Hematologic and Biochemical Profile of Juvenile and Adult Athletes of Both Sexes: Implications for Clinical Evaluation

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Abstract

The aim of the present study was to compare the values of seventeen hematologic and biochemical parameters between juvenile and adult athletes and non-athletes of both sexes. 579 athletes and 241 non-athletes participated in the study. We measured packed-cell volume, hemoglobin, red blood cell count, white blood cell count, platelet count, iron, glucose, urea, triacylglycerols, total cholesterol, high-density lipoprotein cholesterol, total/high-density lipoprotein cholesterol ratio, calcium, magnesium, creatine kinase, as well as alanine and aspartate aminotransferases. We found significant differences according to age, sex, and physical activity in the majority of the parameters. The effect size of physical activity on most parameters was small (< 0.5); however, that on packed-cell volume, glucose, urea, calcium, magnesium, and creatine kinase was moderate to high (0.5 to 0.8). It is remarkable that three of the highest effect sizes of physical activity appeared on parameters thought to be under tight homeostatic control (i.e., glucose, calcium, and magnesium). We conclude that physical training influences most of the biochemical parameters routinely measured in athletes, although, in some cases, its effect appears to be of limited biological importance. Therefore, clinical assessment on the basis of blood tests has to take into account not only the age and sex, but also the training status of individuals.

Key words
Adolescents · biochemical monitoring · exercise · females · males

Introduction

Hematologic and biochemical tests are used widely to assess health and fitness of the intensively training athlete. Studies, mainly on adults, have revealed that athletes exhibit resting values of certain parameters that differ from those of the general population [4, 9, 13, 23]. However, the influence of physical activity on the levels of many routinely measured blood variables seems to be ambiguous. Additionally, it is unclear whether and how age as well as sex affect the hematologic profile of an athlete, since there are no studies comparing juvenile and adult athletes, and only a few comparing male and female athletes (e.g., [23, 27]). Data on biochemical parameters are even more scanty.

Among the parameters in question, those related to oxygen transport have attracted the most attention. Indeed, it has been suggested that the red cell parameters and iron status of athletes should be monitored regularly [26]. However, even with regard to well studied red cell parameters, such as packed-cell volume (PCV), hemoglobin, and red blood cell count (RBC), the effect of exercise training is debatable, with some authors reporting lower values in athletes [18] and others reporting similar values in athletes and non-athletes [27]. Additionally, there are limited data on the resting levels of serum metabolites, such as glucose and urea, as well as of enzymes indicative of muscle and liver damage, even though many studies have found major increases in the serum activities of creatine kinase (CK), alanine aminotransferase (ALT), and aspartate aminotransferase (AST) after acute exercise [14]. Moreover, most of the studies reporting on the effects of chronic exercise on hematologic and biochemical variables have small sample sizes and/or other research goals (e.g., evaluation of performance).

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The divergence of the values of certain hematologic and biochemical parameters of athletes from those of the general population has been noticed in our laboratory during routine assessment of individuals. For a more accurate interpretation of athletes' health and physical fitness status, it would be interesting to establish not merely the presence but also the extent of these differences. Therefore, the aim of the present study was to compare the values of seventeen blood parameters between juvenile and adult athletes and non-athletes of both sexes in order to identify and quantify (through calculation of effect sizes) adaptations to exercise as well as age- and sex-related differences.

Material and Methods

Subjects

Data were collected from 579 Greek athletes as part of the monitoring services offered by our laboratory to athletes and coaches over the course of five years. Subjects were practising sports which include both endurance and strength/power activities, that is, soccer, volleyball, basketball, handball, water polo, middle distance running, middle distance swimming, rowing and table tennis. To be included in the study, subjects had to meet the following criteria, which were assessed through the administration of a questionnaire: a) be in good health, with no known diseases including diabetes, cancer or heart disease, b) not use medications during the week preceding blood sampling, c) not smoke or consume more than 25 g of alcohol per day, d) follow a regular diet, e) not use dietary supplements in excess of the recommended dietary allowances on a regular basis within the trimester preceding blood sampling, f) not use steroids or other banned substances. Additionally, females should not be using oral contraceptives.

All athletes were members of sport clubs and had been training for at least one year, at least 4 days per week, at least 1 h per training session. The control group consisted of 241 subjects who did not participate in any training program (outside physical education classes in school, for juvenile participants). Athletes and non-athletes were subdivided into boys, girls, men and women. The size, age, and training characteristics of each group are presented in Table **1**. Informed written consent was obtained from each subject and the experimental procedures were in accordance with the guidelines of the University of Thessaloniki Ethics Committee.

Blood sampling

Venous blood samples were collected into plain evacuated tubes from a forearm vein with minimal stasis after approximately 10 min of rest in a sitting position between 8 and 9 am, after an overnight fast and at least 24 h from the last workout. An aliquot of each sample was immediately mixed with EDTA solution to prevent clotting for hematology. The rest of the sample was left to coagulate for 30 min at room temperature and was centrifuged at 1500 × *g* for 10 min in order to separate the serum for chemistry. The serum was stored at –20 °C.

Table **1** Size, age, and training characteristics of the experimental groups (mean±SD)

Group	N	*Age*	*Range of age*	*Years of training*	*Training sessions/week*
Boys, athletes	113	14.5 ± 1.5	11 – 17	6.9 ± 3.3	6.9 ± 1.9
Boys, non-athletes	39	14.0 ± 1.6	12 – 17	–	–
Girls, athletes	134	14.2 ± 1.9	10 – 17	7.0 ± 2.6	6.7 ± 1.2
Girls, non-athletes	95	14.5 ± 1.8	12 – 17	–	–
Men, athletes	273	22.3 ± 3.7	18 – 35	11.4 ± 4.0	8.4 ± 3.5
Men, non-athletes	60	22.2 ± 1.8	18 – 26	–	–
Women, athletes	59	22.7 ± 3.6	18 – 30	11.3 ± 2.1	7.9 ± 3.3
Women, non-athletes	47	22.7 ± 3.5	18 – 36	–	–

Assays

We measured five hematologic parameters, i. e., PCV, hemoglobin, RBC, white blood cell count (WBC), and platelet count, as well as twelve biochemical parameters, i. e., iron, glucose, urea, triacylglycerols (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDLC), TC/HDLC ratio, calcium, magnesium, CK, ALT, and AST. The hematologic parameters were measured in a Sysmex K-1000 (Kobe, Japan) autoanalyzer, whereas the biochemical parameters were measured in a Hitachi U-1100 (Tokyo, Japan) spectrophotometer. Iron was determined with a reagent kit from Biosis (Athens, Greece), glucose and urea with kits from Boehringer (Mannheim, Germany), and TG as well as TC with kits from Best (Athens, Greece). HDLC was determined like TC after precipitation of very low-density and low-density lipoproteins with a reagent from Boehringer. Calcium and magnesium were determined with kits from Human (Wiesbaden, Germany), CK with a kit from Dialab (Vienna, Austria), and the two aminotransferases with kits from Best. All biochemical parameters were determined in duplicate with simultaneous use of a control serum from Boehringer. The hematologic measurements were generally performed within 3 h, while the biochemical measurements were performed in duplicate within 1 week of blood sampling. The intra-assay coefficients of variation were: iron 1.4 %; glucose 0.8 %; urea 3.1 %; TG 1.8 %; TC 1.2 %; HDLC 1.2 %; calcium 2.8 %; magnesium 3.3 %; CK 8.2 %; ALT 8.1 % and AST 7.8 %.

Extraction of reference values

The value of a hematologic or biochemical parameter pertaining to an individual will be referred to as a reference value, according to the terminology of the International Federation of Clinical Chemistry [7]. Because some participants visited the laboratory more than once, they had more than one reference value for a certain parameter. In that case, we selected the median for the statistical analysis.

Statistical analysis

The SPSS (version 10.0) was used for all analyses. Data are expressed as the mean ± SD. The normality of distribution of all hematologic and biochemical parameters was checked by using the Kolmogorov-Smirnov test. The distributions of urea, TG, HDLC, CK, ALT, and AST activities were found to depart significantly from the normal distribution; therefore, these parameters were subjected to logarithmic transformation prior to data pro-

Table **2** Hematologic and biochemical profile of participants divided according to age, sex, or physical activity (mean ± SD)

Variable	*Age*			*Sex*			*Physical activity*		
	Juveniles	*Adults*	*Effect size*	*Males*	*Females*	*Effect size*	*Athletes*	*Non-athletes*	*Effect size*
PCV (%)	40.4 ± 2.9	42.8 ± 3.3*	0.77	43.2 ± 2.9	39.3 ± 2.4*	1.44	42.2 ± 3.2	40.2 ± 3.2*	0.63
Hemoglobin (g/dL)	13.7 ± 1.1	14.6 ± 1.3*	0.74	14.8 ± 1.2	13.3 ± 0.9*	1.38	14.3 ± 1.2	13.7 ± 1.4	0.48
RBC (10^{12}/L)	4.73 ± 0.43	4.91 ± 0.46	0.40	5.04 ± 0.39	4.53 ± 0.36*	1.35	4.86 ± 0.45	4.70 ± 0.45	0.36
WBC (10^9/L)	6.41 ± 1.38	6.35 ± 1.52	0.04	6.30 ± 1.49	6.49 ± 1.39	0.13	6.40 ± 1.52	6.33 ± 1.25	0.05
Platelets (10^9/L)	253 ± 52	217 ± 60*	0.63	227 ± 61	249 ± 54*	0.38	234 ± 62	243 ± 51	0.15
Iron (μg/dL)	76 ± 31	89 ± 37*	0.37	86 ± 34	76 ± 36	0.29	84 ± 33	77 ± 38	0.20
Glucose (mg/dL)	85 ± 12	89 ± 10*	0.39	90 ± 11	84 ± 10*	0.57	89 ± 11	83 ± 10*	0.51
Urea (mg/dL)	31 ± 8	38 ± 10*	0.79	38 ± 10	31 ± 9*	0.73	37 ± 10	29 ± 9*	0.82
TG (mg/dL)	60 ± 25	76 ± 38*	0.49	74 ± 38	60 ± 23*	0.43	67 ± 32	71 ± 36*	0.12
TC (mg/dL)	171 ± 36	173 ± 37	0.05	170 ± 37	175 ± 36	0.14	170 ± 36	176 ± 37*	0.17
HDLC (mg/dL)	59 ± 15	51 ± 11*	0.61	50 ± 11	60 ± 14*	0.81	54 ± 14	55 ± 13	0.05
TC/HDLC	2.93 ± 0.82	3.54 ± 0.96*	0.68	3.57 ± 1.03	2.91 ± 0.71*	0.72	3.26 ± 1.00	3.27 ± 0.90	0.01
Calcium (mg/dL)	9.66 ± 1.26	9.49 ± 0.80*	0.16	9.69 ± 0.91	9.48 ± 1.26	0.20	9.86 ± 0.83	9.22 ± 1.29*	0.65
Magnesium (mg/dL)	2.20 ± 0.25	2.28 ± 0.23*	0.33	2.25 ± 0.24	2.20 ± 0.26*	0.20	2.18 ± 0.23	2.30 ± 0.26*	0.50
CK (U/L, 37 °C)	171 ± 170	339 ± 346*	0.60	340 ± 331	152 ± 172*	0.68	321 ± 320	111 ± 90*	0.77
ALT (U/L, 37 °C)	17 ± 10	20 ± 11	0.28	20 ± 12	16 ± 9*	0.37	20 ± 11	15 ± 11*	0.45
AST (U/L, 37 °C)	23 ± 12	6 ± 14	0.23	26 ± 15	23 ± 11	0.22	27 ± 14	21 ± 11*	0.45

*Significantly different from the preceding group ($p < 0.05$).

cessing. Comparisons among the four groups of juveniles and among the four groups of adults with respect to age were performed through 2 × 2 (sex × physical activity) ANOVA. Comparisons among all groups regarding each hematologic and biochemical parameter were performed through 2 × 2 × 2 (age × sex × physical activity) ANOVA. Post-hoc pairwise comparisons were performed through simple main effects analysis.

To determine the meaningfulness of the main effects of age, sex, and physical activity on each dependent variable, effect sizes were calculated as the difference between means divided by the pooled SD. The power of each main effect comparison was also computed. The level of statistical significance was set at $\alpha = 0.05$ for all analyses.

Results

There were no significant differences in age among the four groups of juveniles or among the four groups of adults; in fact, the mean ages were very similar within each of the two age categories (Table **1**). There was no significant interaction of age, sex, and physical activity for any of the hematologic or biochemical parameters measured except hemoglobin ($p < 0.01$). The hematologic and biochemical profile of participants divided according to each independent variable, along with the significance of each main effect and the corresponding effect sizes, are presented in Table **2**. The median power of detecting differences according to age, sex, and physical activity was 0.97, 0.96 and 0.87, respectively. Thus, the study had sufficient power to detect small and moderate differences in most of the comparisons.

The hematologic and biochemical profile of each experimental group, along with the results of the simple main effects analysis, are presented in Table **3**. The mean values of all parameters (except those of CK of all athlete groups) were within the reference intervals for the general population [24].

Regarding the parameters related to oxygen transport, adults, males, and athletes had higher PCV than juveniles, females, and non-athletes, respectively ($p < 0.001$). Adults and males exhibited higher hemoglobin concentrations than juveniles and females, respectively ($p < 0.001$). In RBC, the only significant difference was the higher value of males compared to females ($p < 0.001$). The incidence of anemia (PCV below 39% for adult males, 35% for adult females, 35% for juvenile males, and 34% for juvenile females, as well as hemoglobin below 13.2, 11.7, 12.0 and 11.5, respectively, according to Ref. 24) was 0.8% for girls athletes, 2.1% for girls non-athletes, 5.0% for men athletes, and 4.4% for women non-athletes, whereas there were no anemic individuals in the other groups.

Juveniles, males, and non-athletes had similar WBC with adults, females, and athletes, respectively. Concerning platelet count, juveniles and females had higher values than adults and males, respectively ($p < 0.05$). Iron concentration was significantly different only between juveniles and adults, with the former exhibiting lower concentrations ($p < 0.001$). Adults, males, and athletes had higher glucose and urea concentrations than juveniles, females and non-athletes, respectively ($p \leq 0.001$).

With respect to the lipid profile, juveniles, females, and athletes had lower TG concentrations than adults, males and non-athletes, respectively ($p < 0.01$). The only significant main effect in TC was that of physical activity, with athletes exhibiting lower

Table **3** Hematologic and biochemical profile of juvenile and adult athletes and non-athletes of both sexes (mean ± SD)

Variable	*Boys athletes*	*Boys non-athletes*	*Girls athletes*	*Girls non-athletes*	*Men athletes*	*Men non-athletes*	*Women athletes*	*Women non-athletes*
PCV (%)	42.7 ± 2.9[abc]	40.8 ± 2.9[abc]	39.7 ± 2.1[bc]	38.4 ± 2.0[bc]	43.7 ± 2.9[ab]	44.2 ± 2.3[ab]	39.9 ± 2.7[b]	39.3 ± 2.7[b]
Hemoglobin (g/dL)	14.6 ± 1.1[abc]	14.1 ± 1.1[abc]	13.4 ± 0.8[bc]	13.0 ± 0.9[bc]	14.8 ± 1.1[abc]	15.6 ± 1.1[abc]	13.5 ± 0.9[b]	13.3 ± 1.0[b]
RBC (10^{12}/L)	5.04 ± 0.38[b]	4.98 ± 0.37[b]	4.53 ± 0.31[b]	4.55 ± 0.40[b]	5.04 ± 0.41[b]	5.11 ± 0.31[b]	4.51 ± 0.40[b]	4.41 ± 0.32[b]
WBC (10^9/L)	6.40 ± 1.51	6.09 ± 1.38	6.50 ± 1.44	6.44 ± 1.16	6.27 ± 1.53	6.50 ± 1.15	6.71 ± 1.64	6.16 ± 1.47
Platelets (10^9/L)	255 ± 52[a]	251 ± 57[a]	254 ± 55	251 ± 46[a]	210 ± 61[ab]	209 ± 37[a]	245 ± 62[b]	223 ± 56[a]
Iron (μg/dL)	82 ± 28	77 ± 27[a]	78 ± 30	68 ± 36[a]	88 ± 36	98 ± 39[a]	88 ± 34	85 ± 50[a]
Glucose (mg/dL)	91 ± 13[bc]	84 ± 11[abc]	85 ± 10[abc]	79 ± 9[abc]	89 ± 10	91 ± 7[a]	89 ± 10[a]	87 ± 6[a]
Urea (mg/dL)	34 ± 7[a]	31 ± 7[ab]	33 ± 8[c]	25 ± 7[abc]	40 ± 10[ab]	39 ± 7[ab]	35 ± 9[bc]	30 ± 10[abc]
TG (mg/dL)	59 ± 26[a]	69 ± 32[a]	55 ± 23	61 ± 23	75 ± 36[abc]	96 ± 51[abc]	63 ± 24[b]	63 ± 22[b]
TC (mg/dL)	164 ± 28[b]	171 ± 36	176 ± 43[b]	173 ± 33	170 ± 36	179 ± 50	167 ± 26	183 ± 26
HDLC (mg/dL)	55 ± 14[ab]	53 ± 15[ab]	65 ± 15[abc]	59 ± 15[bc]	48 ± 10[ab]	47 ± 9[ab]	56 ± 11[ab]	59 ± 10[b]
TC/HDLC	3.12 ± 0.97[ab]	3.19 ± 1.03[a]	2.58 ± 0.69[abc]	3.01 ± 0.69[c]	3.66 ± 0.99[ab]	3.81 ± 1.06[ab]	3.04 ± 0.67[ab]	3.12 ± 0.63[b]
Calcium (mg/dL)	10.22 ± 0.81[ac]	9.74 ± 1.05[abc]	9.93 ± 0.99[c]	9.13 ± 1.50[bc]	9.66 ± 0.71[ac]	8.78 ± 0.80[ac]	9.78 ± 0.56	9.32 ± 0.80
Magnesium (mg/dL)	2.15 ± 0.24[ac]	2.30 ± 0.21[ac]	2.13 ± 0.21[c]	2.26 ± 0.29[c]	2.27 ± 0.22[abc]	2.45 ± 0.17[ac]	2.15 ± 0.23[bc]	2.32 ± 0.22[c]
CK (U/L, 37 °C)	280 ± 232[abc]	118 ± 52[abc]	187 ± 150[bc]	72 ± 46[abc]	413 ± 377[abc]	160 ± 135[abc]	234 ± 276[bc]	100 ± 68[abc]
ALT (U/L, 37 °C)	19 ± 14[ac]	14 ± 7[ac]	18 ± 12[c]	15 ± 7[c]	22 ± 10[ab]	22 ± 23[ab]	17 ± 9[bc]	13 ± 8[bc]
AST (U/L, 37 °C)	26 ± 18	21 ± 9	25 ± 9[c]	20 ± 11[c]	28 ± 15[c]	22 ± 12[c]	27 ± 14	24 ± 12

[a]Significantly different between juveniles and adults of the same sex and physical activity group ($p < 0.05$).
[b]Significantly different between males and females of the same age group and physical activity group ($p < 0.05$).
[c]Significantly different between athletes and non-athletes of the same age group and sex ($p < 0.05$).

values than non-athletes ($p = 0.028$). Juveniles and females had higher HDLC concentrations compared to adults and males, respectively ($p < 0.001$). The TC/HDLC ratio was higher in adults and males compared to juveniles and females, respectively ($p < 0.001$), whereas no significant difference was found between athletes and non-athletes.

Juveniles and athletes had higher calcium concentrations than adults and non-athletes, respectively ($p < 0.01$). In contrast, magnesium was lower in juveniles, females, and athletes compared to adults, males and non-athletes, respectively ($p < 0.01$).

As far as the indices of muscle and liver damage are concerned, CK activity was higher in adults, males, and athletes compared to juveniles, females and non-athletes, respectively ($p < 0.01$). ALT was higher in males and athletes than in females and non-athletes, respectively ($p < 0.05$), while the only significant difference in AST was the higher value of athletes compared to non-athletes ($p = 0.002$).

Discussion

We have investigated the influence of age, sex, and physical activity on seventeen blood parameters by employing a large sample of juvenile and adult athletes and non-athletes of both sexes. Furthermore, we present effect sizes in order to explore the importance of the findings and help investigators to choose appropriate sample sizes in future relevant studies. Since our main interest lies in the effects of training rather than age and sex on human biology, we will emphasize on differences between athletes and non-athletes.

The red blood cell parameters (PCV, hemoglobin, and RBC) were significantly higher in adults and males compared to juveniles and females, respectively, with the exception of similar RBC between juveniles and adults. Regarding the effect of age, we did not locate any similar study, while, regarding the effect of sex, our findings agree with the majority of the relevant studies (e.g., [23]). There has been a great deal of concern about the levels of the red blood cell parameters in athletes, owing to their role in oxygen transport, a crucial factor in endurance performance. Our data show that the values of athletes were comparable to or even significantly higher (PCV) than those of the non-athletes. Interestingly, juvenile athletes of both sexes had significantly higher PCV and hemoglobin than their inactive counterparts, whereas the corresponding differences in the adult participants were either not significant or in the opposite direction (hemoglobin of male athletes and non-athletes). This explains the only significant interaction of age, sex, and physical activity found in the present study (in hemoglobin). These results differ from those of studies reporting lower [20] or similar levels of red blood cell parameters in juvenile athletes compared to non-athletes [13]. On the other hand, the dearth of significant differences between adult athletes and non-athletes agrees with most of the relevant studies (e.g., [13]). Overall, the present study provides no evidence that persons participating in strenuous sport activity have lower levels of red blood cell parameters than sedentary individuals.

The similar WBC between juveniles and adults is in accordance with the only relevant study found [1]. The absence of a significant difference between males and females agrees with the study of Weight et al. [27]; however, opposing results, that is, significantly higher [6] and lower values in males compared to females have also been reported [23]. The similar WBC of ath-

letes compared to non-athletes is in agreement with most of the relevant studies (e.g., [13,18]). It is interesting that WBC was the only parameter which was not affected by either age, sex or physical activity and the parameter which exhibited the lowest effect sizes.

We have found significantly higher platelet counts in juveniles compared to adults, a finding which agrees with Kabata et al. [10]. Regarding the significantly higher platelet count of females compared to males, studies have reported similar differences in juveniles [22] and adults [1]. Finally, the majority of relevant studies supports the absence of differences between athletes and non-athletes in platelet count (e.g., [18]).

Regarding iron, only the main effect of age was significant. With respect to the absence of significant sex- and physical activity-related differences, most of the relevant studies agree with our findings, reporting similar levels between males and females (e.g., [27]), as well as between trained and untrained individuals (e.g., [13,27]).

Adults, males, and athletes had significantly higher (by 5 – 7%) glucose concentrations than juveniles, females and non-athletes, respectively, despite the rigid homeostatic control mechanism operating in blood [2]. The difference between athletes and non-athletes disagrees with Crespo et al. [4], who found no differences, but agrees with Le Blanc et al. [12]. Whether repeated exercise bouts affect the homeostatic mechanism of glucose is a matter that requires further examination.

Serum urea has been frequently used to evaluate the load of training and the recovery process. The levels of urea in the present study were significantly higher in adults, males, and athletes compared to juveniles, females, and non-athletes, respectively, by 22 – 26% and with effect sizes exceeding 0.7. We found no studies comparing serum urea concentrations of juveniles and adults. On the other hand, higher urea concentrations in males compared to females have been reported for adult athletes [9]. The increased urea concentration in athletes is suggestive of a catabolic state, which is in accordance with the increased values of CK and AST (discussed further below). Another important factor contributing to high urea values may be the higher protein intake by athletes as part of their higher energy intake and/or as a result of higher percentages of protein in their diet. Unexpectedly, we could not find studies comparing resting levels of urea between trained and untrained individuals. However, acute exercise has been shown to provoke prolonged increases in urea (e.g., [17]), thus justifying the higher resting levels of athletes found in the present study.

The results of the present study support a slightly favourable lipid profile of juveniles and females compared to adults and males, respectively, even though the differences in TC were not significant. Concerning the effect of physical activity, we found a slightly better lipid profile in athletes compared to non-athletes, as evidenced by the significantly lower concentrations of TG and TC, although there were no differences in HDLC and TC/HDLC ratio. Similar findings regarding TG and TC (but not HDLC and TC/HDLC) were reported in recent reviews on children and adolescents [25], as well as adults [5].

The significantly higher calcium concentrations of juveniles compared to adults agree with the literature, which supports higher calcium levels throughout adolescence [16]. On the other hand, the absence of significant differences between the sexes in our study agrees with the findings of Haden et al. [8] in adults. With respect to the influence of physical activity, all four groups of athletes had considerably (and significantly in three out of the four cases) higher calcium concentrations than the corresponding groups of non-athletes. This finding is difficult to interpret considering the tight homeostasis of calcium in plasma [2]. Contradictory results have been reported in the literature, ranging from higher [11] to lower [4] and including similar levels between athletes and non-athletes [21]. It is worth mentioning that the effect size of the comparison between the calcium concentrations of trained and untrained subjects (0.65) was the third highest of the effect sizes of physical activity in the present study.

The age- and sex-dependent values of magnesium are difficult to explain, since no relevant studies were found. Regarding the influence of physical activity, it is interesting to note that all groups of athletes showed significantly lower values than non-athletes, despite the tightly controlled homeostasis of magnesium in plasma [2]. Studies on the effect of chronic exercise on the magnesium levels have provided contradictory results, i.e. higher [15], lower [3] or not significantly different levels in trained compared to untrained individuals [4,21].

CK activity in serum is an indirect index of muscle cell damage and is elevated following strenuous activity. The significantly higher values of adults and males compared to juveniles and females, respectively, are probably due to the higher muscle mass of the former groups. Concerning the effect of age, we could not find a similar study, while, regarding the effect of sex, higher CK activities in males compared to females have been reported by other studies, either at rest or after the same exercise bout [14]. The most pronounced effect on CK was exerted by physical activity, with all groups of athletes exhibiting significantly higher levels than non-athletes. It is noteworthy that the mean values of athletes were from 7 to 137% higher than the upper reference limit for the general population (174 U/L, [24]). The higher levels of athletes are apparently due to the exercise sessions preceding blood sampling, since CK activity peaks 1 – 2 days after exercise and remains elevated for several days [14]. Furthermore, the generally higher muscle mass of athletes has probably contributed to the observed differences. Results similar to ours have been reported by Rotenberg et al. [19].

ALT and AST are widely distributed in tissues and are detected in serum of humans due to their release from damaged cells [14]. ALT is mainly a marker of liver disease, while an increase in AST is more specific to muscle cell disruption [14]. The significantly higher aminotransferase activities found in adults, males and athletes compared to juveniles, females and non-athletes, respectively, (except for AST between males and females) are probably due to the higher muscle mass of the former groups. An additional reason for the higher values in athletes may be the preceding intensive training, since AST activity peaks 1 – 2 days after prolonged exercise and remains increased for several days [14]. No information about ALT kinetics after exercise and

no comparison of resting levels of transaminases between athletes and non-athletes was found in the literature apart from the finding [19] that men athletes had an AST activity higher than the corresponding value of non-athletes by a similar percentage (31 %, although not significant) as in our study. A quite unexpected finding was that the magnitude of the difference between athletes and non-athletes in ALT was equal to that in AST (in terms of effect size), although it is known that AST increases to a greater extent than ALT after acute exercise, probably due to its higher presence in skeletal muscle [14]. Whether chronic exercise and/or special practices of athletes (e. g., diet) increase the disruption of hepatocytes remains an open possibility.

The findings of the present study suggest that regular exercise influences the hematologic and biochemical status of juvenile and adult athletes of both sexes. Most of the parameters measured were significantly different between athletes and non-athletes, with PCV, glucose, urea, calcium, magnesium, and CK exhibiting moderate to high (≥ 0.5) effect sizes. It is remarkable that serum glucose, calcium, and magnesium were different in athletes compared to sedentary counterparts as these parameters are thought to be under tight homeostatic control. Although a genetic factor cannot be ruled out, adaptations to training are probably the main cause for the observed differences. On the other hand, the small effect sizes of physical activity on the majority of the parameters implies that they are of limited diagnostic value in the assessment of training status.

In conclusion, the knowledge of differences in hematologic and biochemical parameters between athletes and sedentary individuals should provide useful information for the clinical assessment of an athlete. Therefore, from a practical point of view, the clinician has to take into account not only the age and sex, but also the training status of individuals when evaluating their blood tests.

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