojkaša, a drugu 18 fudbalera. Ispitanicima su izmereni antropometrijski parametri: telesna visina (TV), telesna masa (TM), indeks telesne mase (*BMI*) i procenat telesnih masti (*%BF*). Elektrokardiografsko testiranje vršeno je u miru, u ležećem položaju, korišćenjem dvanaestokanalnog elektrokardiograma. Iz dobijenih elektrokardiograma, upotrebom Sijetlovskog kriterijuma, analizirani su: srčana frekvencija, ritam, ritmičnost, respiratorna aritmija, električna osovina srca, trajanje i amplituda pojedinačnih talasa, segmenata i intervala, *QTc* interval, uvećanje desne i leve pretkomore, izolovani voltažni kriterijumi za postojanje hipertrofije leve, kao i desne komore, inkompletni blok desne grane, AV blok prvog stepena, AV blok drugog stepena – *Mobitz* tip I (*Wenckebach*), inverzija T talasa. Statistička

¹ Stefan Pandurović, Laboratorija za medicinu sporta i terapiju vežbanjem, Institut za medicinsku fiziologiju „Rihard Burijan“, Medicinski fakultet Univerziteta u Beogradu, stefan.pandurovic@gmail.com

analiza podataka izvršena je korišćenjem Studentovog T testa za zavisne uzorke i Hi kvadrat testa nezavisnosti, u okviru paketa *SPSS*.

Rezultati studije pokazuju prosečno veće vrednosti amplitude P talasa u V_1 odvodu u grupi ispitanika koji treniraju fudbal ($p=0,015$), uz statistički značajnu razliku u učestalosti inverzije T talasa u odvodima $V_1 - V_3$ ($p=0,048$) u istoj grupi ispitanika. Ispitanici koji treniraju odbojku pokazuju statistički značajno veću učestalost uvećanja leve pretkomore ($p=0,019$).

Na osnovu prezentovanih rezultata možemo zaključiti da uočene promene u EKG-u ukazuju da različite vrste sporta mogu dovesti do promena u električnoj aktivnosti sprovodnog sistema srca i srčanog mišića.

Ključne reči: sportsko srce, fizička aktivnost, vežbanje, elektrokardiografija, Sijetlovski kriterijum

Abstract: Continuous physical activity leads to the series of adaptive changes to athletes' cardiovascular system, collectively called Athlete's heart. Recognising such physiological ECG changes and distinguishing them from the pathological myocardium-related findings, play an important role in sudden cardiac death prevention among athletes.

The aim of our study was to examine the effect of the type of sport on the frequency of electrocardiographic changes between two groups of subjects, football and volleyball players.

The study included 47 subjects, students of the University of Belgrade, School of Medicine, divided into two groups depending on type of sport they play. The first group consisted of 29 volleyball players, while the second group consisted of 18 football players. Anthropometric parameters: body height (BH), body weight (BW), body mass index (BMI), body fat percentage (%BF) were measured first. Resting electrocardiographic test was performed in supine position, using twelve-lead electrocardiograph. From obtained electrocardiograms, using the Seattle criteria for interpretation of ECG findings in athletes, following parameters were analyzed: heart rate, heart rhythm, rhythmicity, respiratory arrhythmia, cardiac axis, duration and amplitude of individual waves, segments and intervals, QTc, right and left atrial enlargement, isolated voltage criteria for left and right ventricular hypertrophy, incomplete right bundle-branch block, first degree AV block, second degree AV block-Mobitz type I (Wenckebach), T wave inversion. Statistical analysis was performed using paired T test and Chi square test of independence, within the *SPSS* package.

Study showed on average higher values of amplitude of P wave in the V_1 lead among football players ($p=0.015$), alongside significant difference in frequency of T wave inversion in leads V_1-V_3 ($p=0.048$).

Volleyball players demonstrated significantly higher frequency of left atrial enlargement ($p=0.019$).

Based on presented results, we can conclude that observed ECG changes indicate that different types of sports may lead both to changes in electrical activity of cardiac conduction system and myocardium.

Keywords: athlete's heart, physical activity, physical exercise, electrocardiography, Seattle criteria

Uvod

Fizička aktivnost je definisana kao svaki pokret tela nastao kontrakcijom skeletne muskulature i koji dovodi do potrošnje energije. Vežbanje je vrsta fizičke aktivnosti sastavljeno iz planiranih, definisanih i repetitivnih pokreta koji se izvode sa ciljem unapređenja ili održanja jedne ili više komponenti fizičke sposobnosti. [1] Organizovano bavljenje fizičkom aktivnošću koje je orijentisano ka postizanju rezultata i uređeno nizom pravila definiše se kao sport. Sportska aktivnost uglavnom ima takmičarski karakter – profesionalno (sportisti) ili amaterski (rekreativno bavljenje sportom). Profesionalni sportisti treniraju duže i višim intenzitetom od rekreativnih sportista. [2] Značaj fizičke aktivnosti je višestruk. U neke od istih ubrajaju se: pravilan rast i razvoj dece [3], smanjenje rizika za nastanak hroničnih nezaraznih bolesti (arterijska hipertenzija, diabetes mellitus, maligna oboljenja), poboljšanje mentalnog zdravlja [4], redukcija telesnih masti ($\%BF$), uspostavljanje i održanje optimalne telesne mase [5, 6].

Usled kontinuirane fizičke aktivnosti kardiovaskularni sistem razvija seriju adaptivnih, fizioloških odgovora u organizmu sportiste, zajedničkim imenom nazvanih sportsko srce. Stepen i vrste promena koreliraju sa starošću, polom sportista, kao i vrstom sporta kojim se sportista bavi. [7] Ono podrazumeva kako morfološke tako i funkcionalne i elektrofiziološke adaptacije, koje se pri standardnom sportsko-medicinskom pregledu mogu elektrokardiografski uočiti. Značaj poznavanja ovako nastalih, fizioloških EKG promena je njihova distinkcija od patoloških nalaza koji povećavaju rizik od iznenadne srčane smrti (engl. *Sudden cardiac death* – *SCD*). Prevencija *SCD* se postiže isključenjem sportiste iz trenažnog procesa, jer je *SCD* vodeći uzrok smrti sportista na terenu. [7, 8] U cilju pravilne interpretacije EKG nalaza kod sportista, 2012. godine usvojen je u Sijetlu standardizovan kriterijum (*Seattle Criteria*), korišćen u ovoj studiji, kojim su prikazani fiziološki nalazi na EKG-u, nalazi nastali kao posledica srčane adaptacije na fizičku aktivnost, kao i abnormalni nalazi sugestivni na postojanje patoloških promena na srčanom mišiću koji zahtevaju dalju dijagnostičku evaluaciju. [9] Najčešće fiziološke EKG promene uočavane kod sportista su sinusna bradikardija, sinusna aritmija, ektopični atrijski ritam, AV blok prvog stepena, AV blok drugog stepena – *Mobitz* tip I (*Wenckebach*), inkompletni blok desne grane,

izolovani voltažni kriterijum za hipertrofiju leve komore, rana repolarizacija. [9] Najčešća karakteristika sportskog srca je uvećanje miokardne mase i praktično svih srčanih šupljina, a najpre hipertrofija leve komore [7], proporcionalno ekstenzivnoj nutritivnoj i oksidativnoj potražnji skeletne muskulature tokom fizičke aktivnosti, a u cilju povećanja minutnog volumena. Minutni volumen se uvećava na račun udarnog volumena, što objašnjava komorsku hipertrofiju kao fiziološku adaptaciju. [10, 11] Najčešći uzrok *SCD* kod sportista je hipertrofična kardiomiopatija [8], iz čega proističe važnost njene distinkcije od fiziološki nastale komorske hipertrofije, što može predstavljati pravi dijagnostički izazov. [12]

Cilj ove studije bio je da se analizira uticaj vrste sporta na učestalost elektrokardiografskih promena, između dve različite grupe ispitanika, studenata Medicinskog fakulteta Univerziteta u Beogradu, od kojih jedni treniraju fudbal a drugi odbojku.

Materijal i metode

Ispitanici

U istraživanju je učestvovalo ukupno 47 ispitanika, studenata i studentkinja Medicinskog fakulteta Univerziteta u Beogradu, takmičara Univerzitetske lige. Ispitanici su, u zavisnosti od vrste sporta kojim se bave, podeljeni u dve grupe. Prvu grupu su činila 29 odbojkaša, od čega 12 muškog a 17 ženskog pola, uzrasta od 19 do 26 godina ($22,7 \pm 1,8$ godina), koji se sportom aktivno bave tokom 3–15 godina trenirajući od 1 do 8 časova nedeljno. Drugu grupu su činila 18 fudbalera, od čega 8 muškog a 10 ženskog pola, uzrasta od 21 do 27 godina ($24,5 \pm 1,9$ godina), koji aktivno treniraju tokom perioda od 1 do 19 godina, 1 do 4,5 časova nedeljno. Kriterijum za uključivanje ispitanika u studiju bio je aktivno, takmičarsko bavljenje sportom i učešće u Univerzitetskoj ligi. Sve procedure izvedene su u skladu sa Helsinškom deklaracijom. Protokol studije je odobren od strane Etičke komisije Medicinskog fakulteta, Univerziteta u Beogradu. Svi ispitanici su detaljno upoznati sa procedurom pregleda i protokolom studije i svojim potpisom su dali informisani pristanak za učestvovanje u ovoj studiji.

Materijal i metode

Merenja ispitanika obavljena su u prepodnevnom časovima, u Laboratoriji za medicinu sporta i terapiju vežbanjem Instituta za medicinsku fiziologiju, Medicinskog fakulteta, Univerziteta u Beogradu, na temperaturi komfora ($18\text{--}22\text{ }^{\circ}\text{C}$), pri vrednosti atmosferskog pritiska od 760 mmHg i relativnoj vlažnosti vazduha od 30 do 60%. Na samom početku istraživanja, svim ispitanicima izmereni su sledeći antropometrijski parametri: telesna visina (TV) izražena u centimetrima, korišćenjem standardnog laboratorijskog visinometra (*Seca 214 Portable Stadiometer, Cardinal Health, Ohio, USA*). Odmah potom određivana je telesna masa (TM), izražena u kilogramima,

indeks telesne mase (*Body mass index – BMI*) i procenat telesnih masti (%BF), pomoću bioimpedacionog analizatora telesnog sastava (*InBody 230 Body Composition Analyzer, Seoul, Korea*).

Ispitanici su zatim podvrgnuti elektrokardiografskom testiranju u miru, u ležećem položaju, koristeći dvanaestokanalni elektrokardiograf (*Cardioline Delta 3 Plus Digital ECG Machine, Italia*), standardne brzine kretanja trake od 25 mm/s, baždaren tako da 1 mm visine talasa odgovara vrednosti 0,1mV, što korespondira sa amplitudom talasa, dok 1 mm dužine trajanja talasa odgovara vrednosti od 0,04s. Iz tako dobijenih elektrokardiograma, a shodno Sijetlovskim kriterijumima (*Seattle Criteria, 2012*) [9] za EKG interpretaciju kod sportista, posmatrani su sledeći parametri: srčana frekvencija (*Heart rate – HR*), ritam, ritmičnost, respiratorna aritmija, električna osovina srca, trajanje i amplituda pojedinačnih talasa, segmenata i intervala, *QTc* interval, uvećanje desne pretkomore (*RAE – Right atrial enlargement*), uvećanje leve pretkomore (*LAE – Left atrial enlargement*), izolovani voltažni kriterijumi za postojanje *LVH* (*Left ventricular hypertrophy*) i *RVH* (*Right ventricular hypertrophy*), inkompletni blok desne grane (*IRBBB – Incomplete right bundle branch block*), AV blok prvog stepena, AV blok drugog stepena – *Mobitz tip I* (*Wenckebach*), inverzija T talasa (*TWI – T wave inversion*).

Srčana frekvencija dobijena je deljenjem broja 1.500 (broj milimetara koje milimetarska traka pređe za 60s, kretajući se brzinom od 25 mm/s) sa brojem milimetara koji odgovara rastojanju između dva uzastopna R talasa (R-R interval). Ritam je određen prisustvom ili, pak, odsustvom P talasa pre svakog QRS kompleksa. Za određivanje ritmičnosti srčane aktivnosti korišćen je broj milimetara između dva sukcesivna R talasa, a u cilju određivanja vremenskog odstojanja između dve ventrikularne sistole. Respiratorna (sinusna) aritmija, kao varijacija normalnog sinusnog ritma, zapažana je kao naizmenično ubrzanje pa usporenje srčane aktivnosti, što odgovara inspirijumu i ekspirijumu respektivno, tokom respiratornog ciklusa, a zapaža se kao nejednak R-R interval. Električna osovina srca (srednji QRS vektor) izračunata je pomoću referentno uzetog troosnog i šestoosnog sistema dobijenog ukrštanjem osovina tri standardna i tri unipolarna ekstremitetna odvoda (frontalna ravan), a pomoću Ajnthovenovog zakona, prema kojem je zbir voltaža QRS kompleksa I i III odvoda (pozitivna voltaža R talasa umanjena za negativnu voltažu Q i S talasa) jednak zbiru voltaža QRS kompleksa II odvoda. Trajanje pojedinačnih talasa, segmenata i intervala određivani su množenjem broja milimetara sa 0,04s (što odgovara vrednosti 1 mm u horizontalnoj skali), dok je amplituda dobijena množenjem broja milimetara sa 0,1mV (što odgovara vrednosti 1 mm u vertikalnoj skali). *QTc* interval (*QT interval corrected for heart rate*) dobijen je primenom *Bazzett*-ove korektivne formule kao količnik vrednosti QT intervala i kvadratnog korena RR intervala, oba izražena u milisekundama (ms). Kao pokazatelj postojanja uvećanja desne pretkomore (*RAE*) uzeta je amplituda P talasa $\geq 2,5$ mV u donjim EKG odvodima – II, III, aVF, bez promena u njegovom trajanju, dok je za

kriterijum uvećanja leve pretkomore (*LAE*) uzet bifazičan P talas u V_1 čiji završni deo pokazuje negativnu defleksiju ≥ 1 mm ispod izoelektrične linije, uz trajanje $\geq 0,04$ s. Izolovani voltažni kriterijum za *LVH* i *RVH* je *Sokolow–Lyon index*. Za *LVH* to je suma amplitude S talasa u V_1 i R talasa u $V_5 \geq 3,5$ mV, dok je za *RVH* to suma amplitude S talasa u V_6 i R talasa u $V_1 \geq 10,5$ mV, uz skretanje električne osovine srca udesno. Dominantan dijagnostički kriterijum za inkompletni blok desne grane je prisustvo RSR' obrasca u prva dva prekordijalna odvoda (V_1 i V_2). AV blok prvog stepena karakterisan je prolongiranim PR intervalom ≥ 200 ms. AV blok drugog stepena, *Mobitz* tip I – *Weckenbach*, uočavan je progresivnim prolongiranjem svakog sukcesivnog PR intervala, sve do izostanka kondukcije jednog P talasa kroz AV čvor što se zapaža postojanjem P talasa uz izostanak QRS kompleksa. *TWI* je posmatran u prekordijalnim odvodima $V_1 - V_3$ kao signifikantan ukoliko je negativna defleksija ≥ 1 mm.

Statistička analiza

Prikazani rezultati dobijeni su metodama standardne deskriptivne statistike, a iskazani su kao aritmetička sredina ($\bar{X}$) $\pm$ standardna devijacija (SD), kao i učestalost ispitanika kod kojih postoji ispitivani parametar. U svrhu obrade antropometrijskih podataka, kao i svih numeričkih podataka u sklopu interpretacije EKG zapisa, korišćen je Studentov T test za dva zavisna uzorka, dok je za obradu nominalnih podataka korišćen Hi kvadrat test nezavisnosti. Testovima je dokazivano postojanje statistički značajne razlike u vrednostima parametara među ispitanicima koji treniraju fudbal i onih koji treniraju odbojku, pri čemu je vrednost $p < 0,05$ smatrana statistički značajnom. Statističke analize izvršene su korišćenjem *Statistic package for social sciences 22 IBM U.S.A (SPSS22)* programa.

Rezultati

U Prilogu I dati su antropometrijski parametri ispitanika ženskog pola: TM, TV, BMI i %BF. Statistički značajna razlika nije uočena u ispitivanim parametrima između ispitanica koje treniraju fudbal i onih koje treniraju odbojku.

Prilog II prikazuje antropometrijske parametre ispitanika muškog pola: TM, TV, BMI i %BF. Ne postoji statistički značajna razlika u vrednostima ovih parametara između ispitanika koji treniraju fudbal i onih koji treniraju odbojku.

Analizirani EKG parametri svih ispitanika prikazani su u Prilogu III. Među ispitanicima koji treniraju fudbal i onih koji treniraju odbojku uočena je statistički značajna razlika u vrednostima amplitude P talasa u V_1 ($p < 0,05$). P talas u prvom prekordijalnom odvodu pokazuje prosečno veće vrednosti amplitude kod ispitanika

koji treniraju fudbal ($0,1 \pm 0,04$ mV), u odnosu na ispitanike koji treniraju odbojku ($0,08 \pm 0,03$ mV) dok su vrednosti ostalih parametara – *HR*, *QTc* interval, *LVH* i *RVH*, bez uočene statistički značajne razlike među navedene dve grupe ispitanika.

U Prilogu IV su prikazani EKG parametri ispitanika očitani iz II standardnog odvoda, a koji se odnose na trajanje i amplitudu pojedinačnih talasa, segmenata i intervala. Među navedenim parametrima: trajanje P talasa, voltaža P talasa, PR interval, trajanje QRS kompleksa, QT interval, PQ segment, ST segment, voltaža Q talasa, voltaža R talasa, voltaža S talasa i voltaža QRS kompleksa, nisu uočene statistički značajne razlike među ispitanicima koji treniraju fudbal i onih koji treniraju odbojku.

Podaci prikazani u Prilogu V odnose se na promene na EKG zapisu uslovljene fizičkim vežbanjem. Statistički značajna razlika ($p < 0,05$) uočena je u učestalosti pojave *LAE* kod ispitanika koji treniraju fudbal (10) u odnosu na ispitanike koji treniraju odbojku (25), kao i u pojavi inverzije T talasa (*TWI*) u prva tri prekordijalna odvoda, koja je nađena kod 7 ispitanika koji treniraju fudbal i 4 ispitanika koji treniraju odbojku ($p < 0,05$). U frekvenci javljanja *IRBBB* i *RAE* nije nađena statistički signifikantna razlika među navedene dve grupe ispitanika. Ni kod jednog ispitanika analizom EKG zapisa nisu uočeni AV blok prvog stepena, AV blok drugog stepena – *Mobitz* tip I (*Wenckebach*), kao ni pojava respiratorne aritmije.

Diskusija

Rezultati naše studije pokazali su postojanje sledećih, od značaja, fizioloških promena na EKG među ispitanicima, shodno *Seattle criteria* [9] interpretaciji, i to: sinusna bradikardija, *LVH*, *RAE*, *LAE*, *IRBBB*, *TWI*. Statistički značajna razlika, između dve grupe ispitanika, uočena je samo u učestalosti javljanja *LAE* i *TWI*, kao i amplitudi P talasa u V_1 .

Karagjozova et al. [13] pokazali su povezanost između vrste sporta, shodno *Mitchell*-ovoj klasifikaciji [14] sa frekvencijom i stepenom fizioloških EKG promena nađenim kod sportista. Karagjozova et al. [13] su takođe pokazali da su nastale promene na EKG-u, uslovljene fizičkim vežbanjem (sinusna bradikardija, AV blok prvog stepena, rana repolarizacija, respiratorna aritmija, *IRBBB*), a kao rezultat povećanog vagalnog tonusa, karakteristične za sportove, kakvi su fudbal i odbojka, što je u suprotnosti sa rezultatima drugih autora [15,16], uključujući i našu studiju. Osim incidence *IRBBB* uočene u oko 50% naših ispitanika, ostatak navedenih promena ostao je nezapažen. Uočena učestalost javljanja *IRBBB* približno je ista učestalosti nađenim u studijama drugih autora (35–50%), a nastaje kao posledica remodelovanja desne komore i kašnjenja u sprovođenju impulsa kroz desnu granu AV snopa, usled pojačane plućne funkcije. [16–18] Povezanost između uticaja vrste sporta i učestalosti pojedinih EKG obrazaca nalaze Pelliccia et al. [19], čiji rezultati pokazuju najveću

učestalost javljanja *IRBBB* u populaciji fudbalera i odbojkaša, što je u saglasnosti sa rezultatima našeg istraživanja.

Nasuprot našoj studiji, dve studije: Huttin-a i Pambo-a [20,21], baveći se analizom EKG nalaza posebno kod fudbalera, pokazale su visoku učestalost sinusne bradikardije, AV bloka prvog stepena, produženog ili skraćenog *QTc* intervala, *LVH* i nisku učestalost *IRBBB*. Slično rezultatima koje smo prikazali, uočena je visoka učestalost *TWI* u anteroseptalnim odvodima ($V_1 - V_3$), koja se smatra patološkim nalazom [9], te zahteva dalju dijagnostičku analizu i evaluaciju (ehokardiografija, *MRI* srca), imajući u vidu da je, prema Schnell-u, pojava *TWI* asocirana sa visokom prevalencom predisponirajućih stanja za nastanak *SCD* (do 45% slučajeva sa pozitivnim EKG nalazom), od kojih je najčešća hipertrofična ili aritmogena kardiomiopatija. [8, 12, 22]

Iako čest adaptacijski fenomen, sa učestalošću u preko 50% ispitanika u studijama drugih autora, frekvenca javljanja *LVH*, dobijena po izolovanom voltažnom kriterijumu *Sokolow-Lyon index*, bila je izrazito niska među ispitanicima u ovoj studiji. [15, 18, 23]

LAE predstavlja izuzetno redak nalaz u studijama gorepomenutih autora [15, 18, 23], dok je ista prisutna kod ukupno 35 naših ispitanika. *Seattle* klasifikacija je svrstava među abnormalne nalaze, i time implicira neophodnost dalje dijagnostičke evaluacije. Međutim, rezultati studija pojedinih autora, poput Król-a [24], nalažu da je uvećanje leve pretkomore još jedan u nizu elemenata koji čine sportsko srce, veće učestalosti u sportovima sa nižom dinamičkom a višom statičkom komponentom, što može objasniti prikazanu statističku razliku u okviru naše studije, gde je pojava *LAE* učestalija kod ispitanika koji treniraju odbojku.

Ograničenje ove studije prevashodno predstavlja nekorišćenje ostalih dijagnostičkih metoda za procenu srčane funkcije, uz elektrokardiografiju. Za puno razumevanje svih aspekata srčanog remodelovanja uzrokovanog fizičkim vežbanjem, pored standardnog dvanaestokanalnog elektrokardiografskog testiranja (EKG-a), indikovana je upotreba imidžing metoda, poput ehokardiografije ili *MRI*. [7] Napomenuto je važno zbog moguće niske senzitivnosti i specifičnosti EKG nalaza, pogotovo u diferencijalnoj dijagnostici mogućih stanja koja povećavaju rizik za nastanak *SCD*, među kojima su najčešće kardiomiopatije. [9,12] Zbog svega navedenog ispitanike sa *LAE* i *TWI* u našoj studiji potrebno je podvrgnuti dodatnoj dijagnostičkoj evaluaciji.

Zaključak

Rezultati naše studije pokazali su postojanje statistički značajne razlike među dve grupe ispitanika, u dva ispitivana parametra: *LAE* i *TWI*, dok su preostali parametri, uključujući i one koji predstavljaju čest nalaz, a uslovljeni su fizičkim vežbanjem, bez uočene statistički značajne razlike. Veća učestalost *LAE* kod ispitanika koji treniraju odbojku mogla bi ukazati na veći stepen remodelovanja leve pretkomore. Učestalija pojava *TWI*

kod ispitanika koji treniraju fudbal mogla bi biti indikativan znak većeg stepena remodelovanja leve komore ili znak hipertrofične kardiomiopatije. Na osnovu prikazanih rezultata možemo zaključiti da uočene promene u EKG-u ukazuju da različite vrste sporta mogu dovesti do promena u električnoj aktivnosti sprovodnog sistema srca i srčanog mišića.

Literatura

1. Dean A, Sciences H, Kingston RI, Island R, Edith PC, Heart BF, et al. Advanced fitness assessment & exercise prescription. Vol. 35, Choice Reviews Online. 1998: 35–6295.
2. Mazić S. Exercise as a therapy. *Med Podml.* 2016; 67(2): 1–4.
3. Alves JGB, Alves GV. Effects of physical activity on children's growth. *J Pediatr (Rio J).* 2019; 95: 72–8.
4. Warburton DER, Bredin SSD. Health benefits of physical activity: A systematic review of current systematic reviews. *Curr Opin Cardiol.* 2017; 32(5): 541–56.
5. Westerterp KR. Exercise, energy balance and body composition. *Eur J Clin Nutr.* 2018; 72(9): 1246–50.
6. Swift DL, McGee JE, Earnest CP, Carlisle E, Nygard M, Johannsen NM. The Effects of Exercise and Physical Activity on Weight Loss and Maintenance. *Prog Cardiovasc Dis.* 2018; 61(2): 206–13.
7. De Innocentiis C, Ricci F, Khanji MY, Aung N, Tana C, Verrengia E, et al. Athlete's Heart: Diagnostic Challenges and Future Perspectives. *Sport Med.* 2018; 48(11): 2463–77.
8. Emery MS, Kovacs RJ. Sudden Cardiac Death in Athletes. *JACC Hear Fail.* 2018; 6(1): 30–40.
9. Drezner JA, Ackerman MJ, Anderson J, Ashley E, Asplund CA, Baggish AL, et al. Electrocardiographic interpretation in athletes: The "Seattle Criteria". *Br J Sports Med.* 2013; 47(3): 122–4.
10. Elenan C, Giorgio M, Annik L, Giacomo F, Mariangela P. Exercise for Cardiovascular Disease Prevention and Treatment – chapter 8 : The positive effects of exercise in chemotherapy-related cardiomyopathy. *Adv Exp Med Biol.* 2017; 1000: 103–29.
11. Astorino TA, Edmunds RM, Clark A, King L, Gallant RA, Namm S, et al. High-Intensity Interval Training Increases Cardiac Output and V-O₂max. *Med Sci Sports Exerc.* 2017; 49(2): 265–73.
12. Augustine DX, Howard L. Left Ventricular Hypertrophy in Athletes: Differentiating Physiology From Pathology. *Curr Treat Options Cardiovasc Med.* 2018; 20(12).
13. Karagjozova I, Petrovska S, Nikolic S, Maleska-Ivanovska V, Georgievska-Ismail L. Frequency of electrocardiographic changes in trained athletes in the republic of Macedonia. *Open Access Maced J Med Sci.* 2017; 5(6): 708–13.
14. Mitchell JH, Haskell W, Snell P, Van Camp SP. Task force 8: Classification of sports. *J Am Coll Cardiol.* 2005; 45(8): 1364–7.

15. Pelliccia A, Maron BJ, Culasso F, Di Paolo FM, Spataro A, Biffi A, et al. Clinical significance of abnormal electrocardiographic patterns in trained athletes. *Circulation*. 2000; 102(3): 278–84.
16. Corrado D, Pelliccia A, Heidbuchel H, Sharma S, Link M, Basso C, et al. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. *Eur Heart J*. 2010; 31(2): 243–59.
17. Corrado D, Biffi A, Basso C, Pelliccia A, Thiene G. 12-lead ECG in the athlete: Physiological versus pathological abnormalities. *Br J Sports Med*. 2009; 43(9): 669–76.
18. Drezner JA, Fischbach P, Froelicher V, Marek J, Pelliccia A, Prutkin JM et al. Normal electrocardiographic findings: Recognising physiological adaptations in athletes. *Br J Sports Med*. 2013; 47(3): 125–36.
19. Pelliccia A, Culasso F, Di Paolo FM, Accettura D, Cantore R, Castagna W, et al. Prevalence of abnormal electrocardiograms in a large, unselected population undergoing pre-participation cardiovascular screening. *Eur Heart J*. 2007; 28(16): 2006–10.
20. Pambo P, Adu-Adadey M, Ankrah PT, Agbodzakey H, Scharhag J. Electrocardiographic and Echocardiographic Findings in Ghanaian Female Soccer Players. *Clin J Sport Med*. 2020; Publish Ah(00).
21. Huttin O, Selton-Suty C, Venner C, Vilain JB, Rochecongar P, Aliot E. Electrocardiographic patterns and long-term training-induced time changes in 2484 elite football players. *Arch Cardiovasc Dis*. 2018; 111(5): 380–8.
22. Schnell F, Riding N, O’Hanlon R, Lentz PA, Donal E, Kervio G, et al. Recognition and significance of pathological T-wave inversions in athletes. *Circulation*. 2015; 131(2): 165–73.
23. Sohaib SMA, Payne JR, Shukla R, World M, Pennell DJ, Montgomery HE. Electrocardiographic (ECG) criteria for determining left ventricular mass in young healthy men : Data from the LARGE Heart study. *J Cardiovasc Magn Reson*. 2009; 11(1): 9–15.
24. Król W, Jędrzejewska I, Konopka M, Burkhard-Jagodzińska K, Klusiewicz A, Pokrywka A, et al. Left Atrial Enlargement in Young High-Level Endurance Athletes – Another Sign of Athlete’s Heart? *J Hum Kinet*. 2016; 53(1): 81–90.

PRILOG I

Tabela 1. Antropometrijski parametri ispitanika ženskog pola

	Fudbal (n = 10)	Odbojka (n = 17)	p
Telesna masa (kg)	61,8 ± 7,8	67,1 ± 9,4	0,145
Telesna visina (cm)	171 ± 5	173 ± 6	0,283
BMI	21,1 ± 2,0	22,4 ± 3,5	0,318
%BF	24,0 ± 5,1	23,7 ± 7,3	0,913

Varijable su prikazane kao $X \pm SD$; BMI – Indeks telesne mase; %BF – procenat telesnih masti
Studentov T test za dva zavisna uzorka; * $p < 0,05$

PRILOG II

Tabela 2. Antropometrijski parametri ispitanika muškog pola

	Fudbal (n = 8)	Odbojka (n = 12)	p
Telesna masa (kg)	79,9 ± 13,4	82,4 ± 12,3	0,668
Telesna visina (cm)	186 ± 6	187 ± 7	0.634
BMI	23,2 ± 3,8	23,5 ± 2,5	0,863
%BF	11,5 ± 4,3	12,6 ± 4,8	0.605

Varijable su prikazane kao $X \pm SD$; BMI – Indeks telesne mase; %BF – procenat telesnih masti
Studentov T test za dva zavisna uzorka; * $p < 0,05$

PRILOG III

Tabela 3. Elektrokardiografski parametri svih ispitanika

	Fudbal (n = 18)	Odbojka (n = 29)	p
HR (1/min)	70 ± 11	73 ± 9	0,300
P u V1 (mV)	0,1 ± 0,04*	0,08 ± 0,03	0,015
QTc interval (ms)	350 ± 29	352 ± 35	0,821
RVH (mV)	4,1 ± 2,2	3,5 ± 1,2	0,206
LVH (mV)	24,0 ± 8,1	23,6 ± 6,3	0,864

Varijable su prikazane kao $X \pm SD$; HR – srčana frekvencija, RVH – zbir voltaže R talasa u V1 i S talasa u V6 odvodu; LVH – zbir voltaža S talasa u V1 i R talasa u V5 odvodu

Studentov T test za dva zavisna uzorka; * $p < 0,05$

PRILOG IV

Tabela 4. Elektrokardiografski parametri ispitanika očitani iz II odvoda

	Fudbal (n=18)	Odbojka (n = 29)	p
P talas trajanje (s)	0,08 ± 0,01	0,07 ± 0,02	0,162
P talas voltaža (mV)	0,14 ± 0,04	0,13 ± 0,04	0,209
PR interval (s)	0,14 ± 0,02	0,14 ± 0,02	0,865
QRS trajanje (s)	0,05 ± 0,02	0,05 ± 0,01	0,682
QT interval trajanje (s)	0,36 ± 0,03	0,35 ± 0,04	0,544
PQ segment trajanje (s)	0,05 ± 0,02	0,06 ± 0,02	0,341
ST segment trajanje (s)	0,11 ± 0,03	0,10 ± 0,03	0,183
Q talas voltaža (mV)	0,69 ± 0,50	0,68 ± 0,39	0,912
R talas voltaža (mV)	10,50 ± 3,95	10,29 ± 2,71	0,867
S talas voltaža (mV)	1,39 ± 1,37	1,41 ± 0,82	0,984
QRS voltaža (mV)	0,84 ± 0,38	0,83 ± 0,26	0,917

Varijable su prikazane kao $X \pm SD$;

Studentov T test za dva zavisna uzorka; * $p < 0,05$

PRILOG V

Grafikon 1. Promene na EKG zapisu uslovljene fizičkim vežbanjem

Hi kvadrat test nezavisnosti; * $p < 0,05$

Stefan Pandurović¹, Vladimir Pantoš², Biljana Đurić³, Nikola Topalović⁴, Rada Jeremić⁵, Marina Đelić⁶, Dejan Nešić⁷, Sanja Mazić⁸

EXAMINING THE EFFECT OF THE TYPE OF SPORT ON THE FREQUENCY OF ELECTROCARDIOGRAPHIC CHANGES IN MEDICAL STUDENTS INVOLVED IN SPORTS

Abstract: Continuous physical activity leads to a series of adaptive changes to athletes' cardiovascular system, collectively called Athlete's heart. Recognizing such physiological ECG changes and distinguishing them from the pathological myocardium-related findings, play an important role in sudden cardiac death prevention among athletes.

The aim of our study was to examine the effect of the type of sport on the frequency of electrocardiographic changes between two groups of subjects, football and volleyball players.

The study included 47 subjects, students of the Faculty of Medicine, University of Belgrade, divided into two groups depending on type of sport they play. The first group consisted of 29 volleyball players, while the second group consisted of 18 football players. Anthropometric parameters: body height (BH), body weight (BW), body mass index (BMI), body fat percentage (%BF) were measured first. Resting electrocardiographic test was performed in supine position, using twelve-lead electrocardiograph. From obtained electrocardiograms (ECG), using the Seattle criteria for interpretation of ECG findings in athletes, following parameters were analyzed: heart rate, heart rhythm, rhythmicity, respiratory arrhythmia, cardiac axis, duration and amplitude of individual waves, segments and intervals, QTc, right and left atrial enlargement, isolated voltage criteria for left and right ventricular hypertrophy, incomplete right bundle-branch block, first degree AV block, second degree AV block-Mobitz type I (Wenckebach), and T wave inversion. Statistical analysis was performed using paired T-test and Chi square test, within the SPSS package.

¹ Stefan Pandurović, Laboratorija za medicinu sporta i terapiju vežbanjem, Institut za medicinsku fiziologiju „Rihard Burijan“, Medicinski fakultet Univerziteta u Beogradu, stefan.pandurovic@gmail.com

Results of the study showed higher values of amplitude of P wave in the V1 lead among football players ($p=0.015$), alongside significant difference in frequency of T wave inversion in leads V1-V3 ($p=0.048$). Volleyball players demonstrated significantly higher frequency of left atrial enlargement ($p=0.019$).

Based on presented results, we can conclude that observed ECG changes indicate that different types of sports may lead both to changes in electrical activity of cardiac conduction system and myocardium.

Keywords: athlete's heart, physical activity, physical exercise, electrocardiography, Seattle criteria

Introduction

Physical activity is defined as any movement of the body caused by the skeletal muscle contraction, which leads to energy consumption. Exercise is a type of physical activity composed of planned, defined and repetitive motions that are performed with the aim of improving or maintaining one or more components of physical ability. [1] Organized physical activity, oriented towards achieving results and regulated by a series of rules, is defined as a sport. Sports activity mainly has a competitive character - professional sports (athletes) or amateur sports (recreational sports). Professional athletes train more and on a higher intensity than recreational athletes. [2] Some positive aspects of regular exercising include the following: proper growth and development of children [3], reduced risk of developing chronic non-infectious diseases (arterial hypertension, diabetes mellitus, malignant diseases), improvement mental health [4], reduced of body fat (% BF), establishment and maintenance of optimal body weight. [5, 6]

Due to continuous physical activity, the cardiovascular system undergoes a series of adaptive, physiological responses in the athlete's body, collectively called the Athletes's heart. The degree and types of changes correlate with the age and gender of the athletes, as well as the type of sport which the athlete is engaged in. [7] It implies morphological, functional and electrophysiological adaptations, which can be observed electrocardiographically during a standard sports-medical examination. It is important to recognize those physiological ECG and distinguish them from pathological findings that increase the risk of sudden cardiac death (SCD). Prevention of SCD is achieved by excluding the athlete with pathological ECG findings from the training process, considering that SCD is the leading cause of death of athletes on the field. [7, 8] In order to correctly interpret ECG findings in athletes, a standardized criteria were created in Seattle, USA in 2012, called the Seattle Criteria. This criteria were used in this study, in order to present physiological ECG findings caused by cardiac adaptation to physical activity, as well as the abnormal findings suggestive for pat-

hological changes, that require further diagnostic evaluation. [9] The most common physiological ECG changes observed in athletes are the following: sinus bradycardia, sinus arrhythmia, ectopic atrial rhythm, first-degree AV block, second-degree AV block - Mobitz type I (Wenckebach), incomplete right branch block, isolated voltage criterion for hypertrophy, early repolarization. [9] The most common characteristic of athlete's heart is an increase in myocardial mass and enlargement of all heart cavities, primarily resulting in left ventricular hypertrophy [7], all of which is in direct proportion to extensive nutritional and oxidative demands of skeletal muscles during physical activity, in order to increase cardiac output. The cardiac output increases at the expense of stroke volume, which explains ventricular hypertrophy as a physiological adaptation. [10, 11] The most common cause of SCD in athletes is hypertrophic cardiomyopathy, [8] which implies the importance of its distinction from physiological ventricular hypertrophy, that sometimes can be a true diagnostic challenge. [12]

The aim of this study was to analyze the effect of the type of sport on the frequency of electrocardiographic changes, among two different groups of subjects, football and volleyball players, all of whom are students at the Faculty of Medicine, University of Belgrade.

Material and methods

Subjects

The study included 47 subjects, students at the Faculty of Medicine, University of Belgrade, competitors of the University League. Depending on the type of sport they are involved in, subjects were divided into two different groups. The first group consisted of 29 volleyball players, 12 of whom were males and, 17 females, aged 19 to 26 years (22.7 ± 1.8 years), who have actively been involved in sports for 3–15 years, training from 1 to 8 hours per week. The second group consisted of 18 football players, 8 of whom being males and, 10 females, 21 to 27 years old (24.5 ± 1.9 years), who have actively been training during the period from 1 to 19 years, 1 to 4.5 hours weekly. The criteria used to include the subjects in the study were being actively and competitively involved in sports as well as them being the participants of the University League. All procedures were performed in accordance with the Helsinki Declaration. The study protocol was approved by the Ethics Committee of the Faculty of Medicine, University of Belgrade. All subjects were acquainted in detail with the examination procedure and study protocol. Subjects gave signed informed consent to participate in the study.

Material and methods

All the measurements were performed in the morning hours, in the Centre for Sports Medicine and Exercise Therapy at the Institute of Medical Physiology, Faculty of Medicine, University of Belgrade, at a comfort temperature (18-22°C), atmospheric pressure of 760 mmHg and relative humidity ranging from 30 to 60%. At the beginning of the study, the following anthropometric parameters were measured in all the subjects: body height (BH) expressed in centimeters, using a standard laboratory stadiometer (Seca 214 Portable Stadiometer, Cardinal Health, Ohio, USA). Immediately afterwards, body mass (BM), expressed in kilograms, body mass index (BMI) and body fat percentage (% BF) were measured using a bioimpedance body composition analyzer (InBody 230 Body Composition Analyzer, Seoul, Korea).

The next step was performing the electrocardiographic testing at rest, in a supine position, using a twelve-lead electrocardiograph (Cardioline Delta 3 Plus Digital ECG Machine, Italy), on the standard millimeter strip speed of 25 mm/s, calibrated so that 1 mm of wave height matches to the 0.1 mV. From the obtained electrocardiograms, accordingly to the Seattle Criteria (Seattle Criteria, 2012) [9] for ECG interpretation in athletes, the following parameters were analyzed: heart rate (HR), rhythm, rhythmicity, respiratory arrhythmia, cardiac axis, duration and amplitude of individual ECG waves, segments and intervals, QTc, right atrial enlargement (RAE), left atrial enlargement (LAE), isolated voltage criteria for the left ventricular hypertrophy (LVH) and right ventricular hypertrophy (RVH), incomplete right bundle branch block (IRBBB), first degree AV block, second degree AV block - Mobitz type I (Wenckebach), and T wave inversion (TWI - T wave inversion).

Heart rate was obtained by dividing the number 1500 (the number of millimeters that the millimeter strip crosses in 60s, moving at a speed of 25 mm/s) by the number of millimeters corresponding to the distance between the two consecutive R waves (R-R interval). The rhythm was determined by the presence or absence of P waves before each QRS complex. The number of millimeters between two consecutive R waves was used to determine the rhythmicity of cardiac activity, and in order to obtain the time distance between two ventricular systoles. Respiratory (sinus) arrhythmia, as a variation of normal sinus rhythm, is observed as alternating acceleration and deceleration of cardiac activity, which corresponds to inspiration and expiration, respectively during the respiratory cycle, and was observed as an unequal R-R interval. The cardiac axis was calculated using the reference taken three-axis and six-axis coordinate systems, obtained by crossing the axes of three standard and three unipolar limb leads (the frontal plane), using the Einthoven's law, according to which the sum of voltages of QRS complex in I and III standard ECG leads is equal to the sum of the voltages of the QRS complex in the II standard ECG lead. Duration of individual ECG waves, segments and intervals was determined by multiplying the number of millimeters by 0.04s (corresponding to the value of 1 mm in the horizontal scale), while the amplitude

was obtained by multiplying the number of millimeters by 0.1mV (corresponding to 1mm in the vertical scale). The QTc (QT interval corrected for heart rate) was obtained by applying the Bazett's corrective formula as the quotient of the QT interval and the square root of the RR interval, both expressed in milliseconds (ms). The amplitude of the P wave ≥ 2.5 mV in the lower ECG leads - II, III, aVF without changes in its duration, was taken as an indicator of the existence of right atrial enlargement (RAE), while the biphasic P wave in V1 lead whose final part shows a negative deflection ≥ 1 mm below the isoelectric line, with a duration of ≥ 0.04 s, was taken as the criteria for left atrial enlargement (LAE). The isolated voltage criteria used for determination of LVH and RVH is the Sokolow - Lyon index. For LVH it is the sum of the amplitude of the S wave in V_1 and the R wave in $V_5 \geq 3.5$ mV, while for RVH it is the sum of the amplitude of the S wave in V_6 and the R wave in $V_1 \geq 10.5$ mV, with the cardiac axis turning to the right. The dominant diagnostic criteria for an incomplete right-branch block is the presence of an RSR' pattern in the first two precordial leads (V_1 and V_2). First-degree AV block is characterized by the prolonged PR interval ≥ 200 ms. Second degree AV block: Mobitz type I - Weckenbach was observed by progressive prolongation of each successive PR interval, until the absence of conduction of one P wave through the AV node, which is observed by the existence of P waves with the absence of QRS complex. TWI was observed in precordial leads from V_1 to V_3 and was considered as significant if the negative deflection was ≥ 1 mm.

Statistical analysis

Presented results were obtained by the methods of standard descriptive statistics, and are expressed as the arithmetic mean ($\bar{X}$) $\pm$ standard deviation (SD) as well as the frequency of subjects with the parameter of interest. For processing anthropometric data, as well as all numerical data within the interpretation of ECG recordings, Student's T test for dependent samples was used, while for processing nominal data, the Chi square independence test was used. All the tests were used to determine the existence of a statistically significant difference in the values of observed parameters between the subjects who play football and those who play volleyball, where the value of $p < 0.05$ was considered statistically significant. Statistical analyzes were performed using the Statistic package for social sciences 22 IBM U.S.A (SPSS22) program.

Results

Annex I shows the anthropometric parameters of the female subjects: BM, BH, BMI and %BF. No statistically significant difference was observed in the examined parameters between the subjects who play football and those who play volleyball.

Annex II shows the anthropometric parameters of male subjects: BM, BH, BMI and %BF. There is no observed statistically significant difference in the values of listed parameters between the subjects who play football and those who play volleyball.

Analyzed ECG parameters of all subjects are shown in Annex III. Among the subjects who play football and those who play volleyball, a statistically significant difference was observed in the values of the amplitude of the P wave in V_1 lead ($p < 0.05$). P wave in the first precordial lead shows a higher values of amplitude in the subjects who play football (0.1 ± 0.04 mV) compared to those who play volleyball (0.08 ± 0.03 mV), while the values of other parameters - HR, QTc, LVH and RVH, showed no statistically significant differences between the two groups of subjects.

Annex IV shows the ECG parameters of the subjects read from the II standard ECG lead, which relate to the duration and amplitude of individual ECG waves, segments, and intervals. Among the listed parameters: P wave duration, P wave voltage, PR interval, QRS complex duration, QT interval, PQ segment, ST segment, Q wave voltage, R wave voltage, S wave voltage and QRS complex voltage, no statistically significant differences were observed between subjects who play football and those who play volleyball.

The data shown in Annex V refer to the ECG changes due to physical exercise. A statistically significant difference ($p < 0.05$) was observed in the frequency of LAE in subjects playing football (10) compared to subjects playing volleyball (25), as well as in the occurrence of T wave inversion (TWI) in the first three precordial leads, which was found in 7 subjects playing football and in 4 subjects playing volleyball ($p < 0.05$). No statistically significant difference was found in the frequency of IRBBB and RAE between the two groups of subjects. The analysis of ECG recordings did not show first - degree AV block, second - degree AV block - Mobitz type I (Wenckebach), nor the occurrence of respiratory arrhythmia in any of the subjects.

Discussion

The results presented in this study showed the existence of the following, physiological ECG changes among the subjects, according to the Seattle criteria: [9] sinus bradycardia, LVH, RAE, LAE, IRBBB, TWI. A statistically significant difference between the two groups of subjects, was observed only in the frequency of occurrence of LAE and TWI, as well as the amplitude of the P wave in V_1 .

Karagozova et al. [13] proved the correlation between the type of sport, according to the Mitchell's classification [14], with the frequency and degree of physiological ECG changes found in athletes. Karagozova et al. [13] also showed that ECG changes caused by physical exercise (sinus bradycardia, first-degree AV block, early repolarization, respiratory arrhythmia, IRBBB), are occurring as a result of increased vagal tone, and represent the characteristic of sports such as football and volleyball. This finding contradicts the results

of other authors [15,16], including our study. Apart from the incidence of IRBBB observed in about 50% of our subjects, the rest of these changes went unnoticed. The observed incidence of IRBBB is approximately the same as in studies of other authors (35-50%), and occurs as a consequence of right ventricular remodeling and therefore delay in the conduction of electrical impulses through the right branch of the bundle of Hiss. [16–18] The association between the influence of the type of sport and the frequency of specific ECG patterns is also demonstrated by Pelliccia et al. [19], whose study results showed the highest frequency of IRBBB in the population of football players and volleyball players, which is in accordance with our results.

Opposite to our results, two studies of Huttin and Pambo [20, 21], analyzed ECG findings in football players, and showed a high incidence of sinus bradycardia, first degree AV block, prolonged or shortened QTc, LVH as well as the low IRBBB frequency in these athletes. Similar to the results we presented, a high frequency of TWI in anteroseptal leads ($V_1 - V_3$) was observed, which is considered to be a pathological finding [9], and requires further diagnostic analysis and evaluation (echocardiography, cardiac MRI). According to Schnell, the occurrence of TWI is associated with high prevalence of predisposing conditions for the development of SCD (up to 45% of cases with a positive ECG findings), of which the most common is hypertrophic or arrhythmogenic cardiomyopathy. [8, 12, 22]

Although a common adaptation phenomenon, with a frequency of over 50% of athletes in studies conducted by other authors, the incidence of LVH, obtained by the isolated voltage criterion (the Sokolow-Lyon index), was low among subjects in this study. [15, 18, 23]

LAE is an extremely rare finding in the studies of the above-mentioned authors [15, 18, 23], while it is present in a total of 35 of our subjects. The Seattle criteria classifies it as an abnormal finding, and thus implies the need for further diagnostic evaluation. However, the results of studies by some authors, such as Król [24], suggest that left atrium enlargement is just another in a series of elements that make up the athlete's heart, with higher frequency in sports with lower dynamic and higher static component, which may explain the statistical difference in our study, where the occurrence of LAE is more common in subjects who play volleyball.

The limitation of this study was the absence of other diagnostic methods for the assessment of cardiac function, in addition to electrocardiography. For a full understanding of all aspects of cardiac remodeling caused by exercise, in addition to the standard twelve-lead electrocardiography (ECG), the use of imaging methods, such as echocardiography or cardiac MRI, is indicated. [7] This is important because of the possible low sensitivity and specificity of ECG findings, especially in the differential diagnosis of possible conditions that increase the risk of developing SCD, among which cardiomyopathies are the most common. [9, 12] Due to above mentioned, subjects from this study showing LAE and TWI need to undergo an additional diagnostic evaluation.

Conclusion

The results of our study showed a statistically significant difference between the two groups of subjects, in two examined parameters: LAE and TWI, while the remaining parameters, including those that represent common findings, and are conditioned by physical exercise, remained with no statistically significant difference observed. A higher incidence of LAE in subjects playing volleyball could indicate a higher degree of left atrial remodeling. More frequent occurrence of TWI in subjects playing football could be an indicative sign of a higher degree of left ventricular remodeling or a sign of hypertrophic cardiomyopathy. Based on the presented results, we can conclude that the observed changes in the ECG indicate that different types of sports can lead to changes in the electrical activity of the conduction system of the heart and heart muscle.

Literature

1. Dean A, Sciences H, Kingston RI, Island R, Edith PC, Heart BF, et al. Advanced fitness assessment & exercise prescription. Vol. 35, Choice Reviews Online. 1998: 35–6295.
2. Mazić S. Exercise as a therapy. *Med Podml.* 2016; 67(2): 1–4.
3. Alves JGB, Alves GV. Effects of physical activity on children's growth. *J Pediatr (Rio J).* 2019; 95: 72–8.
4. Warburton DER, Bredin SSD. Health benefits of physical activity: A systematic review of current systematic reviews. *Curr Opin Cardiol.* 2017; 32(5): 541–56.
5. Westerterp KR. Exercise, energy balance and body composition. *Eur J Clin Nutr.* 2018; 72(9): 1246–50.
6. Swift DL, McGee JE, Earnest CP, Carlisle E, Nygard M, Johannsen NM. The Effects of Exercise and Physical Activity on Weight Loss and Maintenance. *Prog Cardiovasc Dis.* 2018; 61(2): 206–13.
7. De Innocentiis C, Ricci F, Khanji MY, Aung N, Tana C, Verrengia E, et al. Athlete's Heart: Diagnostic Challenges and Future Perspectives. *Sport Med.* 2018; 48(11): 2463–77.
8. Emery MS, Kovacs RJ. Sudden Cardiac Death in Athletes. *JACC Hear Fail.* 2018; 6(1): 30–40.
9. Drezner JA, Ackerman MJ, Anderson J, Ashley E, Asplund CA, Baggish AL, et al. Electrocardiographic interpretation in athletes: The "Seattle Criteria". *Br J Sports Med.* 2013; 47(3): 122–4.
10. Elenan C, Giorgio M, Annik L, Giacomo F, Mariangela P. Exercise for Cardiovascular Disease Prevention and Treatment – chapter 8 : The positive effects of exercise in chemotherapy-related cardiomyopathy. *Adv Exp Med Biol.* 2017; 1000: 103–29.
11. Astorino TA, Edmunds RM, Clark A, King L, Gallant RA, Namm S, et al. High-Intensity Interval Training Increases Cardiac Output and V-O₂max. *Med Sci Sports Exerc.* 2017; 49(2): 265–73.

12. Augustine DX, Howard L. Left Ventricular Hypertrophy in Athletes: Differentiating Physiology From Pathology. *Curr Treat Options Cardiovasc Med*. 2018; 20(12).
13. Karagjozova I, Petrovska S, Nikolic S, Maleska-Ivanovska V, Georgievska-Ismail L. Frequency of electrocardiographic changes in trained athletes in the republic of Macedonia. *Open Access Maced J Med Sci*. 2017; 5(6): 708–13.
14. Mitchell JH, Haskell W, Snell P, Van Camp SP. Task force 8: Classification of sports. *J Am Coll Cardiol*. 2005; 45(8): 1364–7.
15. Pelliccia A, Maron BJ, Culasso F, Di Paolo FM, Spataro A, Biffi A, et al. Clinical significance of abnormal electrocardiographic patterns in trained athletes. *Circulation*. 2000; 102(3): 278–84.
16. Corrado D, Pelliccia A, Heidbuchel H, Sharma S, Link M, Basso C, et al. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. *Eur Heart J*. 2010; 31(2): 243–59.
17. Corrado D, Biffi A, Basso C, Pelliccia A, Thiene G. 12-lead ECG in the athlete: Physiological versus pathological abnormalities. *Br J Sports Med*. 2009; 43(9): 669–76.
18. Drezner JA, Fischbach P, Froelicher V, Marek J, Pelliccia A, Prutkin JM et al. Normal electrocardiographic findings: Recognising physiological adaptations in athletes. *Br J Sports Med*. 2013; 47(3): 125–36.
19. Pelliccia A, Culasso F, Di Paolo FM, Accettura D, Cantore R, Castagna W, et al. Prevalence of abnormal electrocardiograms in a large, unselected population undergoing pre-participation cardiovascular screening. *Eur Heart J*. 2007; 28(16): 2006–10.
20. Pambo P, Adu-Adadey M, Ankrah PT, Agbodzakey H, Scharhag J. Electrocardiographic and Echocardiographic Findings in Ghanaian Female Soccer Players. *Clin J Sport Med*. 2020; Publish Ah(00).
21. Huttin O, Selton-Suty C, Venner C, Vilain JB, Rochecongar P, Aliot E. Electrocardiographic patterns and long-term training-induced time changes in 2484 elite football players. *Arch Cardiovasc Dis*. 2018; 111(5): 380–8.
22. Schnell F, Riding N, O'Hanlon R, Lentz PA, Donal E, Kervio G, et al. Recognition and significance of pathological T-wave inversions in athletes. *Circulation*. 2015; 131(2): 165–73.
23. Sohaib SMA, Payne JR, Shukla R, World M, Pennell DJ, Montgomery HE. Electrocardiographic (ECG) criteria for determining left ventricular mass in young healthy men : Data from the LARGE Heart study. *J Cardiovasc Magn Reson*. 2009; 11(1): 9–15.
24. Król W, Jędrzejewska I, Konopka M, Burkhard-Jagodzińska K, Klusiewicz A, Pokrywka A, et al. Left Atrial Enlargement in Young High-Level Endurance Athletes – Another Sign of Athlete's Heart? *J Hum Kinet*. 2016; 53(1): 81–90.

ANNEX I

Chart 1. Anthropometric parameters of female subjects

	Football (n = 10)	Volleyball (n = 17)	p
Body mass (kg)	61.8 ± 7.8	67.1 ± 9.4	0.145
Body height (cm)	171 ± 5	173 ± 6	0.283
BMI	21.1 ± 2.0	22.4 ± 3.5	0.318
%BF	24.0 ± 5.1	23.7 ± 7.3	0.913

The variables are shown as $X \pm SD$; BMI - Body Mass Index; % BF - percentage of body fat
Student's T test for two dependent samples; * $p < 0.05$

ANNEX II

Chart 2. Anthropometric parameters of male subjects

	Football (n = 8)	Volleyball (n = 12)	p
Body mass (kg)	79.9 ± 13.4	82.4 ± 12.3	0.668
Body height (cm)	186 ± 6	187 ± 7	0.634
BMI	23.2 ± 3.8	23.5 ± 2.5	0.863
%BF	11.5 ± 4.3	12.6 ± 4.8	0.605

The variables are shown as $X \pm SD$; BMI - Body Mass Index; % BF - percentage of body fat
Student's T test for two dependent samples; * $p < 0.05$

ANNEX III

Chart 3. Electrocardiographic parameters of all subjects

	Football (n = 18)	Volleyball (n = 29)	p
HR (1/min)	70 ± 11	73 ± 9	0.300
P in V1 (mV)	0.1 ± 0.04*	0.08 ± 0.03	0.015
QTc (ms)	350 ± 29	352 ± 35	0.821
RVH (mV)	4.1 ± 2.2	3.5 ± 1.2	0.206
LVH (mV)	24.0 ± 8.1	23.6 ± 6.3	0.864

The variables are shown as $X \pm SD$; HR - heart rate, RVH - sum of voltage of R wave in V1 and S wave in V6 lead; LVH - sum of voltages of S waves in V1 and R waves in V5 lead

Student's T test for two dependent samples; * $p < 0.05$

ANNEX IV

Chart 4. Electrocardiographic parameters of the subjects read from the II standard lead

	Football (n=18)	Volleyball (n = 29)	p
P wave duration (s)	0.08 ± 0.01	0.07 ± 0.02	0.162
P wave voltage (mV)	0.14 ± 0.04	0.13 ± 0.04	0.209
PR interval (s)	0.14 ± 0.02	0.14 ± 0.02	0.865
QRS duration (s)	0.05 ± 0.02	0.05 ± 0.01	0.682
QT interval duration (s)	0.36 ± 0.03	0.35 ± 0.04	0.544
PQ segment duration (s)	0.05 ± 0.02	0.06 ± 0.02	0.341
ST segment duration (s)	0.11 ± 0.03	0.10 ± 0.03	0.183
Q wave voltage (mV)	0.69 ± 0.50	0.68 ± 0.39	0.912
R wave voltage (mV)	10.50 ± 3.95	10.29 ± 2.71	0.867
S wave voltage (mV)	1.39 ± 1.37	1.41 ± 0.82	0.984
QRS voltage (mV)	0.84 ± 0.38	0.83 ± 0.26	0.917

The variables are shown as $X \pm SD$;

Student's T test for two dependent samples; * $p < 0.05$

ANNEX V

Graph 1. Changes in the ECG record due to physical exercise, RAE – right atrium enlargement, LAE – left atrium enlargement, IRBBB – incomplete right bundle branch block

Chi square independence test; * $p < 0.05$