# SERUM ELECTROLYTE CONCENTRATIONS IN HIGHLY TRAINED YOUNG ATHLETES

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## Abstract:

Many studies suggest that intensive physical activity for a long period of time influences the serum electrolyte profile in adults. However, few studies are dedicated to the effects of long and intensively practised sport during the pubescence on serum electrolytes. The aim of this study was to assess the serum concentrations of the basic electrolytes (K, Na, Cl, Ca, and $PO_4$) in highly trained pubescent sportsmen of different sports and to compare the results obtained with those of a control, non-trained group. Subjects: 845 highly trained athletes (age: 14.01±0.06 years; sports practise: 3.44±0.06 years) were investigated. The group has been divided into 7 subgroups in accordance with the practised sport: athletics, swimming, rowing, wrestling, weight lifting, games, and other sports. The control group consisted of 348 non-trained subjects (age: 14.58±0.09 years). Methods: The serum concentrations of K, Na, Cl, Ca, and $PO_4$ were measured in blood samples in accordance with the EPTRV and IFCC rules. The data were presented as $\bar{X}$±SEM, and ANOVA-factorial analysis was carried out in order to value the significance of the found differences. Results and Discussion: The trained group manifested lower ($p<0.001$) serum K concentration than the non-trained one (4.68±0.02 mmol/l vs. 4.91±0.02 mmol/l), lower ($p<0.001$) Na concentration (144.21±0.12 vs. 146.17±0.21 mmol/l), and lower ($p<0.001$) Cl concentration (104.72±0.13 vs. 108.45±1.27 mmol/l). On the other hand, higher ($p<0.01$) Ca and higher ($p<0.05$) $PO_4$ concentrations in the blood samples were found obtained from the highly trained pubescent sportsmen in comparison with the samples from the control group (2.40±0.01 vs. 2.36±0.01 mmol/l, and 1.19±0.01 vs. 1.15±0.02 mmol/l respectively). The lowest K concentration was found in the swimming subgroup - 10.8% below the control group ($p<0.001$), followed by the wrestling and weight-lifting subgroup - 5.1% below the control group ($p<0.001$). Swimmers had the lowest Na serum concentrations - 2.8% below the control group ($p<0.001$), and those who practised athletics had the lowest Cl serum concentrations - 4.7% under the control group ($p<0.001$). The highest Ca serum levels were found in the weight lifters - 4.4% above the controls ($p<0.001$). The serum $PO_4$ concentrations in swimmers were found to be 14.8% higher than in the control group ($p<0.001$). Conclusions: The evidence of this study suggests that the long-lasting, high-intensive sports training during the age of pubescence affects the blood electrolyte homeostasis. The type of the practised sport is important for the degree of deflection in the K, Na, Cl, Ca, and $PO_4$ serum concentrations.

**Key words:** exercise, serum electrolytes, sportsmen, pubescence

## ELEKTROLYTENSPIEGEL IM BLUTSERUM BEI JUNGEN LEISTUNGSSPORTLERN

## Zusammenfassung:

Die zahlreichen Untersuhungen weisen darauf hin, dass eine intensive körperliche Tätigkeit in einer längeren Zeitspanne bei den Erwachsenen den Elektrolytenspiegel im Blutserum beeinflusst. Es gibt aber wenig Untersuchungen, die sich mit der Auswirkung von langzeitigen und intensiven leistungsportlichen Tätigkeiten auf Elektrolytenspiegel bei Pubertierenden befassen. Das Ziel der Untersuchung war die Spiegelwerte von Hauptelektroyten (K, Na, Cl, Ca und $PO_4$) im Blutserum bei den pubertierenden Leistungssportlern aus unterschiedlichen Sportarten festzustellen und die Ergebnisse mit denen der nichttrainierenden Kontrollgruppe zu vergleichen. Die Testpersonen - 845 Leistungssportler (Alter: 14,01+/-0,06 Jahre; im Leistungssport: 3,44+/-0,6 Jahre). Die Testpersonen wurden in 7 Gruppen geteilt, je nach der Sportart: Leichtathletik, Schwimmen, Rudern, Ringen, Gewichtheben, Ballspiele und sonstige Sportarten. Die Kontrollgruppe bestand aus 349 nichttrainierenden Testpersonen (Alter: 14,58+/-0,9 Jahre). Methode: Die Spiegelwerte von K, Na, Cl, Ca und PO4 wurden in den Blutproben nach den EPTRV- und IFCC-Regeln gemessen. Die gewonnenen Angaben wurden als arithmetisches Mittel +/- Standardeviation ($\bar{X}$+/-SEM) ausgedrückt und sie wurden der ANOVA Faktorenanalyse unterzogen, damit die Bedeutung der festgestellten Unterschiede zur Geltung kommen konnte. Ergebnisse und Auswertung: Die Spiegelwerte der trainierenden Gruppe waren niedriger als bei nichttrainierenden Gruppe bei: K ($p<0,001$) (4,68+/-0,02 mmol/l zu 4,91+/-0,02 mmol/l), Na ($p<0,001$) (144,21+/-0,12 zu 146,17+/-0,21 mmol/l und Cl ($p<0,001$) (104,72+/-0,13 zu 108,45+/-1,27 mmol/l). Anderseits wurden höhere Spiegelwerte von Ca ($p<0,01$) und $PO_4$ ($P<0,05$) in den Blutproben der pubertierenden Leistungssportlern im Vergleich zu denen der Kontrollgruppe gemessen (2,40+/-0,01 zu 2.36+/-0,01 mmol/l bzw. 1,19+/-0,01 zu 1,15+/-0,02 mmol/l). Die niedrigsten K-Spiegelwerte kamen bei den Schwimmern vor -10,8/ unter dem in der Kontrollgruppe gemessenen Durchschnittswert ($p<0,001$) und dann in den Teilgruppen: Ringer bzw. Gewichtheber: -5,1% unter dem in der Kontrollgruppe gemessenen Durchschnittswert ($p<0,001$). Die Na-Spiegelwerte waren am niedrigsten bei den Schwimmern: -2,8% unter dem in der Kontrollgruppe gemessenen Durchschnittswert ($p<0,001$). Der höchste Ca-Blutserumspiegel wurde bei den Gewichthebern gemessen +4,4% über dem in der Kontrollgruppe gemessenen Durchschnittswert ($p<0,001$). Der $PO_4$-Werte waren bei den Schwimmern 14,8% höher von denen in der Kontrollgruppe gemessenen Durchschnittswert ($p<0,001$). Fazit: Ergebnisse dieser Untersuchung beweisen, dass das langzeitige leistungssportliche Training im Pubertätalter Homöostase der Serumelektrolyten beinflusst. Die Sportart beinflusst die Spiegelwerte von K, Na, Cl, Ca und $PO_4$ und ihre Veränderungen.

**Schlüsselwörter:** Training, Serumelektrolyten, Leistungssporler, Pubertät

## Exercise and serum electrolyte concentrations

Many studies suggest that intensive physical activity for a long period of time influences the serum electrolyte profile in adults. For example, a 4-week controlled physical training causes a significant decrease of serum calcium and magnesium concentrations and an increase of serum phosphate levels. The values change gradually to the initial after finishing the training program (Frank et al., 1991). Hong & Lien found that a 4-week endurance training (6 days a week) causes an increase of serum sodium and potassium levels, which they suggest as being associated with the increased amount of fluid losses during the training period (Hong & Lien, 1984). On the other hand, Crespo et al. compared the serum electrolyte concentrations in elite marathon runners and non-trained controls. No differences in serum Ca, $PO_4$, Mg, and Zn were found between the groups investigated (Crespo et al., 1995).

During recent years attention has been paid to the effects of the physical workload on the bone structure and metabolism of sportsmen. In this connection, the serum Ca and $PO_4$ concentrations were investigated at some length. For instance, Brahm et al. found decreased bone density and increased bone turnover rate associated with relatively high serum calcium concentrations in endurance runners compared with non-trained controls (Brahm et al., 1997). This is more expressed in young athletes and even a dietary supplementation with vitamin K is recommended in order to increase the Ca-binding capacity of the circulating bone protein osteocalcin (Craciun et al., 1998). The serum concentration of inorganic phosphorus is of great importance for sportsmen because it is well-known that the hypophosphatemia influences unfavourably the muscle metabolism, and in particular, the glyconeogenesis during a physical workload (Haglin & Essen-Gustavsson, 1992).

Karlsson et al. compared the serum calcium concentrations in present and in former weight lifters. They found that these levels were higher in present ones (Karlsson et al., 1995). However, there is a regularity, according to which, the dietary calcium intake is directly proportional to the physical workload which can explain, to a certain extent, the hypercalcemia found in these cases (Fogelholm et al., 1992).

In literature, studies on the influence of acute exercise on the serum electrolyte status of adult sportsmen are predominant. Similar studies have been performed on experimental animals as well. In endurance horses, for example, a distinguished electrolyte deficit was found, which even required NaCl and KCl dietary supplementation (Rose, 1990).

Buchman et al. found changes in the serum of Ca, Zn, and Cu levels after marathon running, and the Mg change is so significant that it can be assessed as Mg-deficit (Buchman et al., 1998). On the other hand, after an ultra-triathlon, an expressed hyponatremia can be observed (Speedy et al., 1997). Nevertheless, Noakes et al. consider that the NaCl losses during long-lasting physical workload are far from these which have been assumed recently (Noakes et al., 1990). This statement is sustained by the results obtained from some studies on marathon and ultra-marathon runners, where the decrease of serum Mg is accompanied by an increase of serum Na and a slight increase of K concentrations (Cohen & Zimmermann, 1978; McKechnie et al., 1982). In addition, after performing the Wingate test, only ionized Ca and blood lactate, but not the total Ca, were increased (Kristoffersson et al., 1995).

In short, all the data mentioned above concern serum electrolytes in adult athletes and furthermore, no studies on the effects of long and intensively practised sport on the serum electrolytes of pubescent athletes were found.

## The aim of the study

The aim of the study was to assess the basal serum concentrations of the electrolytes - sodium (Na), potassium (K), chloride (Cl), calcium (Ca) and phosphate ($PO_4$) in highly trained pubescent sportsmen of different sports and to compare the results obtained with the basal electrolyte concentrations of a control, non-trained pubescent group.

*Table 1: General characteristics of the highly trained and the non-trained (control) groups (mean±SEM)*

| PARAMETER | HIGHLY TRAINED GROUP (n=545) | NON-TRAINED GROUP (n=348) | DIFFERENCE OF MEANS |
|---|---|---|---|
| 1. AGE (years) | 14.01±0.06 | 14.58±0.09 | not significant |
| 2. WEIGHT (kg) | 56.24±0.52 | 57.75±0.67 | not significant |
| 3. HEIGHT (cm) | 165.51±0.44 | 166.09±0.54 | not significant |
| 4. SPORTS PRACTISE (years) | 3.44±0.06 | - | 0.001 |

## Material and methods

*Subjects:* 845 highly trained athletes (539 boys and 306 girls) from the sports school in Bulgaria were recruited for the study. The subjects were 14.01±0.06 years old, 165.51±0.44 cm in height, weighed 56.24±0.52 kg, and had sports practise of 3.44±0.06 years (all values mean ± SEM) - Table 1.

They were allocated to seven subgroups according to the sport they practised: track-and-field athletes (103), swimmers (105), rowers (224), boxers, wrestlers, and judoists (215), weight lifters (47), players in sport games (89), and other sports - gymnasts, rhythmic gymnasts, acrobats, table tennis players, and court tennis players (62).

The control group consisted of 348 untrained young people (168 boys and 180 girls) matched for age, weight and height (14.58±0.09 years, 57.75±0.67 kg, 166.09±0.54 cm) - Table 1. During their sport practise the athletes trained five days per week for 90 minutes twice a day. The physical activity of the control group was 90 minutes (two 45 minute periods) per week - doing moderate intensity exercise in the classes of physical culture at school.

*Serum electrolyte concentrations:* Venous blood samples were drawn from the cubital vein between 7:00 and 9:00 in the morning in accordance with the EPTRV and IFCC rules, after 48h rest following the last training bout. The samples were obtained and collected using Sarstedt (Germany) closed system needles and tubes. The serum sodium, potassium and chloride concentrations were determined by ion-selective electrodes on 2+3 ion-selective analyser Microlyte 3 (Kone, Finland). Calcium and phosphate concentrations were measured using the chemical analyser Kone (Finland) as follows Ca - by the colour reaction with Arsenazo III in neutral pH of the medium, at 660 nm; $PO_4$ - by the colour reaction with amonium molybdate with a UV-finish at 340 nm.

*Statistics:* Statistical indices were computed for each group and for all parameters (StatView 4.51 statistical software, Abacus Concept Inc., U.S.A.). ANOVA-factorial analysis was used to evaluate the significance of the differences. All data were presented as mean ± SEM.

*Table 2. Basic serum electrolyte concentrations (mmol/l) in the highly trained and the non-trained (control) groups (mean±SEM)*

| PARAMETER | HIGHLY TRAINED GROUP (n=545) | NON-TRAINED GROUP (n=348) | DIFFERENCE OF MEANS |
|---|---|---|---|
| 1. Potassium (K) | 4.68±0.02 | 4.91±0.02 | 0.001 |
| 2. Sodium (Na) | 144.21±0.12 | 146.17±0.21 | 0.001 |
| 3. Chloride (Cl) | 104.72±0.13 | 108.45±1.27 | 0.001 |
| 4. Calcium (Ca) | 2.40±0.01 | 2.36±0.01 | 0.01 |
| 5. Phosphate ($PO_4$) | 1.19±0.01 | 1.15±0.02 | 0.05 |

*Table 3. Serum electrolyte concentrations (mmol/l) in the highly trained subgroups and in the non-trained (control) group (mean±SEM)*

| SUBGROUPS | K | Na | Cl | Ca | P |
|---|---|---|---|---|---|
| 1. Athletics | 4.75±0.06 | 144.10±0.36 | 103.60±0.42 | 2.43±0.01 | 1.14±0.02 |
| 2. Swimming | 4.43±0.04 | 142.91±0.37 | 105.29±0.38 | 2.38±0.02 | 1.32±0.02 |
| 3. Rowing | 4.69±0.04 | 145.04±0.25 | 104.74±0.24 | 2.39±0.01 | 1.12±0.01 |
| 4. Wrestling | 4.67±0.04 | 143.81±0.23 | 105.22±0.23 | 2.36±0.02 | 1.23±0.01 |
| 5. W.-lifting | 4.67±0.06 | 145.57±0.49 | 105.45±0.50 | 2.47±0.03 | 1.21±0.04 |
| 6. Games | 4.86±0.07 | 144.63±0.30 | 104.86±0.32 | 2.43±0.02 | 1.16±0.03 |
| 7. Others | 4.73±0.06 | 143.40±0.38 | 103.26±0.42 | 2.40±0.02 | 1.15±0.02 |
| 8. Controls | 4.91±0.02 | 146.17±0.21 | 108.45±1.27 | 2.36±0.01 | 1.15±0.02 |

## Results and discussion

The trained group manifested lower ($p<0.001$) basic serum K concentration than the non-trained one (4.68±0.02 mmol/l vs. 4.91±0.02 mmol/l), lower ($p<0.001$) basic Na concentration (144.21±0.12 vs. 146.17±0.21 mmol/l), and lower ($p<0.001$) basic Cl concentration (104.72±0.13 vs. 108.45±1.27 mmol/l). On the other hand, it was found that the basic serum Ca levels were higher ($p<0.01$) in the blood samples obtained from the highly trained group (2.40±0.01 vs. 2.36±0.01 mmol/l). The same relation ($p<0.05$) was found for the basic serum phosphate concentrations (1.19±0.01 vs. 1.15±0.02 mmol/l) - Table 2.

Table 3 presents the results from the serum electrolyte concentrations of the blood samples obtained from the sportsmen's subgroups and from the non-trained (control) group.

*Potassium concentrations:* It was found that with the exception of the sportsmen practising games, all other pubescent sportsmen had significantly lower basal K concentrations than the control group. Swimmers had the lowest levels - 10.8% below the controls, followed by the wrestlers and weight lifters - 5.1% , and rowers - 4.7% below the controls ($p<0.001$). With a relatively little, but significant difference below the controls were the basal K levels of the sportsmen practising other sports (3.8% below controls, $p<0.05$), and track-and-field athletes (3.4% below controls, $p<0.01$). No difference was found between sports games players and non-trained controls. The distribution of the K concentrations in the respective subgroups is presented in Figure 1.

*Figure 1: Distribution of K serum concentration values in the subgroups in comparison with the control group*

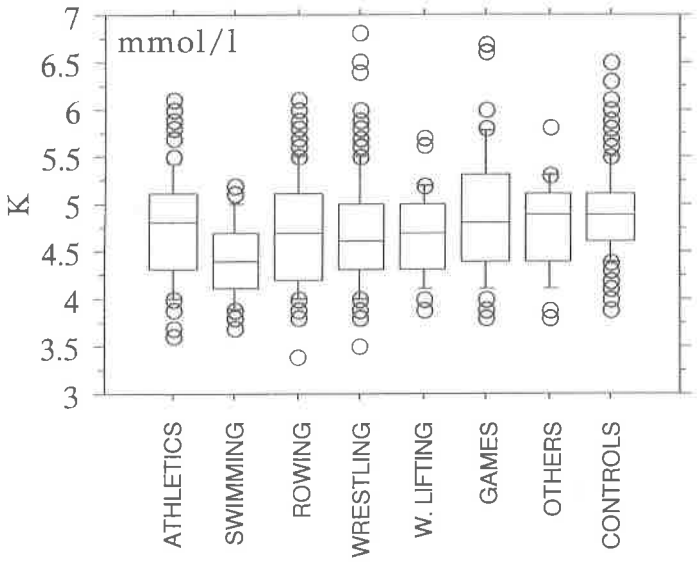
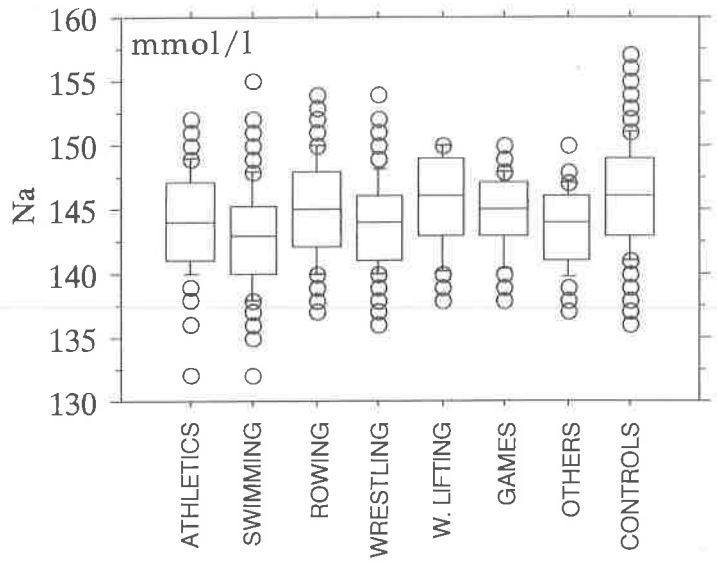


*Figure 2: Distribution of Na serum concentration values in the subgroups in comparison with the control group*




It was evident that the values were in referent value ranges in all subgroups investigated. ANOVA-factorial analysis showed that the long-lasting sports practise influences ($p<0.001$) the serum potassium levels during pubescence.

*Serum sodium concentrations:* The lowest basal Na levels in the serum were found in the blood samples obtained from the pubescent swimmers - 2.3% below the control group ($p<0.001$). 1.9% below the controls was the Na concentration of the pubescent sportsmen practising other sports ($p<0.001$), 1.6% - the wrestlers ($p<0.001$), and 1.4% - the track-and-field athletes ($p<0.001$). These three subgroups did not differ between them. On the other hand, the weight lifters did not differ from the control group. The ranges in all subgroups were found in referent value ranges. The distribution of the values is presented in Figure 2. From the data obtained from ANOVA-factorial analysis we can conclude that the actual sport is able to influence the serum Na levels during pubescence.

*Figure 3: Distribution of Cl serum concentration values in the subgroups in comparison with the control group*

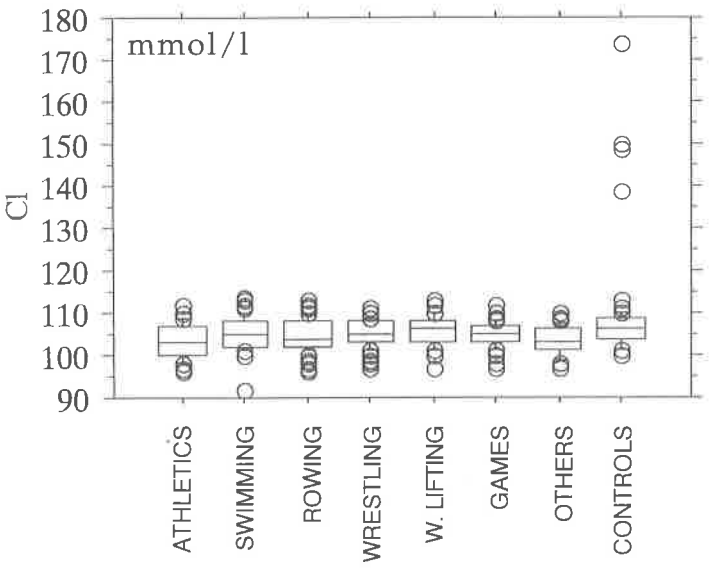
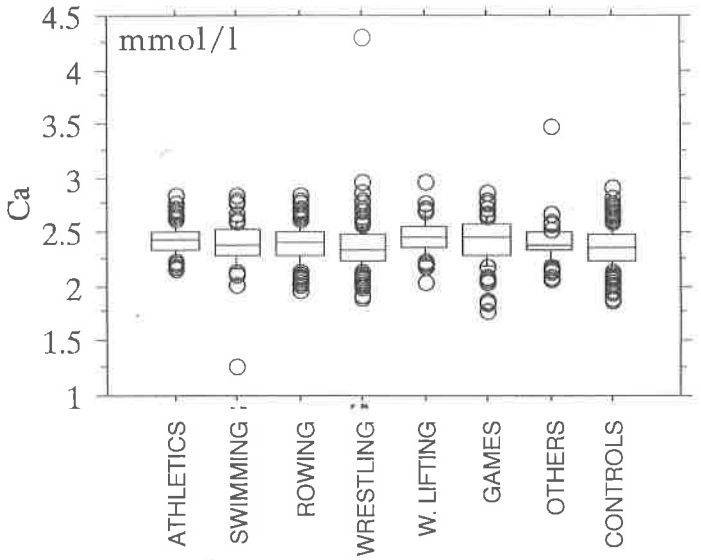


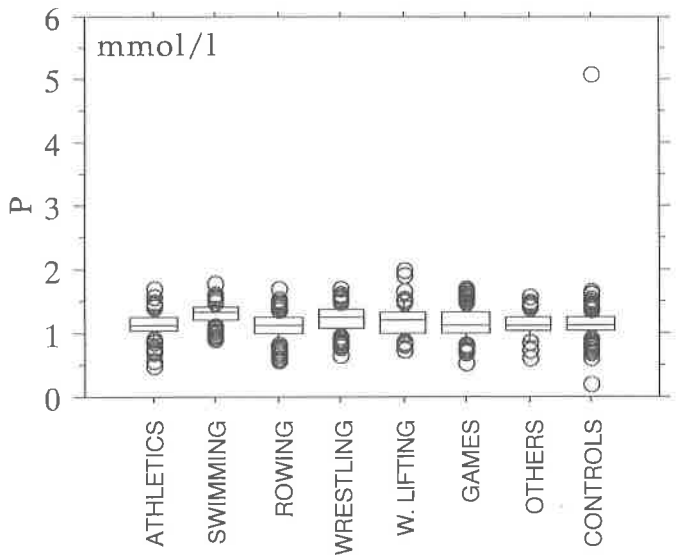
*Figure 4: Distribution of Ca serum concentration values in the subgroups in comparison with the control group*




*Serum chloride concentrations:* The lowest basal serum chloride was found in the track-and-field athletes (4.7% below the Cl in controls, $p<0.001$) and in the pubescent sportsmen practising other sports (5.0% below the control, $p<0.001$). The sports games players and rowers had higher basal serum Cl levels, compared with the above mentioned subgroups ($p<0.05$), but significantly lower, when compared with the non-trained controls ($p<0.001$). Nevertheless, the highest Cl was found in the swimming, wrestling and weight lifting subgroups, these values were significantly lower ($p<0.001$) than in the control group. All values were found in the referent value ranges. Their distribution is presented in Figure 3. ANOVA-factorial analysis showed that the factor 'type of sport' is able to influence ($p<0.001$) the serum Cl levels during pubescence.

*Serum calcium concentrations:* There was no difference between the values of this parameter in the swimmers, wrestlers, and sportsmen practising other sports on one hand, and the non-trained controls on the other. 2.9% above the controls ($p<0.001$) was

*Figure 5: Distribution of $PO_4$ serum concentration values in the subgroups in comparison with the control group*



the basal serum Ca of the track-and-field athletes. The highest Ca was registered in the weight lifting subgroup (4.4% above the non-trained controls, $p<0.001$). All calcium values were in the referent value ranges and are presented in Figure 4. It was evident from the ANOVA-factorial analysis performed that the basal serum Ca concentrations were influenced by long-term habitual intensive sports training.

*Serum phosphate concentrations:* There were no differences between the values of this variables in the athletics, rowing, weight lifting, sports games, and other sports subgroups on the one hand, and the control group on the other. The swimmers and wrestlers had higher ($p<0.001$) basal serum phosphate than the controls. In blood samples obtained from the swimmers, for example, the basal $PO_4$ was 14.8% higher than in the control group, but from wrestlers - 7.0% higher than the controls. On the other hand, the serum $PO_4$ concentration in the swimmers were 7.8% above the $PO_4$ concentrations in wrestlers ($p<0.01$). The distribution of this parameter in the subgroups investigated is shown in Figure 5. The factor 'sport practised' evidently influenced the serum $PO_4$ concentrations as well.

The investigation of the causes generating the differences obtained in the basal serum electrolyte concentrations in pubescent sportsmen practising different sports was not the aim of this study. But these differences were not due to hemodilution or hemoconcentration for which specific clinical laboratory signs were not found in the study.

## Conclusions

The evidence of this study suggests that long-lasting, high-intensive sports training during the age of pubescence affects the basal serum electrolyte homeostasis.

The type of the sports practised during pubescence is important for the degree of deflection in potassium, sodium, chloride, calcium, and phosphate basal serum concentrations when compared with the respective concentrations in the control non-trained pubescent subjects.

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