

Predictive Factors For Electrocardiographic Changes in Young Athletes: a Five-Years Analyses

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Background: Regular physical training in young athletes leads to physiological cardiovascular adaptations, often manifested as electrocardiographic (ECG) changes. Identifying predictors of such changes is essential for distinguishing normal adaptations from potential pathological findings. **Objective:** The aim of this study was to investigate body mass index (BMI), systolic and diastolic blood pressure (SBP/DBP), and heart rate (HR) as potential predictive factors for sinus arrhythmia, incomplete right bundle branch block (IRBBB), and ST-segment elevation in young endurance and strength athletes. **Methods:** This retrospective-prospective study included 60 male athletes aged 12–17 years (30 endurance, 30 strength athletes) who underwent a five-year follow-up with regular ECG monitoring. Anthropometric and cardiovascular parameters (BMI, SBP, DBP, HR) were recorded, and associations with ECG findings were analyzed using descriptive statistics, Student's t-test, Mann-Whitney U test, Chi-square test, and logistic regression. **Results:** Endurance athletes showed a significant increase in BMI during follow-up ($p = 0.035$), while in strength athletes BMI was significantly associated with sinus arrhythmia ($p = 0.045$). Systolic blood pressure at the end of the study significantly differed in endurance athletes with and without ST-segment elevation ($p = 0.029$). However, logistic regression analysis demonstrated that BMI, SBP, DBP, and HR were not independent predictors of ECG abnormalities in either group. **Conclusion:** Basic cardiovascular parameters such as BMI, blood pressure, and heart rate do not appear to independently predict ECG changes in young athletes. Other factors, including training intensity and genetic predisposition, likely play a greater role. Preventive cardiovascular screening remains crucial for the early detection of clinically relevant abnormalities in this population.

Keywords: Electrocardiography, Athletes, Body Mass Index, Blood Pressure, Heart Rate, Sports Medicine.

1. BACKGROUND

The athlete's heart syndrome represents a functional adaptation of the cardiovascular system to physical exertion. It typically develops in individuals who train at least five days per week for more than one hour per day. The hallmark of athlete's heart is physiological myocardial hypertrophy, a reversible condition resulting from the increased workload of the myocardium. Resting electrocardiography (ECG) provides valuable insight into the electrophysiological characteristics of the heart (1). ECG changes are not obligatory in athlete's heart; however, their absence does not exclude the diagnosis of this condition. Moreover, the ECG pattern in athletes is dynamic, evolving with training history, intensity, and aging. Although ECG is a useful diagnostic tool, it should not be regarded as the sole indicator of cardiac adaptation to athletic activity.

Several factors influence the occurrence of ECG

changes in athletes, including the type of sport, training intensity, frequency and duration, sex, age, genetic predisposition, individual variability, and autonomic nervous system activity (2). Among these, training intensity, frequency, and duration are particularly important, as professional athletes and those who train more than six hours per week are more likely to demonstrate ECG changes than recreational athletes. In younger athletes (12–17 years), sinus arrhythmia and incomplete right bundle branch block (IRBBB) are observed more frequently, whereas in older athletes (>20 years) ECG findings related to cardiac hypertrophy predominate. Genetic background and inter-individual variability further modulate the extent of ECG adaptations, explaining why some athletes exhibit pronounced changes while others show minimal or no alterations.

Athletes generally exhibit enhanced parasympathetic tone, which can result in sinus bradycardia or

Variable	Sinus arrhythmia		p	IRBBB		p	ST elevation		p
	No	Yes		No	Yes		No	Yes	
Initial values									
BMI (kg/m ²)	17,23±2,41	17,28±2,49	0,035	17,71±2,58	16,91±2,29	0,379	17,0±1,9	17,4±2,8	0,611
SP (mmHg)	97,5 (90,0-102,5)	97,5 (90,0-100,0)	0,728	95,0 (90,0-100,0)	100,0 (90,0-100,0)	0,650	100,0 (100,0-110,0)	95,0 (90,0-100,0)	0,486
DP (mmHg)	60,0 (58,7-70,0)	60,0 (60,0-67,5)	0,790	60,0 (60,0-70,0)	60,0 (60,0-70,0)	0,773	60,0 (60,0-70,0)	60,0 (60,0-70,0)	0,486
Puls/min	78,71±12,6	74,31±10,1	0,362	75,46±11,6	77,0±11,5	0,710	72,6±9,2	80,0±12,3	0,074
End of the study									
BMI (kg/m ²)	19,26±2,18	20,0±2,22	0,043	19,84±2,27	19,56±2,22	0,736	19,9±2,0	19,3±2,4	0,457
SP (mmHg)	105,0 (100,0-110,0)	110,0 (100,0-110,0)	0,697	110,0 (100,0-110,0)	100,0 (100,0-110,0)	0,263	110,0 (100,0-110,0)	100,0 (100,0-110,0)	0,029
DP (mmHg)	60,0 (60,0-70,0)	60,0 (62,5-73,7)	0,110	60,0 (60,0-70,0)	60,0 (60,0-70,0)	0,341	70,0 (60,0-75,0)	60,0 (60,0-70,0)	0,217
Puls/min	65,42±10,0	71,7±14,5	0,109	65,3±9,62	71,4±15,0	0,184	67,2±15,1	70,3±11,3	0,632

Table 1. Comparative analysis of initial and final values of BMI, DBP, SBP, and HR in endurance athletes in relation to the presence of sinus arrhythmia, IRBBB, and ST segment elevation. The results are presented as mean ± standard deviation ($x \pm SD$), as well as median and interquartile range (25-75th percentiles)

transient atrioventricular (AV) conduction abnormalities, such as first-degree AV block or the Wenckebach phenomenon. These manifestations are largely mediated by autonomic nervous system activity (3). However, certain ECG changes warrant additional clinical evaluation, including T-wave inversion in leads V2–V6 (except in adolescents), deep Q waves suggestive of hypertrophic cardiomyopathy (HCM), prolonged QT interval, and the presence of frequent extrasystoles or tachyarrhythmias (4).

2. OBJECTIVE

The objective of this study was to evaluate body mass index (BMI), systolic and diastolic blood pressure (SBP/DBP), and heart rate (HR) as potential predictive factors for the occurrence of sinus arrhythmia, incomplete right bundle branch block (IRBBB), and ST-segment elevation in young endurance and strength athletes, and to assess their interrelationship.

3. PATIENTS AND METHODS

This study included 60 male athletes who underwent routine medical examinations at the Public Institution Institute of Sports Medicine of Sarajevo Canton. Participants were divided into two groups according to the type of sport: 30 endurance athletes (football players) and 30 strength athletes (combat sports). All participants were between 12 and 17 years of age and had a continuous training history. Athletes

with interruptions in training or those engaged only in recreational activities were excluded.

The study was designed as a retrospective-prospective cohort with a five-year follow-up period. Electrocardiographic parameters (heart rate, sinus arrhythmia, IRBBB, and ST-segment elevation) were analyzed in parallel with measurements of body mass index (BMI) and blood pressure.

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 13.0. The Shapiro–Wilk test was applied to assess the normality of continuous variables. Normally distributed variables are presented as mean ± standard deviation (SD), while non-normally distributed variables are presented as median with interquartile range. Categorical variables are expressed as absolute and relative frequencies.

Comparisons of independent variables with normal distribution were performed using the Student's t-test, whereas the Mann–Whitney U test was applied for variables without normal distribution. For dependent variables, paired t-tests were used when normally distributed, and the Kruskal–Wallis test when non-normally distributed. Categorical variables were analyzed using McNemar's test, Chi-square test, or Fisher's exact test, as appropriate.

Logistic regression analysis was conducted to evaluate the predictive value of BMI, SBP, DBP, and HR for

Variable:	Sinus arrhythmia			IRBBB			ST elevation		
	No	Yes	p	No	Yes	p	Yes	No	P
Initial values									
BMI (kg/m ²)	18,67±2,46	18,4±2,35	0,172	18,63±2,62	18,4±1,22	0,879	18,7±2,4	17,3±1,5	0,356
SP (mmHg)	100,0 (90,0-102,5)	100,0 (100,0-108,7)	0,154	100,0 (90,0-108,75)	100,0 (100,0-107,5)	0,402	100,0 (90,0-110,0)	100,0 (100,0-110,0)	0,795
DP (mmHg)	60,0 (60,0-62,5)	60,0 (60,0-70,0)	0,377	60,0 (60,0-70,0)	60,0 (60,0-63,75)	0,595	60,0 (60,0-70,0)	60,0 (60,0-65,0)	0,315
Puls/min	82,28±16,2	72,6±7,0	0,227	77,7±14,1	87,6±16,6	0,146	80,5±1,4	72,3±6,1	0,376
End of the study									
BMI (kg/m ²)	21,0±2,03	20,4±1,59	0,045	21,0±1,98	20,2±1,56	0,388	21,0±1,8	19,03±1,2	0,078
SP (mmHg)	100,0 (98,7-110,0)	112,5 (100,0-120,0)	0,034	107,5 (100,0-115,0)	105,0 (97,5-112,5)	0,860	110,0 (100,0-115,0)	110,0 (100,0-110,0)	0,072
DP (mmHg)	62,5 (60,0-70,0)	70,0 (65,0-70,0)	0,377	60,0 (60,0-70,0)	62,5 (60,0-66,25)	0,129	60,0 (60,0-70,0)	70,0 (60,0-70,0)	0,948
Puls/min	73,3±16,2	63,2±6,49	0,120	70,0±14,2	73,0±18,4	0,671	71,8±15,1	69,6±4,9	0,183

Table 2. Comparative analysis of initial and final values of BMI, SBP, DBP, and heart rate in strength athletes in relation to the presence of sinus arrhythmia, IRBBB, and ST segment elevation. The results are presented as mean ± standard deviation (x ± SD), as well as median and interquartile range (25-75th percentiles).

the occurrence of ECG characteristics associated with athlete’s heart. A p-value < 0.05 was considered statistically significant.

4. RESULTS

Body mass index (BMI) values showed a significant increase from baseline to the end of the study in both groups (Table 1). Endurance athletes increased from 17.26 ± 2.41 to 19.68 ± 2.20 kg/m² (p = 0.035), while strength athletes increased from 18.60 ± 2.39 to 20.88 ± 1.91 kg/m² (p = 0.029). No significant differences were observed in systolic blood pressure (SBP), diastolic blood pressure (DBP), or heart rate (HR) between the groups at either time point.

When stratified by ECG findings, baseline BMI, SBP, DBP, and HR in the endurance group did not differ significantly according to the presence of sinus arrhythmia, IRBBB, or ST-segment elevation. However, SBP at the end of the study was significantly higher in endurance athletes with ST-segment elevation compared to those without (p = 0.029).

In the strength athlete group, baseline BMI, SBP, DBP, and HR also showed no significant differences when stratified by ECG findings (Table 2). At follow-up,

however, BMI was significantly higher in athletes with sinus arrhythmia compared to those without (p = 0.045). Likewise, SBP was significantly higher in athletes with sinus arrhythmia (p = 0.034). No other parameters showed statistically significant differences in this group.

Multivariate logistic regression was applied to evaluate the predictive value of BMI, SBP, DBP, and HR for ECG changes. None of the analyzed variables emerged as independent predictors of sinus arrhythmia in either endurance or strength athletes (Table 3). Similarly, no significant associations were found between these variables and the occurrence of IRBBB (Table 4).

With respect to ST-segment elevation, BMI, SBP, DBP, and HR did not reach statistical significance as

Variable:	Endurance athletes			Strength athletes		
	B	OR (95%IC)	p	B	OR (95%IC)	p
BMI (kg/m ²)	-0,394	0,675 (0,431-1,056)	0,085	0,106	1,112 (0,705-1,755)	0,647
SP (mmHg)	0,047	1,048 (0,938-1,171)	0,410	0,056	1,058 (0,941-1,188)	0,346
DP (mmHg)	-0,027	0,973 (0,854-1,108)	0,680	0,022	1,023 (0,830-1,250)	0,835
Puls/min	-0,027	0,973 (0,901-1,052)	0,489	0,022	1,033 (0,974-1,096)	0,281

Dependent variable: sinus arrhythmia.

Table 3. Independent Predictors of Sinus Arrhythmia in Endurance and Strength Athletes.

Variable:	Endurance athletes			Strength athletes		
	B	OR (95%IC)	p	B	OR (95%IC)	p
BMI (kg/m ²)	-0,340	0,712 (0,465-1,090)	0,118	-0,260	0,771 (0,384-1,635)	0,498
SP (mmHg)	0,059	1,061 (0,953-1,1180)	0,279	0,165	1,180 (0,951-1,464)	0,134
DP (mmHg)	0,039	1,040 (0,914-1,182)	0,554	-0,099	0,906 (0,656-1,251)	0,549
Puls/min	0,023	1,023 (0,950-1,102)	0,545	0,056	1,058 (0,982-1,139)	0,138

Dependent variable: IRBBB (Incomplete Right Bundle Branch Block)

Table 4. Independent Predictors of IRBBB in Endurance and Strength Athletes

Variable:	Endurance athletes			Strength athletes		
	B	OR (95%IC)	p	B	OR (95%IC)	p
BMI (kg/m ²)	0,212	1,236 (0,805-1,896)	0,332	-0,178	0,837 (0,268-2,609)	0,759
SP (mmHg)	-0,090	0,914 (0,812-1,029)	0,137	0,238	1,269 (0,868-1,855)	0,219
DP (mmHg)	0,009	1,009 (0,892-1,141)	0,888	-2,072	0,626 (0,455-0,864)	0,126
Puls/min	0,084	1,087 (0,996-1,167)	0,062	-0,137	0,872 (0,688-1,104)	0,872

Dependent variable: ST elevation.

Table 5. Independent Predictors of ST Segment Elevation in Endurance and Strength Athletes

independent predictors in either athlete group (Table 5). Although SBP in endurance athletes and BMI in strength athletes showed significant differences in univariate comparisons, these effects did not remain significant in the multivariate regression model.

5. DISCUSSION

Analysis of the obtained data revealed significant changes in BMI among both endurance and strength athletes during the five-year follow-up. Endurance athletes demonstrated a consistent increase in BMI, whereas strength athletes showed a significant association between BMI and the presence of sinus arrhythmia. These findings suggest that anthropometric changes may reflect physiological adaptations to training type, consistent with previous studies reporting that prolonged endurance or strength training can influence body composition and cardiovascular parameters (5,6). Interestingly, neither systolic nor diastolic blood pressure, nor heart rate, exhibited significant differences between groups at baseline or follow-up. This observation indicates that, although these parameters are important for overall cardiovascular function, they may lack sensitivity as predictors of electrocardiographic abnormalities in young athletes. In line with earlier research, our results emphasize that basic cardiovascular measures may not adequately explain the development of specific ECG patterns associated with athlete's heart (7, 8).

In the endurance athlete group, systolic blood pressure at follow-up was significantly higher in those with ST-segment elevation compared to those without. This finding suggests (7) that chronic aerobic training may influence cardiovascular hemodynamics in ways that predispose to ST-segment alterations. Similarly, in the strength athlete group, both BMI and SBP were significantly associated with sinus arrhythmia. However, when tested in multivariate logistic regression models, none of these variables remained independent predictors of ECG abnormalities. This discrepancy highlights the importance of considering training intensity, duration, and genetic predisposition as potentially more relevant determinants of ECG changes (8).

Our results support the notion that athlete's heart is a multifactorial condition, in which morphological and electrophysiological adaptations extend beyond simple anthropometric or hemodynamic predictors. Preventive cardiovascular screening in young athletes remains essential, as early identification of abnormal or borderline ECG findings may help distinguish between benign physiological adaptations and early manifestations of potentially life-threatening cardiac conditions (9, 10).

6. CONCLUSION

Basic cardiovascular parameters such as body mass index, blood pressure, and heart rate do not appear to be independent predictors of electrocardiographic changes in young athletes. Although certain associations were observed in univariate analyses—such as increased BMI in endurance athletes and the relationship between BMI and sinus arrhythmia in strength athletes—these findings did not retain statistical significance in multivariate models.

These results underscore the multifactorial nature of athlete's heart, where training intensity, duration, and genetic predisposition likely play a more prominent role in shaping ECG adaptations. Preventive cardiovascular screening remains indispensable, as it enables early differentiation between physiological changes and potential pathological findings, ensuring the safety of young athletes during intensive training and competition.

Limitations and Guidelines for future research

This study has several limitations, including a rela-

tively small sample size, which may limit the generalizability of the findings to a broader population of athletes. Additionally, we cannot exclude the influence of other factors, such as dietary habits, supplement use, or stress levels, which may significantly affect cardiovascular parameters and the development of arrhythmias. Future research should aim to expand the sample size and monitor these factors to better understand the mechanisms that lead to changes in cardiovascular parameters and their relationship with electrocardiographic abnormalities. Further studies should also investigate the long-term association between different types of training (endurance vs. strength) and cardiovascular health, which could help define optimal strategies for the prevention of cardiac arrhythmias in athletes.

- **Author's contribution:** *The author was involved in all steps of preparation this article, including final proof-reading.*
- **Conflict of interest:** *None to declare.*
- **Financial support and sponsorship:** *Nil.*

REFERENCES

1. Strčić J, Jug J, Čerkez Habek JA. Iznenađna srčana smrt sportaša. *Acta Med Croatica.* 2020;74(4):321-8.
2. Ilić I, Ranković J, Krstić O, Popović-Ilić T, Ilić SH, Mekić B, et al. Change of ECG parameters depending on the load level in athletes. *Acta Med Medicae.* 2012;51(3):57-62. doi:10.5633/amm.2012.0310
3. Martinez MW, Kim JH, Shah AB, Phelan D, Emery MS, Wasfy MM, et al. Exercise-induced cardiovascular adaptations and approach to exercise and cardiovascular disease: JACC state-of-the-art review. *J Am Coll Cardiol.* 2021;78(14):1453-70. doi:10.1016/j.jacc.2021.07.051
4. Palermi S, Sirico F, Fernando F, Gregori G, Belviso I, Ricci F, et al. Limited diagnostic value of questionnaire-based pre-participation screening algorithms: a "risk-exposed" approach to sports activity. *J Basic Clin Physiol Pharmacol.* 2022;33(5):655-63. doi:10.1515/jbcpp-2021-0179
5. Martin-Smith R, Cox A, Buchan DS, Baker JS, Grace F, Sculthorpe N. High intensity interval training (HIIT) improves cardiorespiratory fitness in healthy, overweight and obese adolescents: a systematic review and meta-analysis. *Int J Environ Res Public Health.* 2020;17(8):2955. doi:10.3390/ijerph17082955
6. Johnson NA, Sultana RN, Brown WJ, Bauman AE, Gill T. Physical activity in the management of obesity in adults: A position statement from Exercise and Sport Science Australia. *Pensar En Movimiento.* 2023;21(2):e57055. doi:10.15517/pensarmov.v21i2.57055
7. Williams CJ, Gurd BJ, Bonafiglia JT, Voisin S, Li Z, Harvey N, et al. A multi-center comparison of O2peak trainability between interval training and moderate intensity continuous training. *Front Physiol.* 2019;10:19. doi:10.3389/fphys.2019.00019
8. Brown HA, Topham TH, Clark B, Smallcombe JW, Flouris AD, Ioannou LG, et al. Seasonal heat acclimatisation in healthy adults: a systematic review. *Sports Med.* 2022;52(9):2111-28. doi:10.1007/s40279-022-01694-0
9. Petrović I, Marinković M. Influence of morphological characteristics on running performance of endurance athletes. *Facta Univ Ser Phys Educ Sport.* 2018;16(1):95-106. doi:10.22190/FUPES1801095P
10. Blanco-García C, Acebes-Sánchez J, Rodríguez-Romo G, Mon-López D. Resilience in sports: sport type, gender, age and sport level differences. *Int J Environ Res Public Health.* 2021;18(15):8196. doi:10.3390/ijerph18158196