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ANTHROPOMETRIC CHARACTERISTICS AND WINGATE TEST PARAMETERS OF ADOLESCENT FEMALE FOOTBALL PLAYERS AND TRACK AND FIELD ATHLETES

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ABSTRACT

Anthropometric characteristics and anaerobic fitness are recognized as key factors for successful sports performance. Data thereof are used for more thorough analysis and a better understanding of the results of sports performance. However, the needed data regarding adolescent girls in many sports are still scarce or absent. The aim of this study was to make a comparative assessment of the anthropometric parameters and the characteristics of the anaerobic fitness of 15-year-old female football players and track and field athletes. The study included 32 subjects who had competed in national championships in Bulgaria. We used established standards to determine the anthropometric characteristics. To determine the anaerobic power, we applied the Wingate test to assess anaerobic fitness, which is particularly important for sports such as football and track and field athletics – sprint disciplines. The two groups of studied subjects did not differ significantly in age and height, but there were statistically significant differences between the groups in terms of weight, BMI, and Fat%. The Wingate test results also showed a statistically significant difference between the two samples regarding the indicators Relative Peak Power (RPP) (W/kg) and Relative Average Power (RAP) (W/kg). The 15-year-old female football players studied were characterized by height that was higher than average for the age, BMI and Fat% that were average for the age, and average RPP values. The studied 15-year-old female track and field athletes were characterized by height that was average for the age, BMI and Fat% that were low for the age, and high RPP values. This study is the first in Bulgaria to focus on adolescent female football players and track and field athletes.

Keywords: *Wingate Test, Anthropometric Measurements, Football, Track and Field Athletics*

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INTRODUCTION

In football and sprint disciplines of track and field athletics, anaerobic qualities play an important role in successful sports performance (Stefanova et al., 2017; Valladarez et al., 2021; Lima et al., 2011). Therefore, anaerobic fitness assessment is an important element in the control of these sports. According to Bourdon et al., "a primary goal of load monitoring should be to assist and inform the coach/manager decision making on player availability for training" (Bourdon et al., 2017). Knowledge of the development of anaerobic fitness is among the key factors in "successful talent identification, long-term athlete development, physiological monitoring, and design of training programs" (Armstrong et al., 2020).

Coaching activity in football and athletics requires an adequate evaluation of the results of standardized tests to assess anaerobic fitness.

An example of a strictly standardized test for assessment of anaerobic fitness, which is particularly important for sports requiring

speed qualities such as football and track and field athletics – sprint disciplines, is the Wingate test (Castañeda-Babarro, 2022; Subhra et al., 2022). This test was created in 1974 by the Wingate Institute for Physical Education and Sports in Israel (Ayalon et al., 1974; Castañeda-Babarro, 2022). The test lasts 30 seconds, and the athlete must maintain the maximum possible revolutions during the whole time. The parameters that are usually used to assess anaerobic capacity are: Peak Power (PP) (W), Relative Peak Power (RPP) (W/kg), Average Power (AP) (W), Relative Average Power (RAP) (W/kg), and Power Drop (PD) (%). According to some authors, in a test-retest procedure, the most reliable indicator is RAP, as it shows the best repeatability (Armstrong et al., 1997). A number of modifications to the test have been described in the literature, such as extending the time from 40 to 50 seconds or with a pedal effort of 0.85% per kilogram of body weight; however, these have been applied to high-class competitive cyclists (Vandewalle et al., 1987).

The Wingate anaerobic test shows a high correlation (0.67) with some speed endurance field tests. A recent study by a collective of Bulgarian authors has reported a high correlation between the results of the Wingate test and the STEMPO 300 m field shuttle test (Antonov et al., 2024).

Another field test that correlates highly with the Wingate test is the six maximum 35 m sprints test. In this test, the measured speeds are used to calculate the power in watts, thus allowing a direct comparison of the results with the laboratory anaerobic test. This field test also makes it possible to assess the anaerobic fitness and the fatigue index (Zagatto et al., 2015).

It should be noted that another test typically included in complex battery tests for determining physical fitness is handgrip strength (Alpha, 2009). It is considered that "handgrip strength should be included as a component of multidimensional health evaluation of children and adolescents" (Matsudo et al., 2015). Trosclair et al. announced that "the predictive value of the HGD could serve as a useful tool to predict muscular strength and endurance that would normally require more complex assessment. HG testing requires only a single piece of equipment and minimal effort from subjects who may be unwilling or unable to perform the other more strenuous tests" (Trosclair, 2011). Other authors believe that there is adequate evidence to show that HG testing is an important biomarker of health (Vaishya, 2024).

Physical aerobic and predominantly anaerobic fitness are strongly influenced by anthropometric characteristics, which is the main reason for conducting anthropometric measurements before sports testing. Anthropometric data are needed for a more thorough analysis and a better understanding of sports performance results. Additionally, significant medium-to-large associations have been observed between training and anthropometrics/body composition/physical fitness (Lesinski et al., 2017). A study reported a trend of improvement in muscle strength and power output during the competition season (Miyamoto et al., 2016).

Although there are many standards in the literature for parameters of anaerobic fitness for men and women, as well as boys, it should be noted that standards are still scarce or absent regarding adolescent girls in various sports.

Thus, this study was conducted with the aim of making a comparative assessment of the anthropometric characteristics and anaerobic performance of 19 female 15-year-old football players and those of 13 female 15-year-old track and field athletes, as a step

towards the establishment of relevant data, which is practically lacking in Bulgaria at present.

METHODOLOGY

Participants

The study involved 32 female adolescent athletes (19 football players and 13 track and field athletes). The football players had a mean age of 15.2 ± 0.9 and a mean sports experience of 2 years. All football players were members of a team that placed 3rd in the 2023 Autumn National Girls Football Championship.

The track and field athletes had a mean age of 15.6 ± 1.2 and a mean sports experience of 4 years. Seven of them were finalists in the 60 m and 200 m events of the 2024 National Winter Championship.

Criteria for inclusion in the study:

- age 15 years ± 1 year;
- regular training process, minimum three training sessions per week (some of the tested subjects had up to 7 training sessions per week).

Criteria for exclusion from the study:

- athletes with injuries;
- athletes with illnesses.

An institutional approval for this study was granted by the National Sports Academy „Vassil Levski" in Bulgaria (EC–NSA–2025-010), and informed parental consent was obtained for each participant, in accordance with the requirements of the Declaration of Helsinki for Human Research (WMA, 2013).

Design of the study

The study was observational, based on the comparative assessment of the anthropometric parameters and the characteristics of the anaerobic fitness of 15-year-old female football players and track and field athletes.

The testing was carried out in February 2024 at the Center for Research and Applied Activity in Sport of the National Sports Academy "Vassil Levski", in the time range from 9:00 a.m. to 12:00 p.m. The participants were instructed to take a light carbohydrate breakfast consisting of 100 g muesli of their choice and tea with up to two spoons of sugar in the morning before the test. They were told not to perform any physical exercises before the test.

Body composition

The height was measured with an accuracy of 0.1 cm using a SECA stadiometer (made in Germany). The body mass was measured to the nearest 50 g using a CAS CK200-SC scale (made in Australia PTY LTD). The Body Mass Index was determined according to the formula: BMI (kg/m^2) = Weight (kg)/ $Height^2$ (m). The percentile scores of these indicators for girls aged 5 to 19 years were determined with the software of the World Health Organization (WHO AnthroPlus 1.0.4).

We accepted BMI scores from the 5^{th} to the 85^{th} percentile as normal weight and BMI scores from the 85^{th} to the 95^{th} percentile as overweight (Hampl et al., 2023).

To determine the percentage of fat tissue, we used the method of Slaughter (Slaughter et al., 1988). This method determines the percentage of fat tissue according to age, sex, and two skin folds – triceps and scapula. We measured the skin folds twice with an accuracy of 1 mm with a Harpender skinfold caliper, model 2019, RH15 9LR (made in England), and took the mean value as a result.

We used the formula for females aged 8 to 18 as follows:

Fat% = 1.33 (triceps + subscapular) - 0.013 (triceps + subscapular) 2 – 2.5

For a sum of triceps and subscapular greater than 35 mm, the following equation was applied:

Fat% = 0.546 (triceps +subscapular) + 9.7

For estimating the percentile scores of Fat%, we used those for girls up to 19 years of age, published by Schwandt (Schwandt et al., 2012).

We also determined the Lean Body Mass (kg) = Body Mass * (100 - %BF) /100. Bone mass was included in LBM.

Wingate test

The Wingate test was conducted with a specialized cycle ergometer, "Monark" 834E (Vansbro, Dalarna, Sweden).

Before the test began, we instructed each participant. We explained that the test was maximal and required a powerful start and an effort to maintain maximum revolutions until the very end of the test. Before the beginning, we adjusted the seat height for each participant. The participants performed a 5-minute warm-up with a resistance of 60 watts and a pedaling rate of 60 revolutions per minute. During the warm-up, at the end of the 3rd minute and the end of the 5th minute, they made two sprints, each reaching maximum revolutions. A 3-minute recovery break was given before the start of the test.

After 5 seconds of pedaling without resistance to reach maximum revolutions, pedaling resistance was individually set at 7.5% of body weight (Inbar & Skinner, 1996), and participants were encouraged to maintain maximum revolutions for the next 30 seconds.

Based on the registered power during the Wingate test, we calculated the following parameters: Peak Power (PP) in watts (W), Relative to Body Mass Peak Power (RPP)in watts per kilogram (W/kg), Relative Peak Power to Lean Body Mass (RPP/LBM) in watts per kilogram of lean body mass (W/kg LBM); Average Power (AP) in watts (W); Relative to Body Mass Average Power (RAP) in watts per kilogram (W/kg); Power Drop (PD) as a percentage (%); and Hand Grip (HG) in kilograms (kg).

All Wingate tests were performed with heart rate monitoring using belts and watches, Vantage 2, Polar. The maximum heart rate in the range of 80-90% of the predicted maximum for the age (220 - Age) was accepted as an additional criterion for a correctly performed maximum Wingate test.

Measurement of handgrip strength

Handgrip strength was measured with a TKK 5101 Grip-D dynamometer (Takey, Tokyo, Japan). The test was conducted with the arm extended parallel to the body in a standing position. This measurement method has been justified as optimal by other researchers (Espana-Romero et al., 2010; Kolimechkov et al., 2020). We recorded the better of two consecutive attempts for each hand and took the arithmetic mean of the left and right hand as the grip strength score.

Statistical analyses of the data

Statistical analyses were performed using the IBM, USA SPSS 23.0 statistical package. We used the Shapiro-Wilk test to determine the normality of the distributions. We determined the studied parameters' mean values, standard deviations, and maximum and minimum values with descriptive statistics. The mean values in the text and the tables have been presented with their standard deviations. To assess the statistical significance of the difference in the mean values of height and BMI of each of the two studied groups as compared to the 50th percentile for 15-year-old females according to the World Health Organization (WHO. BMI-for-age 5-19), we used the One-Sample T-test. To assess the statistical significance of the differences in the means of the normally distributed variables, we used a Student's t-test for independent samples, and for the rest, we used the non-parametric Mann-Whitney U-test for independent samples. We created prelimi-

nary percentile scores for the Wingate anaerobic test parameters concerning 15-year-old females based on the results we obtained with the same statistical package.

RESULTS

Table 1 presents the mean values of the anthropometric parameters and the statistical significance of the differences in the mean values between the studied groups of adolescent female athletes. The mean age of the football players was 15.2 ± 0.9 years and was not significantly different from the mean age of the track and field athletes, 15.6 ± 1.2 years. The mean height of the football players was 165 ± 0.04 cm and was not significantly different from the mean height of the track and field athletes, 164 ± 0.1 cm. The mean weight of the football players was 56.2 ± 6.1 kg. It was statistically significantly different from the mean weight of the track and field athletes, 51.7 ± 6.1 kg ($p < .05$). The mean BMI of the football players was 20.7 ± 2.2 (kg/m^2) and was statistically significantly different from that of the track and field athletes 19.2 ± 1.5 (kg/m^2) ($p < .05$). The mean Fat% of the football players was 21.4 ± 4.0 and was significantly different from that of the track and field athletes 16.6 ± 2.7 ($p < .01$). The mean LBM of the football players was 44.01 ± 3.6 kg and was not significantly different from that of track and field athletes 43.1 ± 4.5 kg.

Table 1. *Mean values of the anthropometric parameters and statistical significance of the differences between the studied groups (Mean ± SD).*

Group	Age[A] (y)	Height (m)	Weight[A] (kg)	BMI[A] (kg/m^2)	LBM[A] (kg)	Fat (%)
Football	15.2 ± 0.9	165 ± 0.04	56.2 ± 6.1*	20.7 ± 2.2*	44.01 ± 3.6	21.4 ± 4.0**
Track and field athletics	15.6 ± 1.2	164 ± 0.1	51.7 ± 6.1	19.2 ± 1.5	43.1 ± 4.5	16.6 ± 2.7

** - $p < .05$; ** - $p < .01$ Football vs Track and field athletics; A – indicators with abnormal distribution*

Table 2 presents the mean values of the percentile scores of height and BMI and the statistical significance of the differences in the mean values between the studied groups of adolescent female athletes. The mean percentile score of height of the football players was 65.8 ± 21.0 and was significantly different from that of the track and field athletes, 50.4 ± 26.7 ($p < .001$). The mean BMI percentile score in the football players was 50.4 ± 26.7 and was significantly different from that of the track and field athletes, 26.8 ± 14.6 ($p < .001$). In interpreting the BMI data, we used Hampl's rating scale, where the values from the 5th to 85th percentile are normal weight values (Hampl et al., 2023). The mean height of the football players was higher and significantly different from the mean height of girls their age (50th percentile) ($p < .01$). The mean BMI of the track and field athletes was lower and significantly different from the mean BMI of girls their age of the general population (50th percentile) ($p < .001$) (WHO. BMI-for-age 5-19). Only one football player was overweight (BMI > 25.0). All track and field athletes were of normal weight.

Table 2. *Mean values of the percentile scores for height and BMI and statistical significance of the differences between the studied groups (Mean ± SD).*

Groups		N	Mean percentile score of the studied group vs. the 50th percentile	Statistical significance of the difference vs the 50th percentile
Football	Height	19	65.8 ± 21.0***	$p = .002$
	BMI	19	50.4 ± 26.7***	$p = .822$
Track and field athletics	Height	13	55.3 ± 26.8	$p = .407$
	BMI	13	26.8 ± 14.6	$p = .0001$

*** - $p < .001$ *Football vs. Track and field athletics*

Table 3 presents the percentile scores for the PP and RPP parameters from the Wingate anaerobic test. We have also presented percentile scores for RPP (W/kg LBM).

Table 3. *Percentile norms for Wingate anaerobic power in Watts, Watts per body weight (W/kg), and lean body mass (W/kg LBM) of adolescent female athletes (both football players and track and field athletes).*

Percentiles	PP (W)	RPP (W/kg Body mass)	RPP (W/kg LBM)
10	415.3	8.4	10.0
20	433.5	8.7	10.5
30	465.2	8.8	10.6
40	472.6	9.2	11.0
50	473.1	9.5	11.1
60	480.3	9.5	11.3
70	500.7	9.9	12.0
80	544.6	10.5	13.0
90	602.3	11.1	13.2
100	616.9	11.4	13.4
Average	493.2	9.1	11.2
SD±	79.7	1.1	1.4
Max	693.0	11.4	13.6
Min	371.8	7.2	8.6

Table 4 presents the mean values of the parameters of the Wingate test and the manual dynamometry and the statistical significance of the differences in the mean values between the studied groups. The mean PP in the football players was 491 ± 77 W and was not significantly different from that in the track and field athletes, 490 ± 62 W. The mean RPP in the football players was 8.7 ± 0.9 W/kg. There was a statistically significant difference from that in the track and field athletes, 9.5 ± 0.9 W/kg ($p < .03$). The mean RPP/LBM in the football players was 11.1 ± 1.2 W/kgLBM and was not significantly different from that of the track and field athletes 11.4 ± 1.2 W/kgLBM. The mean AP in the football players was 377.8 ± 46.3 W and was not significantly different from that in the track and field athletes, 379.5 ± 46.0 W. The mean RAP in the football players was

6.7 ± 0.6 W/kg and was significantly different from that in the track and field athletes 7.4 ± 0.6 W/kg ($p < .05$). The mean PD in the football players was 53.7 ± 12% and was not significantly different from that in the track and field athletes 48.5 ± 9.6%. The average HG kg in the football players was 26.8 ± 3.4 kg and was not significantly different from that in the track and field athletes, 26.6 ± 1.6 kg.

Table 4. *Mean values of the Wingate test parameters and statistical significance of the differences between the studied groups (Mean ± SD).*

Group	PP[A] (W)	RPP (W/kg)	RPP/LBM[A] (W/kg LBM)	AP (W)	RAP[A] (W/kg)	PD (%)	HG[A] (kg)
Football	491 ± 77	8.7 ± 0.9*	11.1 ± 1.2	377.8 ± 46.3	6.7 ± 0.6*	53.7 ± 12	26.8 ± 3.4
Track and field athletics	490 ± 62	9.5 ± 0.9	11.4 ± 1.2	379.5 ± 46.0	7.4 ± 0.6	48.5 ± 9.6	26.6 ± 1.6

** - $p < .05$ Football vs Track and field athletics; [A] – indicators with abnormal distribution*

Heart rate dynamics showed a slight rise around 120 bpm before the start of the test, reflecting the pre-start state (Figure 1). Maximum heart rate values ranged from 168 to 197 bpm, with a mean value of 177.6 ± 8.59 bpm and expressed as a percentage of 86.6 ± 4.2% of the maximum heart rate. Other authors who monitored heart rate during the Wingate test reported 90.7% of the maximum heart rate (Astorino et al., 2015). The maximum heart rate reached in all the studied athletes was within the criterion for maximal effort, which we accepted to be 80-90% of the age-predicted maximum heart rate.

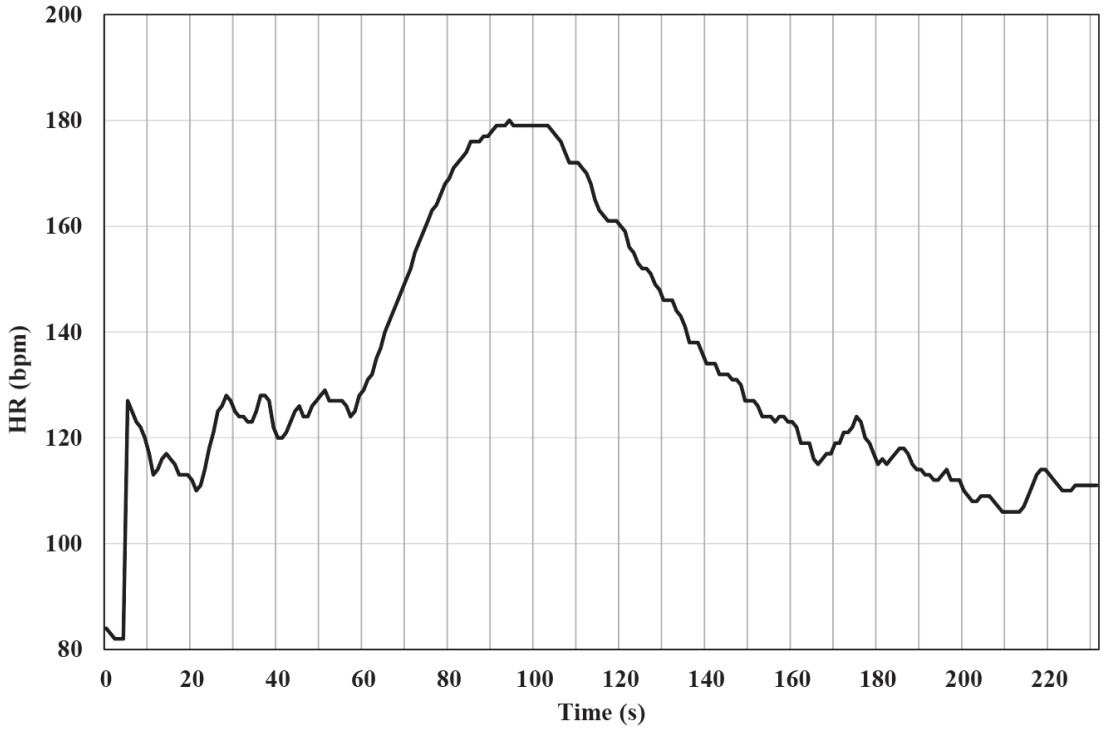

Figure 1. *Dynamics of the heart rate of one of the track and field athletes during the Wingate test*

DISCUSSION

Comparative analysis of the anthropomorphic characteristics

Anthropometric characteristics are closely related to sports performance. According to some authors, a correct interpretation of

strength and speed characteristics should also be based on body composition data (Dotan & Bar-Or, 1983). Our study determined the leading indicators of body composition reflecting physical development and the prerequisites for high physical fitness.

The mean height of the studied football players was statistically significantly higher than the mean for the age (65th percentile), while the mean height of the track and field athletes did not differ from the mean for girls their age (55th percentile).

The mean BMI of the football players was corresponding to the mean for the age (50.4th percentile), while the mean BMI of the track and field athletes was below the median for girls their age (26.8th percentile). The percentage of fat tissue was statistically significantly higher in the football players (21.4%) than in the track and field athletes (16.6%) (Table 1). The mean Fat% of the football players was average for the age (53rd percentile), while the mean Fat% of the track and field athletes was below the average for girls their age (25th percentile) (Table 2). Analysis of anthropometric data showed a higher mean body mass in football players at the expense of a higher Fat%, which can be explained by the fact that body-to-body contact is often observed in football games.

The BMI of the studied adolescent female athletes in both groups was within healthy limits (18.2 - 25.0).

Comparative analysis of the results of the anaerobic Wingate test.

There were no significant differences between the studied football players and the track and field athletes regarding peak power (PP). The latter is a parameter used to reflect the capacity of the anaerobic lactate energy supply system (ATP and CP) (Castaneda-Babarro, 2021).

However, the relative peak power (RPP W/kg) was lower in the football players than the track and field athletes (football players – 8.7 ± 0.9 W/kg vs track and field athletics – 9.5 ± 0.9 W/kg). Our findings are consistent with other studies where it could be noted that with almost identical values of PP, differences are observed in RPP (Zupan et al., 2009).

In our opinion, this statistically significant difference was mainly due to the lower body mass of the track and field athletes at the expense of their lower fat percentage (Fat%). The high relative peak power RPP allows track and field athletes to reach maximum speed faster.

We determined that the mean RPP percentile score of the studied adolescent female football players corresponded to the 33rd percentile for male football players of the same age, using the published data by Nikolaidis (Nikolaidis et al., 2018). In an analogical comparison, we found that the female track and field athletes corresponded to the 40th percentile.

The results were similar for the mean AP values, which did not differ significantly between the two studied groups. However, the mean RAP values were again statistically significantly higher for the track and field athletes than the football players (track and field athletes 7.4 ± 0.6 W/kg vs football players 6.7 ± 0.6 W/kg). AP mainly reflects the capacity of the glycolytic energy supply system (Castaneda-Babarro, 2021).

Based on the published data by Nikolaidis (Nikolaidis et al., 2018), we determined that the mean RAP percentile score of the studied adolescent female football players corresponded to the 30th percentile for male football players of the same age. An analogical comparison showed that the female track and field athletes corresponded to the 40th percentile. A high RAP allows more stable performance of the track and field athletes while maintaining revolutions per minute.

Power drop (PD) was 53.7% in the football players and 48.5% in the track and field ath-

letes. Using the published data by Nikolaidis (Nikolaidis et al., 2018), we determined that the mean PD percentile score of the studied female football players corresponded to the 90th percentile for male football players of the same age. Analogically, female track and field athletes were found to correspond to the 75th percentile.

Based on the literature review and the results of this study, we consider that the anaerobic Wingate test provides important information for controlling the anaerobic capabilities of adolescent female football players and track and field athletes. In the literature, we found percentile scores and classification for Wingate test parameters for highly trained males and females (Baker et al., 2011; Zupan et al., 2009) and adolescent male football players (Nikolaidis et al., 2018). However, we found no percentile scores and classifications for adolescent female athletes. Therefore, we presume that, despite the relatively small number of subjects studied, the percentile scores we determined in our study may serve as a basis for further studies on a larger scale to establish normative standards. Last but not least, this study included handgrip strength (HG) testing due to its applicability and efficiency regarding adolescent children and athletes. We used the HG percentile scores for non-training girls of the same age published by some authors from Pakistan (Hamdani et al., 2023) and determined the HG percentile scores of the female athletes we studied. The mean percentile scores of both groups were higher than the 90th percentile, indicating the need to create percentile scores for HG for competitive adolescent female athletes.

CONCLUSION

This study presents a comparative analysis of anthropometric characteristics and Wingate test parameters of adolescent female football players and track and field athletes. It is the first study of this kind in Bulgaria and a step towards complementing insufficient data and gaining a better understanding of the anaerobic fitness of adolescent girls in sports with a view to more efficient physiological monitoring and design of training programs.

We established the typical characteristics of the two studied groups. Despite the similar age, sex, and body mass, and the similar requirements for the motor abilities of the studied adolescent female football and track and field athletes, differences in the anaerobic performance were found regarding the relative power indexes RPP (W/kg) and APP (W/kg). In our opinion, relative power indices are more precise in measuring and assessing the anaerobic performance of adolescent female athletes.

To use the Wingate test as an important element in control systems in athletics and football, it is necessary to develop percentile scores of anaerobic fitness indicators for both sexes and for all ages. In order to achieve this, however, further studies on a larger scale would be needed.

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