

# EXPERIMENTAL INVESTIGATIONS

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## Assessment of the Effect of Anthropometric Data on the Alterations of Cardiovascular Parameters in Lithuanian Elite Male Basketball Players During Physical Load

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**Key Words:** athletes; body composition; basketball; physiology; cardiovascular system; bicycle ergometry test.

**Summary.** *Objectives.* The aim of the study was to assess the effect of the anthropometric data of basketball players on the alterations of cardiovascular parameters during the physical load applying the model of integrated evaluation.

*Material and Methods.* The research sample consisted of 113 healthy Caucasian male basketball players, candidates of the Lithuanian National men's basketball teams. Basketball players were divided into 2 groups: 69 taller and heavier male basketball players (with a higher percentage of body fat) (TMB) and 44 shorter and less heavy male basketball players (with a lower percentage of body fat) (SMB). The amount of fat, expressed in percentage, was measured using the body composition analyzer TBF-300. "Kaunas-Load," a computerized ECG analysis system, was used to evaluate the functional condition of the cardiovascular system during the load.

*Results.* The TMB group had a lower heart rate during the warming-up phase and the steady state of the load as compared with the SMB group ( $P < 0.05$ ). The JT interval in the TMB group was greater during the warming-up and the steady state as compared with the SMB group ( $P < 0.05$ ). The JT/RR ratio index in the TMB group was found to be lower in the warming-up phase and in the steady state compared with the respective parameter in the SMB group ( $P < 0.05$ ).

*Conclusions.* The cardiovascular system of taller and heavier male basketball players with a greater relative amount of body fat functioned more economically.

### Introduction

The human body is a complex dynamical system that is effectively organized following the principles of the dynamical systems theory (1). A complex interaction between components participating in motor behavior and the self-organization process will produce the emergence of an individual response (2, 3). All parts of the system are affected by other parts and by the interaction among them (4). Research on the dynamical systems theory has shown how a small change in a control parameter that constrains the system can lead to abrupt changes in the overall behavior of that system (4). This control parameter can come from the environment (1, 5, 6), internal processes of the subject (7), or interaction with other subjects (4, 8, 9).

It is clear that low levels of physical activity and obesity are cardiovascular risk factors. In order to avoid this risk, it is necessary to control nutrition

and physical activity. Many studies have demonstrated the influence of lifestyle modification (including physical activity of moderate intensity and/or weight control) on the normalization of arterial blood pressure (10, 11) and blood lipids (12).

The model of integral evaluation has been applied by other researches for the investigation of cardiovascular adaptation to physical load. Poderys with coauthors analyzed long- and short-term adaptation to physical load (13, 14). Bertašienė with coauthors (15) evaluated the characteristics of short-term adaptation to physical load in healthy patients and patients with ischemic heart disease. Jaruševičius (16) investigated the relationship between the JT interval duration and the heart rate at rest and during physical load in persons with different physical activity. However, we did not find any information about the impact of the anthropometric data on cardiovascular adaptation. How does low body fat affect short-term cardiovascular adaptation? Athletic amenorrhea is linked with low body weight and low body fat (17). These authors noted that the elements of the female athlete triad are pathophysiologically linked, leading

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to several disease risks and even to mortality. Several studies have demonstrated that inadequate athlete's nutrition causes amenorrhea, low bone mineral density (18), trauma, and iron deficit anemia (19). The data of Karila and coauthors (20) showed that fast weight and body fat mass loss in high-level wrestlers caused a decrease in testosterone levels, which could be dangerous for adolescents' health. We were unable to find any data on the cardiovascular response to physical stress when body fat was low. In this study, we tried to evaluate the reaction of basketball players' cardiovascular system to the bicycle stress test depending on the anthropometric data and to reveal how internal factors affected the reaction of the body to physical load.

The aim of the study was to assess the effect of anthropometric data of Lithuanian elite male basketball players on the alterations of cardiovascular parameters during physical load by applying the model of integrated evaluation.

### Material and Methods

The prospective cohort trial was performed in accordance with the ACC/AHA guidelines (21). The study sample consisted of 113 volunteers, elite Lithuanian men's basketball players (candidates of the National basketball men's teams; aged less than 18, less than 19, less than 20 years, and adults). The average athletic experience of subjects in basketball was  $10.04 \pm 0.35$  years.

The study included healthy Caucasian men who had no complaints about their health, no history of chronic diseases, did not take any medication, had a heart rate at rest of  $<90$  beats/min, arterial blood pressure of  $<140/90$  mm Hg, and there were no pathological findings in history, examination, auscultation, and electrocardiogram registration at rest. The subjects were excluded from the study if they had the signs of myocardial ischemia, inadequate response of arterial blood pressure to the physical load, arrhythmia or blockade registered, or if technical difficulties in recording an electrocardiogram or arterial blood pressure appeared. The athletes were introduced to the experimental design, informed about potential complications, and then they gave written informed consent.

Before the bicycle ergometry test, the height (cm), weight (kg), and the percentage of fat in the bodies of the subjects tested were recorded. The quantities of fat, expressed in percentage, were registered after performing the evaluation of the body mass components using the bioelectric impedance method applying the foot-pad body composition analyzer TBF-300 (TANITA). The accuracy and reliability of the method applied was similar to the one used for measuring skinfolds and dual-emission x-ray absorptiometry (22, 23). The subjects were divided into 2 groups according to the median of

Table 1. The Main Characteristics of Subjects Grouped by the Median of Height (195 cm) and Weight (84.50 kg)

Variable	TMB	SMB
Age, years	19.28±0.49	18.59±0.47
Weight, kg	91.16±1.12	75.61±1.03*
Body fat, %	8.42±0.36	6.69±0.40*
Height, cm	199.61±0.69	187.75±0.79*
Heart rate at rest before the test, beats/min	81.52±1.45	80.82±2.19
Systolic blood pressure at rest, mm Hg	126.33±1.64	124.70±1.80
Athletic experience, years	10.75±0.46	10.04±0.35

Values are mean±standard error. TMB, taller and heavier male basketball players (whose bodies contained relatively more fat); SMB, shorter and less heavy male basketball players (whose bodies contained relatively less fat).

\* $P < 0.05$ , the SMB group vs. the TMB group.

height (195 cm) and weight (84.50 kg): 69 taller and heavier male basketball players (whose bodies contained relatively more fat) (TMB) and 44 shorter and less heavy male basketball players (whose bodies contained relatively less fat) (SMB) (Table 1). The TMB group included basketball players whose height and weight were greater than the median. If the basketball player's weight or height was less or equal to the median, he was included into the SMB group.

A computerized electrocardiogram (ECG) analysis system "Kaunas-Load" developed at the Institute of Cardiology, former Kaunas University of Medicine, capable of both registering and analyzing the power developed by the subject and 12-lead of ECG synchronically, was used for the evaluation of the functional status of the cardiovascular system (24, 25). All athletes did not exercise for at least 12 hours and did not eat at least 2 hours before the test. The physical load test was carried out during the competitive period of the sports season. A short-term provocative protocol was used. The initial power of the load applied to everybody was 50 W, and it was increased by 50 W every minute until submaximum power was developed ( $50 \text{ W} + n \times 50 \text{ W}$ ). Usually the power is limited by clinical symptoms that are regarded as absolute and relative indications to discontinue the load (21).

During the bicycle ergometry test, the parameters reflecting several basic interrelated systems of the human organism, i.e., the executive, supplying, and regulatory systems, were registered. Making use of the integral model of evaluation (24, 25), both separate and integrated functions of the systems mentioned above were evaluated (Fig.). The interrelationship among the systems functioning in the human organism was described in a similar way as by other authors (26).

During the bicycle ergometry test, a 12-lead ECG was registered synchronically at the last 10

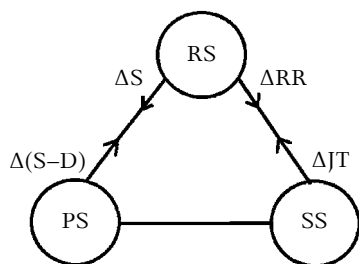


Fig. The integral model of evaluation

RS, regulatory system; PS, executive system; SS, supplying system; S, systolic arterial blood pressure; RR, time interval between two heart contractions (RR interval); S-D, difference in systolic and diastolic blood pressure, pulse amplitude of blood pressure; JT, interval in an electrocardiogram from junction point J to T wave end (JT interval).

seconds of each minute. The following ECG parameters at rest and during the load were evaluated: heart rate (HR), JT interval, and the deduced JT/RR ratio index. According to the model of integral evaluation, the supplying system was reflected by the JT interval of ECG, and the heart rate represented the regulatory system (24, 25).

The JT interval is an interval of the ECG from the J point to the end of T wave. The J point is the point where the QRS complex joins the ST segment. The JT interval describes the duration of ventricular repolarization. During physical activity, this interval is shorter. The shortening of the JT interval during physical activity suggests the intensification of metabolism (27).

The JT/RR ratio describes the relationship between the supplying and regulatory systems according to the model of integrated evaluation.

The arterial blood pressure was measured in a sitting position at rest at the last 15 seconds of every step of physical load test, the measurements being made every minute. The pulse amplitude of arterial blood pressure (S-D) was evaluated; and this parameter reflects the executive system. The pulse arterial blood pressure ratio amplitude ((S-D)/S) that shows the association between the executive (PS) and regulatory (RS) systems was also evaluated.

The regional Bioethics Committee approved the research protocol (No. BE-2-12).

The values are presented as arithmetical means and standard error of the mean. The representative sample size of 113 (N=160, 95% confidence level, sampling error  $\pm 5\%$ ) was calculated. The test of normality (Shapiro-Wilk) was performed. It was shown that data did not differ from normal distribution significantly ( $P > 0.05$ ). For the comparison of two groups, the Student *t* test for independent samples was applied ( $P = 0.05$ ).

### Results

The taller and heavier male basketball players whose bodies contained relatively more fat showed the lower heart rate when compared with the shorter and less heavy male basketball players whose bodies contained relatively less fat. This index in the TMB group was significantly lower during the warming-up phase and the steady state of the load (108.65 $\pm$ 1.21, 125.72 $\pm$ 1.37, and 140.36 $\pm$ 1.05 beats/min) than that in the SMB group (115.27 $\pm$ 1.62, 134.18 $\pm$ 1.74, and 150.05 $\pm$ 1.73 beats/min, respectively) ( $P < 0.05$ ) (Table 2).

Changes in the JT interval during the exercise between the groups were compared. The duration of JT interval in both groups was gradually decreasing.

Table 2. Heart Rate, Duration of JT Interval, and JT/RR Index During Physical Load in Taller and Heavier Male Basketball Players and in Shorter and Less Heavy Male Basketball Players

Group	Load, W						
	0	50	100	150	200	250	300
Heart rate, beats/min							
SMB	80.82 $\pm$ 2.19	98.64 $\pm$ 1.59	115.27 $\pm$ 1.62*	134.18 $\pm$ 1.74*	150.05 $\pm$ 1.73*	158.47 $\pm$ 1.33	161.00 $\pm$ 0.43
TMB	81.52 $\pm$ 1.45	96.26 $\pm$ 1.31	108.65 $\pm$ 1.21	125.72 $\pm$ 1.37	140.36 $\pm$ 1.05	153.48 $\pm$ 1.59	154.64 $\pm$ 1.55
Duration of JT interval, s							
SMB	0.259 $\pm$ 0.005	0.239 $\pm$ 0.003*	0.219 $\pm$ 0.003*	0.199 $\pm$ 0.003*	0.181 $\pm$ 0.002*	0.179 $\pm$ 0.002	0.180 $\pm$ 0.002
TMB	0.265 $\pm$ 0.003	0.248 $\pm$ 0.003	0.231 $\pm$ 0.002	0.208 $\pm$ 0.002	0.192 $\pm$ 0.002	0.182 $\pm$ 0.002	0.182 $\pm$ 0.001
JT/RR index							
SMB	0.348 $\pm$ 0.006	0.394 $\pm$ 0.004	0.419 $\pm$ 0.004*	0.440 $\pm$ 0.003*	0.461 $\pm$ 0.003*	0.460 $\pm$ 0.004	0.450 $\pm$ 0.004
TMB	0.354 $\pm$ 0.003	0.399 $\pm$ 0.009	0.407 $\pm$ 0.003	0.425 $\pm$ 0.003	0.437 $\pm$ 0.003	0.452 $\pm$ 0.003	0.449 $\pm$ 0.003

Values are mean $\pm$ standard error.

JT, time interval in an electrocardiogram from junction point J to T wave end (JT interval); RR, time interval in an electrocardiogram between 2 heart contractions (RR interval). According to the model of integral evaluation, the heart rate represents the regulatory system; the supplying system is reflected by the JT interval in the electrocardiogram, and the JT/RR ratio describes the relationship between supplying and regulatory systems. TMB, taller and heavier male basketball players (whose bodies contained relatively more fat); SMB, shorter and less heavy male basketball players (whose bodies contained relatively less fat).

\* $P < 0.05$ , the SMB group vs. the TMB group.

This interval in the TMB group was significantly greater ( $0.248\pm 0.003$ ,  $0.231\pm 0.002$ ,  $0.208\pm 0.002$ , and  $0.192\pm 0.002$  s) during warming-up and steady state compared with the SMB group ( $0.239\pm 0.003$ ,  $0.219\pm 0.003$ ,  $0.199\pm 0.003$ , and  $0.181\pm 0.002$  s, respectively) ( $P<0.05$ ) (Table 2). Table 2 shows that the male basketball players in the SMB group (with lower percentage of body fat) reached the range limit of JT interval earlier than those in the TMB group. It is also obvious that the heart rate of the male basketball players in the TMB group was lower and the JT interval at rest and every step of the load was greater than in the male basketball players of the SMB group. Therefore, the regulatory and supplying systems of the taller and heavier male basketball players were recruited to the load more slowly and functioned more economically.

The analysis of JT/RR ratio dynamics in the groups showed the slightly greater JT/RR ratio at rest and at the physical load of 50 W in the TMB group than the SMB group; however, this difference was not significant ( $P\geq 0.05$ ). Starting from 100 W (at 100, 150, and 200 W), the JT/RR ratio of the taller and heavier male basketball players ( $0.407\pm 0.003$ ,  $0.425\pm 0.003$ , and  $0.437\pm 0.003$ ) was significantly lower compared with the respective parameter ( $0.419\pm 0.004$ ,  $0.440\pm 0.003$ , and  $0.461\pm 0.003$ ) of the shorter and less heavy male basketball players ( $P<0.05$ ) (Table 2). It would be logical to believe that the JT/RR ratio in taller and heavier men should be smaller than in shorter and less heavy men, because a taller and heavier man's heart is larger. That was found in our research.

No significant differences in the systolic blood pressure were detected at rest and during exercise in both groups ( $P\geq 0.05$ ). The systolic blood pressure of the taller and heavier male basketball players at rest and during submaximal physical load was  $126.33\pm 1.64$  mm Hg and  $215.73\pm 1.88$  mm Hg, respectively, while in the shorter and less heavy male basketball players, the corresponding values were  $124.70\pm 1.80$  mm Hg and  $201.00\pm 1.92$  mm Hg, respectively.

The pulse amplitude of arterial blood pressure during exercise varied equally in both the groups. At the physical load of 300 W, the pulse amplitude of arterial blood pressure decreased in the SMB group, like the executive system reached a critical threshold. There were no significant differences in the pulse amplitude of arterial blood pressure ( $P\geq 0.05$ ).

The pulse arterial blood pressure ratio amplitude (S-D)/S of the taller and heavier male basketball players was found to be lower at each step of the load. There was a significant difference in this parameter at 50 W between the TMB and SMB groups ( $0.500\pm 0.007$  vs.  $0.537\pm 0.008$ ,  $P<0.05$ ). Maybe it

should be considered as the higher the body weight, the less involvement of the regulatory system? This index, reflecting interaction between the regulatory and executive systems during physical load, is higher in athletes than untrained individuals.

### Discussion

The model of integrated evaluation helps better understand the body functioning during exercise (24). In this study, we analyzed the effect of anthropometric data on the alternations of cardiovascular system indicators. As many as 113 bicycle stress tests were performed; parameters characterizing each holistic system and the relationships between those systems were analyzed.

Heart rate describes the regulatory system (24). We suppose that the regulatory system of shorter and less heavy basketball players depletes itself more actively during the same physical load in comparison with that of taller and heavier basketball players. The taller and heavier male basketball players (TMB) had a lower heart rate as compared with that of the shorter and less heavy male basketball players whose bodies contained relatively less fat (SMB). Thus, the regulatory system of taller and heavier male basketball players recruits to load more slowly and more economically.

Some researchers have discovered the importance of measuring the duration of JT interval for persons with cardiovascular risk (27). Stierle and coauthors (28) investigated patients with coronary artery disease and found the more active shortening of JT interval during physical load in the healthy myocardium, where repolarization was earlier and metabolic changes were faster (27). Measuring the duration of JT interval is important in terms of arrhythmia and sudden cardiac death as well (27). A study by Jaruševičius (16) revealed that the duration of JT interval at rest in healthy men was  $267\pm 29$  ms; in the athlete group,  $258\pm 28$  ms. There was no significant difference in the JT interval duration between healthy men and athletes. Jaruševičius (16) found a very strong and strong negative correlation between the heart rate and the duration of JT at rest: when the heart rate increased, the duration of JT interval shortened, and vice versa, when the heart rate decreased, the duration of interval JT lengthened. During the maximal physical load in the group of healthy subjects, only moderate correlation ( $r=-0.38$ ) between the duration of interval JT and the heart rate was found, while in the athletes' group, it was strong ( $r=-0.56$ ) (16). In our study, the duration of interval JT in both the groups was gradually decreasing. Moreover, JT interval at rest and each step of load of the taller and heavier male basketball players was longer compared with that of the shorter and less heavy male basketball players,

and the difference was statistically significant during warming-up and the steady state. Shortening in the JT interval during physical load suggests the increase of metabolic rate in the myocardium (27). Metabolic changes are closely associated with repolarization changes. A linear relationship between stress-induced dispersion of JT interval and lactate rates in the blood was found. The faster and greater the change in the JT interval, the greater amount of lactate is in blood (27). The duration of interval JT in the group of the less heavy male basketball players whose bodies contained relatively less fat decreased more rapidly and reached a minimum threshold earlier.

The JT/RR ratio describes the relationship between the regulatory and supplying systems (24). The results of our research have shown the JT/RR ratio of the heavier male basketball players during the load to be lower than that of the less heavy male basketball players. Cardiac involvement in physical activity of taller and heavier men is slower and more economical; the regulatory system influences the supplying system slower in comparison with shorter and less heavy men. Poderys with coauthors (13) analyzed the JT/RR ratio change during exercise in wrestlers and nonathletes. They found that the cardiovascular function during exercise was activated more in nonathletes than wrestlers (13).

A muscle shape influences the pulse amplitude of arterial blood pressure (S-D) (29). The higher the pulse amplitude of arterial blood pressure (within certain limits), the better blood flow in the muscle is (29). It is known that athletes significantly decrease diastolic blood pressure at the peak of exercise (30). This ability improves the situation for increasing pulse arterial blood pressure amplitude (29). Poderys (29) evaluated the changes in the pulse amplitude of arterial blood pressure in sprinters in regard to systolic arterial blood pressure, and the changes were smaller compared with those of long-distance runners. Our previous studies showed that persons involved in sports (football, basketball) had the higher values of pulse amplitude during exercise than nonathletes (31). In the present study, we did not find any differences in the pulse amplitude of arterial blood pressure between the taller and heavier male basketball players and the shorter and less heavy male basketball players.

## References

1. Haken H, Kelso JAS, Bunz H. A theoretical model of phase transitions in human hand movements. *Biol Cybern* 1985;51:347-56.
2. Kelso JAS. *Dynamic patterns*. Cambridge: MIT Press; 1999.
3. Kurz MJ, Stergiou N. Applied dynamic systems theory for the analysis of movement. In: *Innovative analyses of human movement*. Stergiou N, editor. USA: Human Kinetics; 2004. p. 93-120.
4. Torrents C, Balague N. Dynamic systems theory and sports training. *Education. Physical Training. Sport* 2006;1(60): 72-83.
5. Large EW. On synchronizing movements to music. *Human Movement Science* 2000;19:527-66.
6. Stergiou N, Jensen JL, Bates BT, Scholten SD, Tzetzis G. A

However, the ratio index (S-D)/S of the taller and heavier male basketball players was found to be significantly lower in the warming-up phase compared to the respective parameter of the shorter and less heavy male basketball players. In case of greater body weight and greater relative fat mass, the regulatory system may be less active.

We see that the recruitment of the cardiovascular system to physical load of taller and heavier male basketball players is slower and more economical, i.e., the regulatory system “controls” the supplying system more slowly than in the case of shorter and less heavy male basketball players. This is likely to be because the bodies of taller and heavier male basketball players contain relatively more fat, i.e., they possess more energy resources compared with shorter and less heavy male basketball players.

The results of the study extend the understanding about the specificity and consistent patterns of basketball players’ short- and long-term adaptation to physical load. The peculiarities are demonstrated by absolute values and their changes during exercise as well the relative rates, revealing the interaction between systems. Many athletes believe that the less is body fat amount, the better is the physical and functional status, and the better sports results can be achieved. Our study shows that athletes with relatively more fat (but not too much) have more reserves: the regulatory and supplying systems are recruited more slowly and they participate more efficiently during exercise. These data have practical benefits. We believe that athletes with more fat (but at normal levels) will have a greater energy reserve during exercise. In basketball, a player is assigned to a specific position based on his height and weight as well as the physical and functional capacities of his body. The results of the study may help individualize physical activity, predict early deadaptation and fatigue, revise the athlete’s diet, and find the most appropriate positions for players.

## Conclusions

The cardiovascular system of taller and heavier Lithuanian elite male basketball players with a relatively greater amount of fat functions more economically.

## Statement of Conflict of Interest

The authors state no conflict of interest.

- dynamical systems investigation of lower extremity coordination during running over obstacles. *Clin Biomech (Bristol, Avon)* 2001;16:213-21.
7. Pellecelia GL, Turvey MT. Cognitive activity shifts the attractors of bimanual rhythmic coordination. *J Mot Behav* 2001;33(1):9-15.
  8. McGarry T, Anderson DI, Wallace A, Hughes MD, Franks IM. Sport competition as a dynamical self-organizing system. *J Sports Sci* 2002;20:771-81.
  9. Schmidt RC, O'Brien B, Sysco R. Self-organization of between-persons cooperative tasks and possible applications to sport. *Int J Sport Psychol* 1999;30:558-79.
  10. Barengo NC, Hu G, Tuomilehto J. Physical activity and hypertension: evidence of cross-sectional studies, cohort studies and meta-analysis. *Hypertens Rev* 2007;3:255-63.
  11. Tsioufis C, Kyvelou S, Tsiachris D, Tolis P, Hararis G, Koufakis N, et al. Relation between physical activity and blood pressure levels in young Greek adolescents: the Leontio Lyceum Study. *Eur J Public Health* 2011;21(1):63-8.
  12. Stasiulis A, Mockienė A, Vizbaraitė D, Mockus P. Aerobic exercise-induced changes in body composition and blood lipids in young women. *Medicina (Kaunas)* 2010;46(2):129-34.
  13. Poderys J, Buliuolis A, Poderytė K, Sadzevičienė R. Mobilization of cardiovascular function during the constant-load and all-out exercise tests. *Medicina (Kaunas)* 2005;41(12):1048-53.
  14. Poderys J, Misekaitė B, Ežerskis M. Sportininko organizmo adaptacijos ypatybės nuvykus į XXIX olimpiados žaidynių sostinę Pekiną. (Peculiarities in adaptation of body functioning during the exercise and recovery after the flight to Beijing.) *Sport Science* 2007;1(47):27-31.
  15. Bertašienė Z, Brazdžionytė J, Žaliūnas R, Vainoras A. Moterų išeminė širdies liga: skilvelių repoliarizavimosi rodmenų prognozinė vertė. (Ischemic heart disease in women: prognostic value of ventricular repolarization variables.) *Medicina (Kaunas)* 2004;40(1):54-63.
  16. Jaruševičius G. Išeminės širdies ligos požymių fizinio krūvio metu paieška ir įvertinimas pagal vainikinių arterijų pažeidimo vietą. (Searching for predictors of ischaemic heart disease during exercise testing and their evaluation according to localization of coronary artery.) [dissertation]; Kaunas: KMU; 2000.
  17. Weinstein Y, Weinstein A. [Energy balance, body composition and the female athlete triad syndrome]. *Harefuah* 2012;151(2):97-101, 127, 126.
  18. Ducher G, Turner AI, Kukuljan S, Pantano KJ, Carlson JL, Williams NI, et al. Obstacles in the optimization of bone health outcomes in the female athlete triad. *Sports Med* 2011;41(7):587-607.
  19. Nattiv A, Loucks AB, Manore MM, Sanborn CF, Sundgot-Borgen J, Warren MP; American College of Sports Medicine position stand. The female athlete triad. *Med Sci Sports Exerc* 2007;39(10):1867-82.
  20. Karila TA, Sarkkinen P, Marttinen M, Seppälä T, Mero A, Tallroth K. Rapid weight loss decreases serum testosterone. *Int J Sports Med* 2008;29(11):872-7. Epub 2008 May 30.
  21. Gibbons RJ, Balady GJ, Beasley JT, Chaitman BR, Fletcher GF, Froelicher VF, et al. ACC/AHA guideline update for exercise testing; summary article: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1997 Exercise Testing Guidelines). *Circulation* 2002;106:1883-92.
  22. Ostojic SM. Estimation of body fat in athletes: skinfolds vs bioelectrical impedance. *Sports Med Phys Fitness* 2006;46(3):442-6.
  23. Jakimavičienė E, Tutkuviene J. Antropometriniai ir kiti kūno sudėties nustatymo metodai. (Anthropometry and other methods for assessment of body composition.) *Medicinos teorija ir praktika* 2004;2(38):138-43.
  24. Vainoras A, Gargasas L, Jarusevicius G. The bicycle ergometry and the possibility of complex evaluation. *Lithuanian Journal of Cardiology* 1999;6(4):760-3.
  25. Berškienė K. Elektrokardiografinių signalų parametrų dinaminė sąsaja analizė. (The analysis of dynamic interrelationships of electrocardiographic signal parameters.) [dissertation]; Kaunas: UT; 2010.
  26. Myers TW. *Anatomy trains: myofascial meridians for manual and movement therapists*. Edinburgh: Churchill Livingstone; 2001. p. 33.
  27. Jaruševičius G, Navickas R, Vainoras A, Gargasas L, Vaicekavičius E. Ligonių, sergančių ūminiu miokardo infarktu, JT intervalo kitimai mechaninės vainikinių arterijų rekanalizacijos metu. (JT interval changes in acute myocardial infarction following coronary angioplasty.) *Medicina (Kaunas)* 2004;40(Suppl 1):90-3.
  28. Stierle U, Giannitsis E, Sheikhzadeh A, Krüger D, Schmücker G, Mitusch R, et al. Relation between QT dispersion and the extent of myocardial ischemia in patients with three-vessel coronary artery disease. *Am J Cardiol* 1998;81:564-8.
  29. Poderys J. Ištvėrmę ir greitumą lavinančių sportininkų raumenų kraujotaka ir širdies-kraujagyslių sistemos greitosios ir lėtosios adaptacijos savybės atliekant fizinius pratimus. (Acute and chronic adaptation peculiarities of cardiovascular system during physical exercising.) *Habilitacinis darbas [synopsis of thesis]*; Kaunas: LKKI; 2000.
  30. Ketelhut RG, Ketelhut R, Messersli FH, Badtka G. Fitness in the fit: does physical conditioning affect cardiovascular risk factors in middle-aged marathon runners? *Eur Heart J* 1996;17:199-203.
  31. Žumbakytė-Šermukšniene R, Kajėnienė A, Vainoras A, Berškienė K, Augutienė V. Assessment of functional conditions of basketball and football players during the load by applying the model of integrated evaluation. *Medicina (Kaunas)* 2010;46(6):421-8.

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