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Original Article

Hematologic, biochemical, and physiologic characteristics of elite and professional basketball players

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Abstract
Objectives: The aim of this study was to investigate the hematologic, biochemical, and physiologic characteristics of male elite and professional basketball players during an annual training season. **Materials and Methods:** This study included 18–34-year-old healthy males (elite and professional basketball athletes) and involved VO_2 max and counter movement jump performance tests, as well as measurements of hematocrit, hemoglobin, ferritin, red blood cell volume, creatine kinase, and cortisol levels. Blood sampling was conducted at the beginning, mid-way, and at completion of the training season after a 48-h rest period. Statistical analysis was performed via SPSS (Statistical Package for the Social Sciences version 17.00) and included t-tests and two-way analyses of variance (ANOVA) with and without repeated measures. **Results**: There was no difference between the groups in terms of anthropometric characteristics. Elite athletes showed a 12.4% increase in VO_2 max compared to professional athletes. Regarding hematologic parameters, elite athletes were characterized by a 3.87% decrease in hematocrit levels mid-season as well as a 4.62% decrease in hemoglobin levels at the end of the training season compared to professional athletes. In terms of intra group differences within the training period, serum creatine kinase levels were 53.5% higher for the elite athletes mid-season, compared to the two abovementioned measurements at the beginning and the end of the training season. **Conclusion:** In an effort to elucidate the effect of training season and athletic level on hematologic, biochemical, and physiologic parameters, we showed that the performance level greatly affected the hematologic and biochemical profile. More importantly, hematocrit, hemoglobin, and serum creatine kinase were the parameters that were mostly affected. Our results indicate the importance of athletic level and different training regimens at different parts of the training season. However, more research is needed to explore the biological significance of the current findings.
Key words: hematologic profile, cortisol, creatine kinase, hematocrit, hemoglobin, basketball athletes.

Introduction

Periodical assessment of hematologic, biochemical, and physiologic parameters has been widely used to evaluate the health, fitness, and performance status of athletes at different stages of their training season (Crespo *et al.*,1995; Hartman & Mester, 2000; Malczewska *et al.*, 2000; Telford, 1991; Nikolaidis *et al.,* 2003).
The hematologic profile of athletes, which is comprised of iron metabolism and blood chemistry, can be affected by various parameters such as the different types of training and intensity of physical effort (Nikolaidis *et al.*, 2003; Banfi & Del Fabro, 2008; Banfi *et al.*, 2011; Banfi *et al.*, 2011; Mercer & Densmore, 2005). However, previous studies do not specify the exact differences between athletes of different levels who follow different training regimens.

There are few studies on the hematologic characteristics of athletes at different performance levels and "sporting disciplines", which did not show a significant effect of physical training on hematological variables of athletes compared to those of untrained individuals. However, exercise type and duration have been shown to significantly affect hematologic profile and, more specifically, iron metabolism (Schumacher *et al.*, 2002). In addition, a study has recently been performed on the hematologic parameters of male elite basketball players (Córdova Martínez *et al.*, 2017). However, the sample number was too small, and the study was focused on magnesium supplementation (Córdova Martínez *et al.*, 2017). In summary, there are no studies comparing hematologic, physiologic, and biochemical characteristics of elite (competing at the International level-Euroleague) and professional athletes (competing at the National level) (Ricci *et al.*, 1988; Ricci *et al.*, 1988; Weight *et al.*, 1992).

This experimental procedure for the first time defines in a systematic manner the hematologic, biochemical, and physiologic profile of male elite basketball athletes compared to that of professional athletes

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throughout the entire training season. Furthermore, this is the first study to focus on basketball players at different performance levels.

Materials and Methods

Participants

The experimental population of the study was comprised of healthy male participants (i.e., elite and professional basketball players). To be included in the study, the subjects had to meet the following criteria:

a) Be in relatively good health without any chronic diseases and without any episodes of fever for at least 4 weeks before the measurements
b) Not use any medications or nutrition supplements at least two weeks before each measurement (confirmed by dietary recall)
c) Follow a healthy lifestyle with stable dietary conditions before all experimental procedures
d) Follow a balanced nutrition with an average intake of 55% of carbohydrates, 30% of fat, and 15% of protein per day and reporttheir diet daily via dietary recall

This study included 45 participants, 30 elite athletes competing at Euroleague and 15 professional athletes competing at the National level. There was no difference in the training load between the groups.

Before initiating the measurements, both verbal and written informed consent were obtained from all of the participants, who knew that they could leave the study at any time. In addition, all athletes underwent routine clinical examinations includingechocardiogram (ECG), blood pressure and heart rate measurement, and chest X-ray.

Experimental procedure

VO_2 max and vertical counter movement squat jump (CMJ) performance measurements were performed at the beginning of the training season for each participant. The VO_2 max test was performed to assess the maximal aerobic capacity of the participants, as previously described (Cavalho *et al.*, 2013). Specifically, the maximal oxygen production was examined using an incremental running test on a motorized treadmill. The test started at the speed of 8km/h (for 3 min), which was gradually increased by 2 km / h every 3 min until the speed of 14 km/h was reached. Subsequently, exercise intensity was increased by 2.5% elevation after 12 min and every 3 min until fatigue. Fatigue/exhaustion was mostly reached in approximately 8–12 min (Cavalho *et al.*, 2013). CMJ performance measurements were performed with a stable dynamometer (Bertec / Columbus, OH, U.S.A.) using previously described procedures (Bosco *et al.*, 1995). In summary, the athletes performed three attempts, and the best one was recorded. There was a 15-second break between each attempt. The height of the jump was estimated according to the time of flight.

Blood sampling was performed a) at the beginning of the training period, b) 2 months after the initiation of the training period, and c) at the end of the training season. Furthermore, blood sampling was performed at the same time of the day (7–9am) and at the same training stage for all participants.

Blood sampling

Blood sampling was performed under a 12-h fasted state. A total of 20 mL of blood was collected each time from each participant. A 3-mL aliquot of each sample was mixed with EDTA solution to prevent clotting duringthe measurement of hematological parameters. A total of 2 mLwas used for glycosylated hemoglobin; 1mL was placed in a special tube with a sodium citrate anticoagulant to measure the sedimentation velocity of red blood cells. The rest of the sample was placed in special tubes (which accelerated coagulation), left to coagulate at room temperature, and subsequently centrifuged (Eppendorf, UK) at 3500 rpm for 5 min to separate the serum. The serum was stored at −20°C before being measured using automatic analyzers. Specifically, hematologic parameters were measured using automatic analyzers [Sysmex k-x21w (Kobe, Japan). Creatine kinase, ferritin, and iron levels were measured via aspecialized biochemical analyzer [Mindray-BS-200 / China]. Cortisol was determined via CLIA (Vidas, Roche, Basel, Switzerland).

Anthropometric characteristics

All participants underwent body weight (kg) (Bilance Salus, Milano) and height (cm) with 0.1-cm accuracy (SECA, model 220 Germany) measurements.

Statistical analysis

The SPSS, version 17.00 (SPSS Inc, Chicago, IL) software was used for all analyses. The values are presented as the mean ± sem (standard error of the mean). The normality of samples was evaluated via the Kolmogorov–Smirnov test and normal probability plot. The comparison between groups was performed via t-test. Paired analyses were performedusing the Bonferroni test. In the case of not normal distribution, Kruskal–Wallis and Mann–Whitney tests were used. To compare repeated measurements in the groups, two-way ANOVA for repeated measures was used. Analysis of covariance was used from the beginning of the training season, between the two teams by always adjusting differences that exist between the groups (the beginning of the training season is considered as a covariate). The correlations between variables were evaluated via the

Pearson correlation coefficient, where the p-value was set at $p < 0.05$ to determine the statistically significant results. The demographic characteristics between groups were compared using the t-test, Welch test in non-even standard deviation, or Mann–Whitney test in the case of not normal data distribution.

Results
The results of this study are presented as the mean ± sem.

Anthropometric characteristics
There was no difference between the groups regarding the age or somatometric/anthropometric characteristics. The data are presented in Table 1 below.

Table 1- Anthropometric characteristics of the participants. The results are presented as the mean ± sem, n=15–30 per group.

GROUP	PROFESSIONAL ATHLETES	ELITE ATHLETES
Age (years)	22.67 ± 1.83	25.63 ± 0.58
Body height(cm)	199.60 ± 1.89	198.90 ± 1.50
Body weight(kg)	95.73 ± 2.52	95.28 ± 1.80
Body mass index (BMI)	23.99 ± 0.41	24.04 ± 0.25

Increased VO_2 max in elite basketball players
The elite athletes were characterized by increased aerobic capacity, as indicated by a 12.4% increase in their VO_2 max levels compared to professional athletes competing at the National level (Figure 1A). However, there was no difference in the CMjump performance between the groups (Figure 1B).

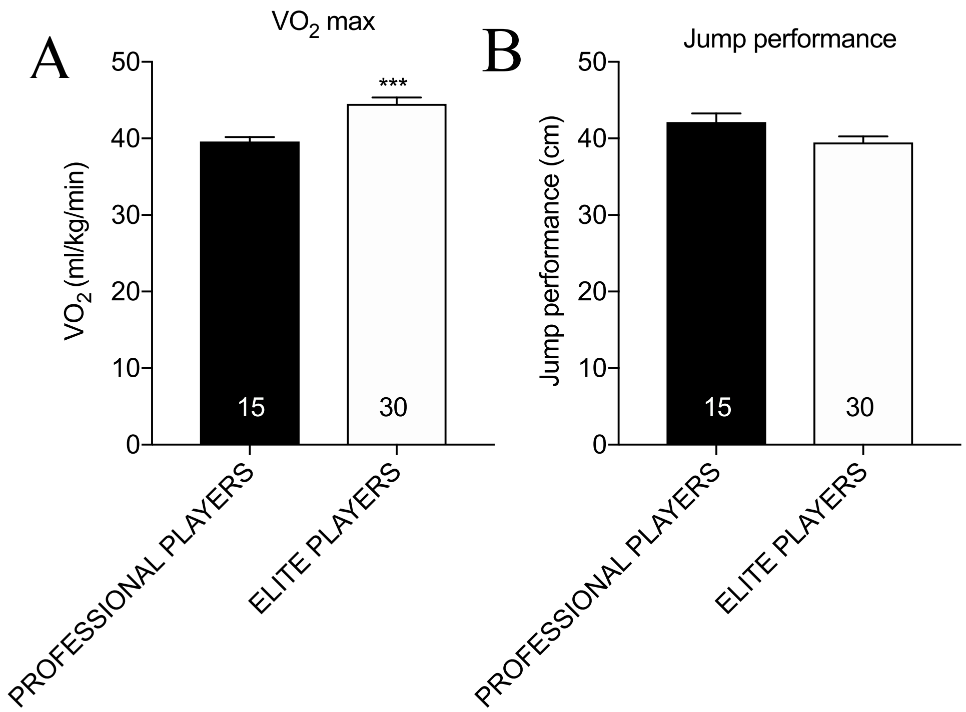

Figure 1- Performance characteristics of elite and professional athletes. VO_2 max (A) and CMJ performance (B). The results are presented as the mean ± sem, *** $p < 0.005$ vs. professional athletes, n = 15–30 per group.

Hematologic profile of elite and professional basketball players
The results of basic hematologic markers are shown in Figure 2. Specifically, elite athletes were characterized by 3.87% reduced hematocrit levels mid-season and 4.62% reduced hemoglobin levels at the end of the training season compared to professional athletes. For the rest of presented parameters, there was no significant difference between the groups or betweenthree measurements in each group.

However, there was also a decreasing trend (3.32%) in hematocrit levels for elite athletes compared to professional athletes at the end of the training season. In addition, in terms of intra-group variability, hematocrit showed an increasing trend during the second measurement mid-way of the training season compared to the first measurement for both groups, but it did not reach statistical significance.

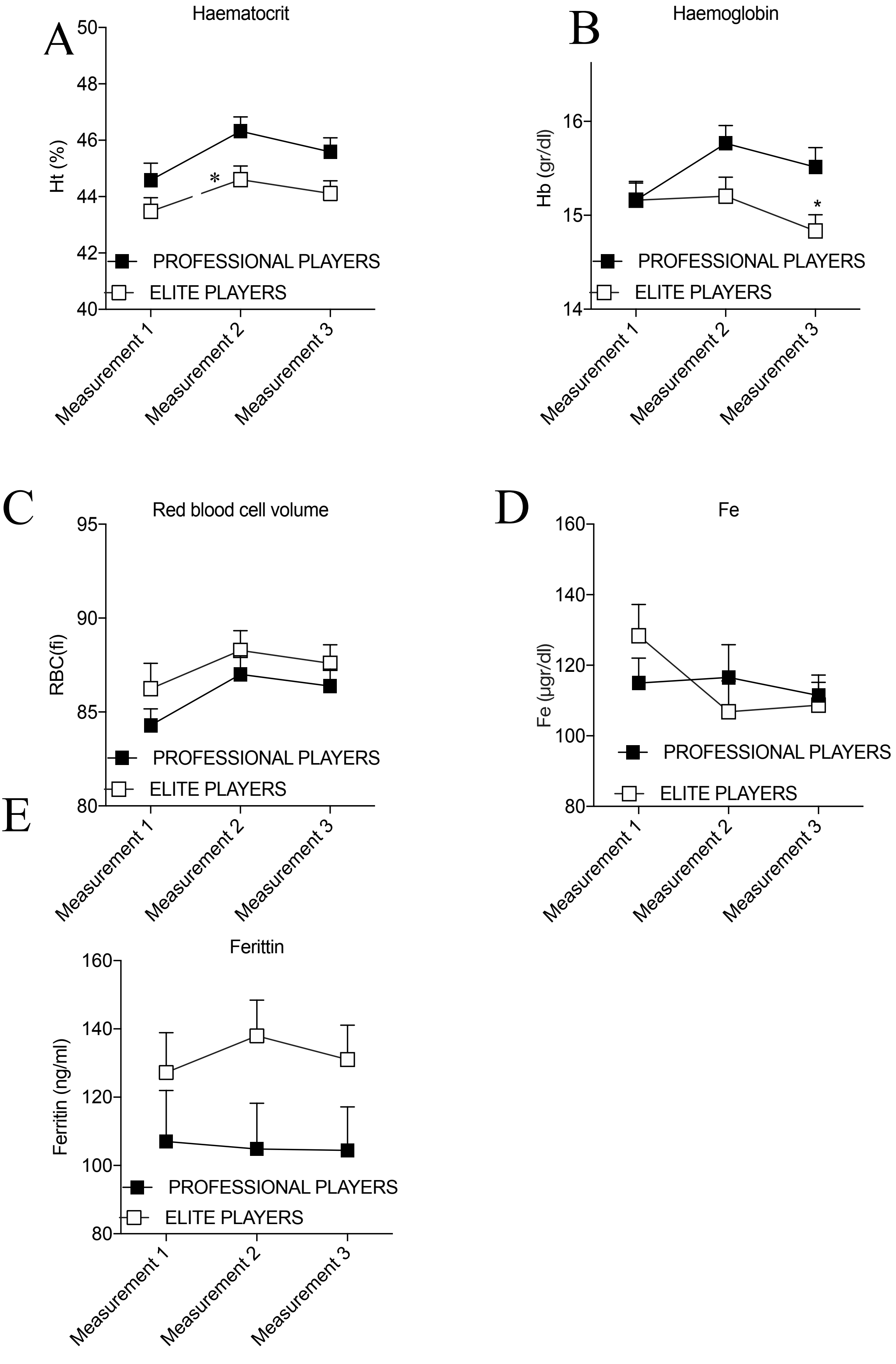

Figure 2- Hematologic profile of elite and professional athletes. Hematocrit (A), hemoglobin (B), red blood cell volume (C), iron (Fe) (D), and ferritin (E). The results are presented as the mean ± sem, *** $p < 0.05$ vs. professional athletes, n = 15–30 per group.

Cortisol and serum creatine kinase levels

Elite basketball players showed an increasing trend for cortisol levels during the first measurement. However, the obtained value did not reach statistical significance. Overall, there was no difference in the groups or between repeated measurements of the same group (Figure 3A). In addition, there was a decreasing trend for serum creatine kinase levels for the elite athletes duringthe third measurement at the end of the season. However, the obtained value did not reach statistical significance compared tothe variation of results ofthe professional athletes. Regarding intra group differences within the training period, there was a 53.5% increase in serum creatine kinase levels for the elite players mid-season compared to their initial measurement (Figure 3B). The creatine kinase levels returned to the initial levels at the end of the season. There was also an increasing trend for the professional athletes between the first andsecond measurements. However, the obtained value did not reach statistical significance owingto the largevariation betweenthe results. In the final measurement, the serum creatine kinase levels returned to the initial values for the elite basketball players. However, the result was not the same for the professional players because their serum ck levels remained at a high value that was similar to their second measurement.

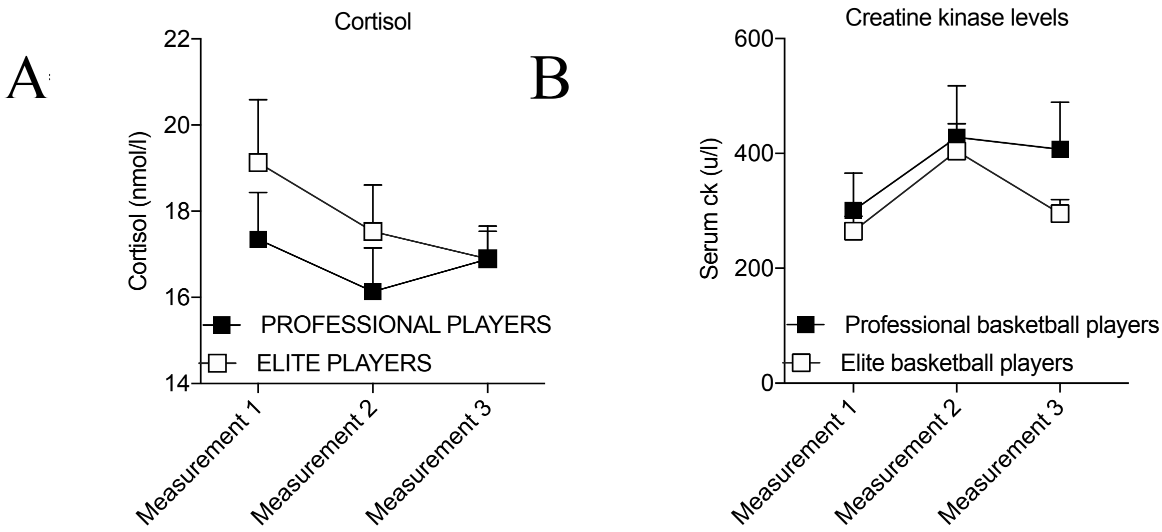

Figure 3- Biochemical/hormonal profile of elite and professional athletes. Cortisol (A) and creatine kinase (B) levels. The results are presented as the mean ± sem, * $p < 0.05$ vs. professional athletes, n = 15–30 per group.

Discussion

The effect of different training regimens and performance levels on hematologic pathways and skeletal muscle metabolism presents special interest both for the elite and professional athletes and their coaches in various sports (Tyler *et al.*, 1999; Wu *et al.*, 2004; Davidson *et al.*, 1987; Warburton *et al.*, 2002; Chaouachi *et al.*, 2009). To our knowledge, few studies have analyzed the hematologic parameters of basketball athletes (Dubnov *et al.*, 2004). However, most previous studies performed screening of the athletes and did not continuously follow different measurements throughout their training cycle (Dubnov *et al.*, 2004). A new study (Córdova Martínez *et al.,* 2017), in which elite basketball players underwent measurements of skeletal muscle damage parameters four times during the training season, mainly showed no significant differences during the entiretraining season. However, the sample number was small, and the focus of the study was on magnesium supplementation. The tested parameters were insufficient to provide a clear picture of the result (Córdova Martínez *et al.,* 2017). This study for the first time focused on basketball players at two different performance levels and performed serial measurements during the entireannual training period.

To elucidate the effect of each part of the basketball training season for two different performance levels on several hematologic parameters, hematocrit, hemoglobin, red cell volume, creatine kinase, iron, ferritin, and cortisol levels were evaluated during the entire annual training season (3 repeated measures at the beginning of the season, mid-season, and at the end of the season). Furthermore, their physiologic profile was assessed at the beginning of their training season. All parameters presented in this study consist of crucial factors of the physiological homeostasis of each athlete.

Regarding the anthropometric characteristics of participants, there was no difference between the groups, which has been shown in the past (Gonzalez *et al.*, 2013). The values for the elite athletes agree with those in previous studies for elite athletes (Apostolidis *et al.*, 2004). This allowed an even comparison between the groups, which was optimal for our current experimental procedure. The elite athletes were characterized by increased aerobic capacity, as indicated by the VO_2 max measurements (Figure 1A). However, there was no difference in the counter movement squat jump performance between the groups (Figure 1B), which was attributed to the initial measurements performed at the beginning of the training season. If the measurements were conducted at the end of the season, it would be more likely that the elite athletes would be also characterized by better jump performance. However, we were not able to evaluate this owing to technical reasons because we were not able to assess their performance after the training season. Further research is required regarding CMJ. Nevertheless, both the VO_2 max and CMJ results agree with those in previous studies conducted onelite athletes (Apostolidis *et al.*, 2004). Regarding the 12.4% VO_2max difference between the groups, similar differences between elite and professional athletes have been previously shown in Russia (Zakharova *et al.*, 2016). The VO_2 max difference is also justified because aerobic metabolism represents 65% of each basketball game (McInnes *et al.*, 1995). Therefore, the increased capacity of elite athletes can explain their ability to endure and maintain high-performance level for longer amount of time both atnational and international games. In this study, elite athletes were characterized by reduced hemoglobin and hematocrit compared to the professional athletes. This result agrees with that in a previous study with a smaller sample size (Córdova Martínez *et al.*, 2017). The difference in the elite athletescan be attributed to the "traumatic" movement of running and endurance training used for elite athletes, which can improve their performance but may lead to the destruction of red blood cells, as has been previously shown (Schumacher *et al.*, 2002). This reduction in hematologic parameters is always more pronounced in athletes, whose training program is mainly comprised of endurance training and running, which suggests that the exercise type and duration arecritical forthe iron metabolism adaptation in both elite and professional athletes (Córdova Martínez *et al.*, 2017)

In terms of the biochemical profile, different training regimens and performance levels can affect important hormones that canbe modified by exercise such as serum creatine kinase and cortisol.

Serum creatine kinase activity is widely used as a biomarker for skeletal muscle cell damage and recovery. It is increased at several timepoints after strenuous exercise (Nikolaidis *et al.*, 2003) and can stay elevated for days in case of inadequate recovery or any skeletal muscle pathological conditions (Baird et *al.*, 2012, Brancaccio *et al.*, 2007; Koutedakis *et al.*, 1993). In this study, both athletes showed initial increased serum ck levels duringthe second measurement compared to the first one, and there was noinitial difference between the groups. Elite athletes were characterized by a significant increase mid-season compared to the initial measurement (53.5%). In addition, there was an increasing trend forthe professional athletes. However, the values varied, and the increase did not reach statistical significance. This significant increase could be due to increased training and competition demands (followed by increased stress on skeletal muscles) for the elite athletes at both national and international levels during this period of time. In addition, the elite athletes showed reduced serum ck levels duringthe third measurement compared to the initial one, which was not the case for the professional athletes, where serum ck remained high. This result indicates a quicker recovery rate for the elite athletes, which is expected; it has been previously shown that elite athletes have better adaptation to exercise stimuli (Baird *et al.*, 2012).

In terms of cortisol levels, elite athletes showed a decreasing trend for cortisol compared to the professional athletes for whom cortisol was similar during the training season. However, the values did not reach statistical significance. This trend for cortisol levels agrees with a decrease in cortisol levels observed inelite athletes, which is possibly due to increased chronic stress for competitions during the training period (Rist&Billymo, 2019). In general, regarding cortisol levels, there is no clear picture in the literature because different studies show different results (He *et al.*, 2010; Nikolaidis *et al.*, 2003). Therefore, additional research is needed.

Overall, in this study, a serial exploration of the hematologic and physiologic profile of elite and professional basketball playerswas performed for the first time. More research is needed to elucidate the exact mechanisms that affect their profile and performance on the basketball court.

Conflicts of interest: The authors declare that they have no competing interest.

Ethical approval: All procedures performed in our studies involving human participants were in accordance with the ethical standards of the Institutional (National and Kapodistrian University of Athens Ethics Committee) and National research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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