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VARIATIONS IN IMPORTANT AEROBIC FITNESS PARAMETERS AND PHYSICAL CHARACTERISTICS DURING TWO CONSECUTIVE PRESEASON PERIODS IN ADOLESCENT SOCCER PLAYERS

original paper
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VASILIKI MANOU, ATHANASIOS A. DALAMITROS, SPIROS KELLIS

Faculty of Physical Education & Sport Sciences, School of Physical Education & Sport Sciences, Aristotle University of Thessaloniki, Greece

ABSTRACT

Purpose. This study examined the variations in selected aerobic fitness parameters, namely maximum oxygen consumption (VO_2max), running velocity at VO_2max (vVO_2max), running velocity at ventilatory threshold (vAnT) and 1-minute post-exercise heart rate recovery (%HRrec) as well as height, body mass and percentage of body fat (%BF) in high-level adolescent soccer players. The relationship between %BF and VO_2max values was also analyzed.

Methods. 25 athletes (mean age: 14.5 ± 1.3 years) were measured at the second week of the preseason period (1st period) and at the same corresponding week after a 12-month period (2nd period).

Results. VO_2max, vVO_2max and vAnT increased significantly by 6.6, 6.5 and 3.27%, respectively, from the 1st to 2nd period ($p \leq 0.01$ – 0.05; effect size (*ES*) = -0.35 – 0.66). In contrast, %HRrec remained relatively unchanged (-0.5%) during the same period ($p > 0.05$; effect size (*ES*) = 0.01). %BF showed a negative trend, but no significant correlation with VO_2max was found during the same period (r = -0.331; $p > 0.05$). Significant variations were found for height and body mass (2.64 and 11.17%; $p \leq 0.01$; effect size (*ES*) = -0.56 and -0.72, respectively), but not for %BF (1.34%; $p > 0.05$; effect size (*ES*) = -0.27).

Conclusions. This data can provide useful information regarding physiological aerobic adaptations and changes in physical characteristics as a result of a year of soccer training, including growth and maturations processes, during the specific periods tested.

Key words: aerobic indices, anthropometrics, training year, soccer

Introduction

While there is evidence that anaerobic activities, including repeated high intensity runs, jumps and kicks, play a crucial role in soccer [1, 2], the importance of an enhanced level of aerobic fitness is also considered essential [3]. Indeed, a previous study has revealed the predominant contribution of aerobic metabolism during a soccer game [4]. In addition, the positive relationship between specific aerobic parameters, performance during high-intensity intermittent tasks [5, 6] and team success [7–9] has been reported.

Therefore, it is not surprising that soccer players' aerobic performance is frequently evaluated during laboratory testing by analyzing the seasonal changes in maximal oxygen uptake (VO_2max) in young [10, 11] and professional soccer players [12]. In these reports, enhanced values were found right after the preseason period, likely due to the fact that aerobic fitness development is one of the major goals during this period, whereas other studies reported higher VO_2max values at the end of the entire season [13, 14].

Considering that the ability of the sensitivity of VO_2max to detect changes in soccer player's fitness status is highly debated, anaerobic threshold (AnT) has also been proposed as a more "sensitive" indicator of a player's training status [15, 16]. Moreover, the study by Kalapothrakos et al. [12] evaluated addi-

Correspondence address: Athanasios A. Dalamitros, Faculty of Physical Education & Sport Sciences, School of Physical Education & Sport Sciences, Aristotle University of Thessaloniki, Greece, e-mail: dalammi@phed.auth.gr

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tional aerobic fitness parameters in adult soccer players, with the exception of VO_2max and AnT, providing useful and practical performance monitoring tools.

Young soccer players' physical characteristics such as height, body mass and percentage of body fat (%BF) are also of high importance and, therefore, regularly used for talent identification. Several investigations have been undertaken to analyze the contribution of anthropometrics to soccer performance. For instance, a decrease in body fat values can positively affect sprint time [17], whereas different height and body mass values can influence performance during a vertical jump and a 30m sprint time task, respectively [18]. Other studies have examined the relationship between values of %BF and VO_2max, presenting conflicting results [19–21]. However, in these cases, only individuals with relatively low VO_2max and high %BF values were studied, and no available data in soccer exists.

Significant seasonal variations in body mass and %BF have also been noted during the preseason period in male adult soccer players [22, 23]. For young soccer players (mean age 14.4 ± 4 years), the in-season period can induce significant changes in both height and body mass values [24]. Meanwhile, the off-season period usually results in increased body mass and %BF [17], as players abstain from regular exercise and tend to alter their in-season nutritional plan.

The preseason period is considered the optimal time to conduct a general fitness evaluation in soccer, as it is the period following the summer intermission, allowing for time-consuming measurements [25]. Interestingly, apart from studies conducted by Brady et al. [26], Clark et al. [15] and Sliwowski et al. [27], the available data in soccer only concerns seasonal alterations. Furthermore, during adolescence, significant variations often occur in parameters related to aerobic fitness [28] and physical characteristics [18] due to physical growth and maturation. Therefore, our main purpose was to examine the changes of a comprehensive aerobic fitness profile including a variety of parameters (VO_2max, velocity at VO_2max, velocity at AnT, and heart rate recovery) and physical characteristics (height, body mass, %BF) at the start of the preseason period during two consecutive seasons in high-level, male, adolescent soccer players. A secondary purpose was to analyze the relationship between %BF and VO_2max values after the same time period. Based on previous observations on athletes of similar chronological age, our hypothesis was that the physiological parameters and the physical characteristics evaluated would present significant differences as a response to growth and maturation and well as the training period. Moreover, since this study implemented highly-trained adolescents we expected a significant negative correlation between %BF and VO_2max values after the 12-month period.

Material and methods

A total of twenty-five adolescent soccer players from three different clubs, with an age range of 13.0 to 16.1 years and a training experience of 6.7 ± 1.8 years, volunteered to participate in this study. Playing positions were not recorded. Data was collected during the first two weeks of the preseason period over two consecutive years. All players were familiarized with the testing procedures before the beginning of the experimental phases. All tests were performed under controlled environmental conditions (temperature 20–22°, relative humidity ~45%) and at the same time of day (9.00 – 11.00). Subjects were instructed to follow their normal diet and to have sufficient rest the night before the testing day. Parental informed consent was signed for each player, providing information about the procedures of the experiment. The study conformed to the standards set out in the Declaration of Helsinki (2000) and was approved by the Institutional Ethical Committee.

Measures

At the beginning of each testing session, subjects reported to the laboratory for assessments of height, body mass, and percent body fat. Body mass and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, using a calibrated physician's scale (Seca, Hamburg, Germany). The percentage of body fat was estimated with the bioelectrical impedance analysis technique (Bodystat 1500; Bodystat, Isle of Man, British Isles). The evaluation of the aerobic parameters was conducted after a standardized warm-up consisting of a 4-minute run at 5 km $\cdot$ h^{-1} on a treadmill (Cosmed HP Cosmos Rome, Italy). Breath-by-breath analysis was used for measuring respiratory gas exchange (Cosmed Quark CPET system, Rome, Italy) throughout the incremental test. The O_2 and CO_2 analyzers were calibrated before and after each test using ambient air and calibration gases of known concentrations. HR was continuously recorded using chest belt telemetry (Polar Electro, Kempele, Finland). Verbal encouragement was given throughout each test. The initial speed was set at 8 km $\cdot$ h^{-1} and it was increased steadily by 1 km $\cdot$ h^{-1} every 2 minutes until volitional exhaustion. The maximum effort criteria have been described in detail elsewhere [29], and at least three of the criteria had to be fulfilled. Gas exchange data was averaged over 15 sec periods, as previously proposed during progressive exercise protocols [30]. VO_2max (ml · kg^{-1} · min^{-1}) was considered the highest 15-second VO_2 value attained. Velocity at VO_2max (vVO_2max) was assessed as the maximum velocity attained for at least 1 minute before the test was completed [31]. Velocity at AnT (vAnT) was defined as the corresponding velocity at O_2 consumption at which the linear relationship between pulmonary ventilation and VO_2 was no longer sustained during the incremental exercise, despite the increase in the intensity [32]. vAnT was identified by visual inspection of graphs by an experienced exercise physiologist. Percentage of post-exercise heart rate recovery (%HRrec) was calculated as the HR reduction during the incremental test (peak value) to one minute after the completion of the test.

Statistical analysis

A paired samples t-test was used to identify any possible differences between the two preseason periods in each dependent variable (height, body mass, %BF, VO_2max, vVO_2max, vAnT, %HRrec). Pearson product-moment correlations were calculated to examine the relationship between %BF and VO_2max tests. Cohen's d effect sizes (*d* = difference between means¸ pooled SD) were calculated for the difference between means. Small, medium and large effects were reflected in values greater than 0.20, 0.50, 0.80, respectively [33]. All statistical tests were processed using the SPSS statistical package (v. 21; SPSS Inc.; Chicago, IL, USA). The level of significance was set at $p < 0.05$. Data was reported as mean ± *SD*.

Ethical approval

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the authors' institutional review board or an equivalent committee.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Table 1 presents the mean ± *SD* values for all the aerobic parameters evaluated during both preseason periods. VO_2max and vVO_2max were significantly enhanced by an approximately equal degree. Similarly, vAnT was significantly improved during the same period, while %HRrec values remained almost

Table 1. Mean ± *SD* values, level of significance (*p*), percentage changes and *ES* for the aerobic parameters evaluated during both preseason periods (*n* = 25)

Parameter	1st period	2nd period	*p* value	%Change	ES
VO_2max (ml · kg^{-1} · min^{-1})	55.73 ± 5.62	59.43 ± 5.60	0.008†	6.64	0.66
vVO_2max (km · h^{-1})	15.65 ± 1.46	16.69 ± 1.38	0.000†	6.65	-0.73
vAnT (km · h^{-1})	12.23 ± 1.10	12.63 ± 1.19	0.012*	3.27	-0.35
%HRrec	15.58 ± 6.70	15.66 ± 6.67	0.964	-0.51	-0.01

† $p \leq 0.01$, compared to 1st period values
* $p \leq 0.05$, compared to 1st period values
VO_2max = maximal oxygen uptake; vVO_2max = running velocity at maximal oxygen uptake; vAnT = running velocity at anaerobic threshold; HRrec = percentage reduction of peak heart rate value to one minute after completion of the test.

Table 2. Mean ± *SD* values, statistical significance (*p*), percentage changes and *ES* for the physical characteristics evaluated during both preseason periods (*n* = 25)

Parameter	1st period	2nd period	*p* value	%Change	ES
Height (kg)	170.6 ± 8.6	175.1 ± 7.4	0.000†	2.64	-0.56
Body mass (cm)	56.4 ± 8.9	62.7 ± 8.5	0.000†	11.17	-0.72
%BF	6.9 ± 2.4	7.6 ± 2.7	0.056	1.34	-0.27

† $p < 0.01$, compared to 1st period values.
%BF = percentage of body fat.

unchanged. Small to medium effect size for changes was detected for all the aerobic parameters measured, with the exception of %HRrec.

Table 2 presents the mean ± *SD* values for physical characteristics. Participants demonstrated significant greater height and body mass values. On the contrary, %BF showed no significant increases. Small to medium effect size for changes was detected for all the physical characteristics measured.

Finally, a negative and not significant correlation was revealed between the %BF and VO_2max values after the tested period (r = -0.331).

Discussion

In this study, a number of selected aerobic indices and physical characteristics were measured to investigate possible variations during the same weeks of two consecutive preseason periods in adolescent soccer players. The results demonstrate that aerobic fitness, as reflected by the VO_2max, vVO_2max and vAnT values as well as physical characteristics (with the exclusion of %BF values) were significantly altered over this 12-month period, supporting our hypothesis. Thus, the preseason, in-season and off-season training program that participants in this study followed, in conjunction with growth and maturation process, allowed them to improve specific aerobic parameters and anthropometrics that are considered important for soccer performance. Contrary to our hypothesis, we observed a negative but not significant correlation between %BF and VO_2max values after the 2^{nd} preseason period.

More specifically, both VO_2max and vVO_2max values in this study showed similar improvements (~6.6%), despite the notion that vVO_2max is more sensitive to aerobic training adaptations than VO_2max in soccer [34]. Indeed, Kalapotharakos et al. [12] reported larger improvements in vVO_2max, compared to VO_2max, after a season training period including the preseason and the in-season evaluation (until the initiation of the 2^{nd} round) in professional soccer players (7.8 vs. 4.5%, for vVO_2max and VO_2max values respectively). However, in the latter case, the evaluation of the off-season period was not included, a fact that may explain the difference in the results, as decrements in aerobic enzyme activity can occur as a result of the summer intermission [35]. Both VO_2max and vVO_2max are useful for performance monitoring. According to Bangsbo [4], VO_2max is linked with the total distance run per soccer match, indicating a faster recovery between high-intensity runs, whereas vVO_2max combines aerobic power and running economy [32], with the latter parameter also associated with greater match distance [1].

The percentage change in running velocity at AnT observed here (3.27%) is quite similar to that of the previous study by Sliwowski et al. [27] (4.40%) that evaluated running velocity at a fixed blood lactate concentration of 4mmol^{-1} after the completion of two consecutive competitive seasons in soccer players of similar chronological age. This parameter is considered quite important as it translates to increased running velocity during a submaximal effort test. Moreover, the importance of the AnT evaluation has been denoted as most of the runs performed during a soccer game are closely associated with its corresponding intensity [4]. In most soccer studies, the AnT determination included running velocity at a fixed blood lactate concentration value [34,26,12,10,27]. However, several methodological issues may arise during its determination [36]. As such, the usefulness of the AnT evaluation, in terms of ventilator measurement, has been previously applied in professional soccer players to indicate training-induced changes during an off-season period, showing similar changes with blood lactate concentration values [16].

During the 12-month period tested here, %HRrec remained constant, showing only trivial changes. We can assume that the high volume of training characterizing the preseason period may account for this result since fatigue status seems to have a negative effect on HR recovery. In fact, Callegrano et al. [37], reported impairment in 1-minute HR recovery values in adult players that was attributed to the high-intensity exercises performed during the competitive soccer period. Post-exercise HR recovery is a relatively new index proposed as a low cost and time-consuming alternative to blood lactate concentration measurement for aerobic fitness evaluation [38]. According to Suzic et al. [39], VO_2max is inversely related with 1-minute post-exercise HR values in both adolescent and adult elite athletes, while it is known that faster recovery is generally associated with enhanced sports performance.

The finding of an improved aerobic fitness profile during two consecutive preseason periods is not supported by the study of Brady et al. [26], who, in a sample of twenty-four professional soccer players, reported no significant differences in work intensity expressed as running velocity at a specific HR value (170b · min^{-1}). Similarly, Clark et al. [15], found no significant changes in mean VO_2max values tested before the preseason phase over a 3-year period in professional adult soccer players. Nevertheless, it is reasonable to suggest that the age range of the players who participated in our study (13.0 – 16.1 years) can be considered very "sensitive" to VO_2max improvements. In fact, the largest increases, even in untrained individuals, generally occur between the ages of 13- to 14 and 14- to 15-years old [40], reaching an average increase of 38% as measured in approximately 80 male adolescents of the same age range [41]. This data accounts for the significant alterations found in our sample. Likewise, Geithner and his colleagues [42], determined a mean age of 14.1 ± 1.2 years as the time for peak VO_2 increases in male adolescents, closely concurring with the peak height velocity period (i.e., the period where maximum rate of growth during adolescence occurs). The results of Angius et al. [43] support this result, indicating that adult soccer players present a fully developed aerobic capacity, while for younger athletes this parameter is still under development, a finding also reported in the study of Nikolaidis [44] in a sample of 135 soccer players 13.1 to 16.0 years of age. Nevertheless, VO_2max, vVO_2max and vAnT values of the 2nd preseason period showed in the current study are very close to those reported for the same period in elite soccer players in the study by Kalapothrakos et al. [12] and within the range previously reported for young soccer players [45].

As expected, values of height and body mass of our sample showed significant increases over the tested period. The development of physical characteristics in adolescents has been previously analyzed, presenting significant gains even in untrained individuals that are more profound during the ages of 12- to 15- years of age [46]. Our data is in accordance with the reference values of a prior study for the equivalent ages in the study of Nikolaidis & Karydis [47] in a large sample of Greek soccer players (n = 146), and quite similar with those obtained by Perroni et al. [48] in Italian soccer players (n = 59). On the other hand, %BF values of our participants were considerably lower compared to those previously reported [47], likely due to the training levels and years of experience that influence this outcome. %BF showed a subtle increase (1.34%), a result that was not surprising considering that players were heavier by 11.17% after the 2nd period. This result, in conjunction with the 2.64% increase in height values, is translated to improved body composition, a critical parameter for soccer performance and closely associated with enhanced scores during physical fitness testing in young soccer players [49]. Supplementary, this increase was not associated with greater VO_2max values after the 2nd preseason period. Generally, studies examining the potential relationship between these two parameters have mainly involved obese or untrained individuals [50, 20], while in the case of Shete et al. [21] a significant correlation was also not confirmed in female athletes.

The analysis of individual variations in the tested parameters was not included in the purposes of this study, as the participants followed different training programs, and peak height velocity was not predicted. Even so, we observed that three players presented reduced VO_2max values during the 2nd period, compared to the 1st period (~ -5.2%), while in one case the respective values remained constant. It should also be noted that these decrements were not concurrent with changes regarding the rest of the physiological parameters, where most small variations were shown. In contrast, measures of body mass and %BF, also based on the visual inspection of the individual data, presented a large variability in line with a previous study in adolescent soccer players [47], indicating the need for considering this concept, as previously proposed [51].

An obvious limitation of this study is the fact that the participants were recruited from different soccer clubs and, therefore, the training plan followed was not the same for all athletes. However, our aim was not to examine the efficacy of a specific training program. Secondly, the players' maturity status was not controlled. Still, our sample can be characterized as homogeneous since the large majority had normal-for age-height and body mass values, similar training experience, and relatively narrow chronological age range, while all players were participating in regular and intensive training sessions. A third limitation could be addressed regarding the absence of an additional testing procedure within the 12-month period (e.g., during the off-season period) as aerobic fitness in soccer is altered seasonally. Future studies should address these concerns.

Conclusions

In summary, we observed that the aerobic fitness profile evaluated during the same weeks of two consecutive preseason periods was improved in terms of significant alterations in VO_2max, velocity at VO_2max and velocity at AnT values. In contrast, the percentage change of 1-minute heart rate recovery remained relatively unchanged. Regarding the physical characteristics, height and body mass were significantly greater, whereas body fat percentage showed only trivial increases. Finally, there was no significant correlation between the percentage of body fat and VO_2max values after the tested period in this group of highly-trained adolescent soccer players. The results obtained from this study should be referenced as time-period specific, considering that during seasonal evaluations in soccer, important variations may occur in all the variables included.

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Conflict of interest

The authors state no conflict of interest.

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