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Physiological profile of Greek elite soccer players

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Abstract
Modern professional soccer is a sport of especially high physiological demands and consequently physical condition is one of the most crucial and defining factors for succeeding in the sport. The aerobic and anaerobic mechanisms that are employed during a game are extremely demanding and the athlete must be in a position to cope with all kinds of physical strain. The purpose of this study was to investigate the short term and long term physiological adjustments observed in Greek soccer players and to point out the strong and weak points of their physiological profile. In order to examine the long term variation of the physical condition parameters, measurements were taken from a sample of one hundred professional soccer players in four different time periods; before and after preseason, in the middle and at the end of the season. The measurements included the assessment of a) anthropometric characteristics b) cardio respiratory endurance c) anaerobic capacity. The results showed there is statistically significant change (p>.01) in the maximal oxygen uptake capacity (VO2max), the maximal aerobic speed v-VO2max, the velocity at the anaerobic threshold, while there was a reduction in the variation of the maximal heart rate-HRmax and an increase in the mean pulmonary ventilation. The mean 10m velocity was reduced by 4%, while regarding the 30m velocity a reduction by 3.5% in average occurred. The ability to maintain mean speed during the Running Anaerobic Speed Test was reduced by 3.0 %. The mean agility speed according to the Illinois Agility Run Test was reduced by 3%. Lastly, the explosive power jumping ability and Squat Jump increased by 8.5%. In conclusion, soccer is a complex sport which poses high demands on all aspects of the athletes' the physical condition. The coaches should be aware of their athletes' training level and the results of the present study could contribute in designing suitable training plans and improving the training process on the whole.

Keywords: Football players, physiological characteristics, aerobic and anaerobic capacity

1. Introduction
Modern professional soccer is a sport of high physiological demands and therefore the players' physical condition is one of the most crucial and defining factors of success [1, 2, 3]. The energy mechanisms employed during a game are especially demanding and the athlete should be in a position to cope with all kinds of physical strain [4, 5]. Moreover the abrupt and intense changes of rhythm during the game render it a fast, demanding, strenuous and unpredictable sport [6, 7, 8]. Simultaneously, the passive rehabilitation rates and the low intense periods during the game are constantly reduced while on the contrary the demands on speed are constantly increased [5, 9, 10]. Finally, the distance a player covers in a game can reach 12 - 13 km; this pinpoints the fact that the metabolic demands in a soccer game are huge and the athlete's physiological characteristics are a defining factor regarding success [4, 6, 11, 12, 13, 14]. Researches have shown that when the players' physical condition is low, lactic acid quickly reaches and surpasses 6 mmol/l, leading to technical and tactical mistakes [15].
Parameters of the physiological factor, such as aerobic and anaerobic capacity, muscle strength and power, should be evenly developed in the modern soccer player and act as a single mechanism, in order for the player's technique not to be distorted due to fatigue but also because a good level of physical condition allows for the right implementation of tactical development on a team level [11, 16, 17, 18, 19]. Moreover these indexes are extremely interesting as the training process is assessed and judged based on them and the training planning and orientation is designed and organized accordingly [3, 13, 20, 21, 22, 23, 24, 25].
The determining effect of the physiologic characteristics on the development of the game has been supported by many researchers.

Studies have pinpointed the dominant role of aerobic skill through the maximal oxygen uptake index, since the VO2max level is related to the total distance players run during the game [20, 21, 23]. Hergerud *et al*. [16] purport that the focused and targeted training of soccer players in the maximal oxygen uptake for eight weeks increases the total number of engagements with the ball by 24% and the total number of sprints run by 100%. The anaerobic mechanism which dominates the intense rhythm changes during the game such as sprints and headers is also a crucial factor. The importance of how fast energy can be drawn without oxygen usage has been studied by researchers [22, 6, 9] as this process can lead to scoring a goal.

The performance is also significantly affected by the muscle strength and power, since in many instances in game high muscle strength and power is required (vertical jumps for headers, tackling, acceleration up to 30m etc.) [20, 1, 5]. Studies have shown [25, 26] that training which is oriented towards the increase of maximal strength improves the maximal vertical jump (Sj) and acceleration up to 30m.

Research interest in the soccer players' physiological profile is intense and this fact is reflected in the great amount of literature [3, 21, 23, 24, 27, 28, 29, 30]. However other studies investigate the effect of only some parameters of physical condition [27, 28, 29, 30] while others draw data from a sample of semi-professional soccer players [32], or investigate samples at developmental ages [22, 23]. In Greece there is no complete data of the physiological characteristics of Greek soccer players and the variations that may occur during a season regarding all the parameters of their physical condition have not been adequately studied. The present research investigates all the indicators of physical condition in regular time periods (before and after preseason-in the 24th week- in the 47th week) during the season. This data offers the opportunity to record the physiological profile of Greek soccer players and simultaneously to facilitate appropriate training planning and correct training guidance.

2. Materials and methods

2.1 Sample

The sample of the study was one hundred (n=100) Greek professional soccer players, playing in the highest professional league in Greece. Their average age was 25.7 (±4.7) years old, their height 180.7 (±6.5) cm, their body mass was 77.2 (±7.6), their fat percentage 8.40 (±2.20), and their body mass index (BMI) 23.55 (±1.26). In order to be included in the sample they should participate in 60% of the games and they should not have been absent from trainings for over a month. Lastly, goal keepers were not included in the sample.

2.2 Measurement procedure

The soccer players underwent a series of ergometric tests on four (4) different dates in order to record the annual variation of their physical condition: a) before preseason begins (3-4 days), b) after preseason (12 weeks after preseason had begun) c) in the middle of the season (during the 24th week approximately) d) at the end of the season (47th week) [beginning of the transitional season].

2.3 Measurements- Assessment tools

The following variables were investigated by the assessment tests: [i] maximal oxygen uptake VO2max (ml/kg/min), [ii] maximal velocity in oxygen uptake- vVO2max (Km/h), [iii] oxygen uptake at the anaerobic threshold VO2 AT/LT (ml/kg/min), [iv] maximal pulmonary ventilation - VEmax (L min-1) stpd. An automated ergospirometer (Medgraphics Ultima cardio2 USA) connected to a treadmill (Technogym Treadmill excite 900) and a computer were employed for the above measurements, [v] maximal hear rate – HR max with a chest belt (Polar T31), [vi] velocity in kilometers per hour at the anaerobic threshold -Velocity at OBLA (km/h), [vii] and heart rate at the anaerobic threshold -HR at OBLA (bpm); these measurements were conducted with an ergospirometer (Medgraphics Ultima cardio2 USA) connected to a treadmill (Technogym Treadmill excite 900) and a computer and also a wireless transmitter Polar T31 connected to the athlete, [viii] the athlete's height (cm) with a measuring rod (Seca Leicester, U.K.), [ix] the athlete's body weight with a scale (Tanita 300 U.K.), [x] the athlete's body fat percentage with a skin fold caliper (Harpenden, U.K.), [xi] body mass index (BMI), calculated by the skin fold caliper (Harpenden, U.K.) according to the Jackson & Pollock[33] equations, [xii] explosive leg power in centimeters-Sj explosive power (cm), [xiii] explosive power in centimeters- Cmj elastic power (cm), [xiv] and power measured in watt/kg-Rj 15 sec (watt/kg), assessed with a vertical jump on a force platform equipped with piezoelectric sensors (Bosco platform Microgate OptoJumpNext, version 1.10), [xv] 10 meters velocity, [xvi] and 30 meters velocity on field turf which were calculated by the Microgate Witty Manager program with 2 pairs of wireless photocells (Witty Wireless Training Timer), [xvii] RAS test (total/time, sec) on the field turf with special football shoes and maximal speed distance sprint 35m X 6 times with a 10 sec interval and [xviii] Illinois Agility Run Test, on the field turf with special football shoes, calculated by the Microgate Witty Manager program with 2 pairs of wireless photocells (Witty Wireless Training Timer).

2.4 Statistical Analysis Methods

The statistic package SPSS 20 was employed for the statistical analysis and in order to analyze data descriptive statistics, frequencies, mean, median, standard deviation, variance, range, minimum, maximum as well as correlation Pearson Sig 2-tailed with significance level p>0.01 were also employed.

3. Results & Discussion

3.1 Somatotype characteristics

Body weight: the variation of the mean body weight of the soccer players showed a statistically significant change (p>0.01). The average body weight was reduced during preseason from 77.21 kg to 76.39 kg while in the 47th week it reached 76.76 kg.

Percentage of body fat: the mean long-term variation of the body fat percentage was statistically significant (p>0.01). There was a 7% reduction approximately at the end of preseason (7.94%) compared to the mean body fat before preseason (8.42%); however, this difference was statistically significant due to the high standard deviation (±1.74%).

Body Mass Index: the mean long-term variation of the body weight percentage was statistically significant (p>0.01). There was an approximately 1.5 % reduction during the 3rd measurement in the 24th week (23.17%) compared to the mean body mass before preseason (23.55%); however, this difference was statistically significant due to the high standard deviation (±1.17%).

3.2 Cardio respiratory parameters

VO2max: The results showed a statistically significant change in the VO2max ml/kg/min mean variation (p>0.01). The mean maximal oxygen uptake showed a progressive increase, from the 1st assessment (before preseason) 58.62 up until the 2nd (24th week) 60.87 when a 4% increase was observed, while during the last assessment (47th week) 59.30 it approached the levels before preseason (graph 1)

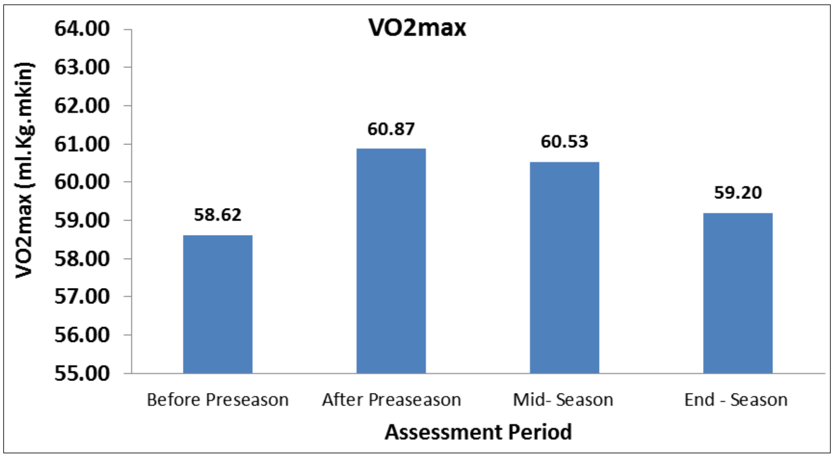

Fig 1: Bar chart of the annual mean variation of the players' VO2max ml/kg/min

V-VO2max: The variation of the mean speed in v-VO2max showed a statistically significant change (p>0.01). The most significant change was noticed before and after preseason (12th week) and in the 24th week, with 18.30, 19.45 and 19.50 respectively, and an increase of about 6% (graph 2).

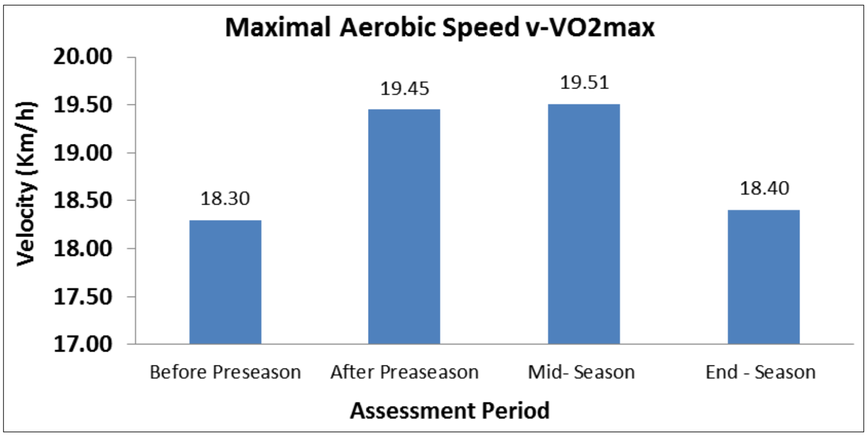

Fig 2: Bar chart of the annual mean variation of the players' v-VO2max

Speed at the anaerobic threshold (km/h): A statistically significant change (p>0.01) in the mean variation of the players' speed at the anaerobic threshold was observed. The most intense change occurred between the mean measurements before and after preseason- 13.29 and 14.37 respectively- while during the 3rd measurement it was 14.47 with an increase of about 8%. The mean speed at the anaerobic threshold was reduced by about 6% in the 4th measurement (graph 3).

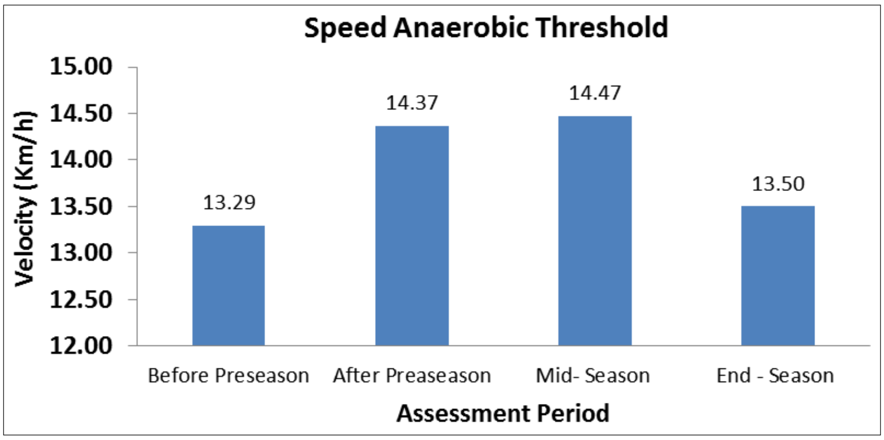

Fig 3: Bar chart of the long-term mean variation of the players' speed at the anaerobic threshold

Maximal heart rate (HRmax): the mean long-term variation of the maximal heart rate showed statistically significant difference (*p*>0.01). The players' maximal heart rate was reduced after preseason and in the 24th week, from 195 to 190 bpm/min. A reduction of about 2.5% was observed during the preseason assessment; in the rest of the assessments the measurements did not return to the ones before preseason.

Heart rate variation at the anaerobic threshold (HR/AT): The results showed there was a statistically significant change (*p*>0.01) in the heart rate variation at the anaerobic threshold. More specifically, there was a reduction after preseason and in the 3rd assessment in the 24th week in comparison to the assessment before preseason from 169 to 166 respectively, a reduction of 1.5% approximately as well as at the end of the season in the 47th week, at 0.7%.

Pulmonary Ventilation *VEstpd* $(L*min^{-1})$: The mean variation of VEstpd (L*min1) showed a statistically significant change (*p*>0.01). More specifically the mean pulmonary ventilation was progressively increased from the 1st assessment (during preseason) 127.71 until the 3rd one (in the 24th week) 145.24, an increase of about 15%, while in the last assessment (in the 47th week) 129.73 it almost reached the levels before preseason.

3.3 Anaerobic parameters

10m velocity: regarding the anaerobic velocity parameters, the results showed a statistically significant change (*p*>0.01) in the mean variation of the 10m race. In the 3rd assessment (in the 24th week) it was reduced by 4% in comparison to the previous assessment.

30m velocity: The long term mean variation of the 30m race presented a statistically significant change (*p*>0.01). More specifically during the 3rd assessment (in the 24th week) a 3.5% reduction occurred in comparison to the 1st assessment.

Total speed time in the Running Anaerobic Speed Test (RasTest): the results showed a statistically significant change in the mean variation of the long term variation of the total time performance in the Ras test. In the 3rd assessment (24th week) a 3.0% reduction occurred in comparison to the previous assessment.

Agility speed (Illinois Agility Test): the results showed a statistically significant change (*p*>0.01) in the mean variation of the Illinois Agility Test. During the 3rd assessment (24th week) an approximately 3% reduction occurred in comparison to the previous assessment consisting a statistically significant change.

Explosive power jumping ability (SJ): the mean variation in the squat jump was statistically significant (*p*>0.01). During the 2nd and 3rd assessments an 8.5% increase occurred while in the 4th assessment there was a 4% reduction.

CMj Elastic power variation (cm): the results showed a statistically significant change (*p*>0.01) in the countermovement jump mean variation. After each assessment an increase occurred. During the season before preseason until the 3rd assessment (24th week) there was an increase by 8.5%.

Power performance variation *(Rj15sec) Watt/Kg:* the mean variation of the countermovement jump presented a statistically significant change (*p*>0.01). A small increase occurred after each assessment. There was an increase of 5% from the preseason assessment until the 3rd assessment (24th week) while during the 4th assessment a 4% reduction occurred.

4. Discussion

4.1 Anthropometry and Somatotype characteristics.

Regarding the somatotype characteristics, an important parameter which affects the players' sport performance is body weight. The average body weight before preseason was 77.2 kg, which is in accordance with the range (75-78kg) reported by other researchers [24, 27, 34 35]. The body mass variation during the assessments (before preseason-in the 24th week and in the 47th week) was stable with minor fluctuations. These results are in accordance with other researches [27, 28 30].

Percentage of Body Fat: the annual mean variation of the body fat percentage shortly before preseason was 8.42% and the data agree with studies that show 8.6% body fat [27] and 7.9% body fat [36]. Other studies place the percentage as high as 12.3% [37, 38]. On the contrary, the variation of the parameter during the season is in accordance with other relevant researches [2, 28, 32].

Body Mass Index: The players' body mass index before preseason was on average 23.6 and was subsequently reduced from the 2nd assessment (12th week) onwards, until the 3rd assessment in the middle of the season (24th week) while it remained relatively stable until the end of the season (23.4) during the 4th measurement, in the 47th week. It should however be noted that the comparison of the Body Mass Index results in the present study is significantly restricted by the employment of different calculation methods for this parameter. The body mass index was measured with a skin fold caliper in the present study, a measuring tool which may not always be in accordance with other methods such as hydro densitometry, DEXA reference methods and electric conductivity [39].

4.2 Cardiorespiratory Parameters

Maximal oxygen uptake (VO2max): the players' mean VO2max that occurred during the 1st assessment [58.62 ml.kg-1.min-1] is significantly below the scores that concern soccer players from other countries such as Spain [65.5 ml.kg-1.min-1] [27], Norway [63.7 ml.kg-1.min-1] and the UK [59.4 ml.kg-1.min-1] [37]. Reilly *et al*. [40] purport that elite players' VO2max should be over 60 ml/kg/min, in order to enable them to cope with the demands of modern soccer. VO2max was significantly improved after preseason, a fact in accordance with relevant studies [27, 28, 29, 32]. The reduction of the mean VO2max towards the end of the season is noted in other studies as well.

Maximal aerobic speed v-VO2max: During the preseason the mean v-VO2max was significantly improved by 6%. After the middle of the 3rd assessment (24th week) until the 47th week the reduction of the parameter by 6% was also significant and at the end it reached preseason levels. This data is in accordance with another study [29] in which v-VO2max showed similar variation during the season. This variation can be accounted for by the training adjustments during preseason [16]. The fact that in the last assessment the mean v-VO2max was reduced can be correlated with the respective reduction the maximal oxygen uptake presented. The similar behavior these parameters demonstrated during the season may indicate that they are affected by the same training stimuli.

Speed at the anaerobic threshold *(v-VAT):* Speed at the anaerobic threshold (v-VAT) defines the performance level in maximal efforts that last >2 min [16, 41, 42, 43] demonstrates the same annual variation as VO2max and v-$VO2_{max}$. The players' mean v-VAT before preseason was either higher compared to relevant studies [27] or lower [44]. It is difficult however to compare the studies because the training program the players followed during the transitional period is not known. The parameter's variation during the annual macrocycle followed the same trajectory with $VO2_{max}$ and v-$VO2_{max}$ and is most likely affected by the same training stimuli.

Maximal hear rate: The mean maximal hear rate followed a vice versa course compared to v-VO2max and demonstrated a 2.5% reduction. Before preseason the mean $HR_{\mathbf{max}}$ was higher compared to data from other researches [27, 35]. The reduction of the mean $HR_{\mathbf{max}}$ is apparently due to the cardio respiratory adjustments, the increase of the heart rate volume [45] and the improvement of running economy [46]. The mean was not further reduced in the middle of the season while another relevant study does not report any significant change for the same time period [27]. During the last assessment the mean hear rate increased. It is possible that this is due to the general reduction observed regarding the cardiorespiratory stamina parameters.

Heart rate at the anaerobic threshold: The reduction of the mean hear rate at the anaerobic threshold from the preseason through the 3rd assessment was 1.5%. An analogous reduction is reported in a study conducted with Spanish players [27]. Other studies report higher scores [47]. The players' age as well as methodological discrepancies may be responsible for the differences observed regarding this parameter.

4.3 Anaerobic parameters

10m and 30m races: The mean variation of the 10m race declined in the 3rd assessment (24th week) by 4%, in comparison to the previous assessment. A similar reduction was reported in the 35m race, as in the 3rd assessment (24th week) the mean was reduced by 3.5% in comparison to the preseason measurement. The Greek soccer players' physiological profile seems to be inferior regarding leg muscles explosive power and stride length and number, elements that contribute the development of maximum speed from the biomechanical point of view. Speed takes up 5%-10% of the total distance the players cover in the game which is equivalent to 1%-3% of the total game time and plays a very important part during the game [14]. The training programs should focus on the development and improvement of the aforementioned parameters.

35m race: The mean variation of the running skill (35X6m race performance) throughout the annual macrocycle was slightly improved by 3% after preseason, an improvement that remained stable until the 3rd assessment (24th week) and at the end of the season (47th week) it reached preseason levels. In the relevant literature, the running skill has been assessed by employing 30m or 40m distances [25, 48 and 49]. Several results have been reported, from 4 sec to 4.22 sec for the 30m distance, and from 1.79 to 1.90 sec for the 10m distance [5]. Speed is of vital importance for the important duels, affecting the game result. In the last assessment the mean 35m time is significantly improved while during the same time period all the cardiorespiratory stamina parameters decline. This may be due to the fact that the physiological parameters on which running skill and stamina depend are different and do not affect each other [48].

Agility assessment (Illinois Agility Test): The mean agility in the Illinois Agility Test declined. More specifically in the 3rd assessment (24th week) it was significantly reduced by 3% in comparison to the 1st assessment while at the end of season (47th week) it reached preseason level. The results pinpoint the view that the Greek players' agility is inferior to that of other players since similar results were reported in researches concerning semiprofessional athletes [32]. However agility is considered a necessary factor of success in soccer, since, for example the quick/rapid change of direction skill while the player already in movement is of vital importance [22, 50]. The fact that a player changes direction about 1.200-1.400 times in a 90 minute game [51] underpins the significance of the specific skill.

Squat Jump and Counter Movement Jump: the players' performance regarding squat jumps and counter movement jumps was increased by each new assessment. From preseason until the 3rd assessment (24th week) an increase of 8.5% was reported. This indicates the Greek players' high level concerning these specific skills, since relevant studies have reported lower results [25, 27, 52].

4. Conclusions

The purpose of this study was to present the Greek players' short term and long term physiological adjustments and pinpoint the strong and weak aspects of their physiological profile. The results can contribute to the elaboration of appropriate training plans and the improvement of training procedures. In conclusion, based on the data pertaining to the somatotype characteristics, the cardiorespiratory adjustments, the aerobic and anaerobic skill, the agility and the flexibility, it can be argued that soccer is a complex sport which requires high standards regarding the whole of the physical condition parameters. Trainers should on the one had be aware of these requirement and on the other to have a clear picture of their athletes' physiological profile in order to be in a position to organize and execute their training sessions successfully.

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