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ORIGINAL ARTICLE

Effects of a paddle match on the urinary excretion of trace minerals in high-level players

Effets d'un match de padel sur l'excrétion urinaire des mineraux trace dans les joueurs de haut niveau

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Summary
Purpose. — Trace elements are micronutrients involved in the maintenance of an optimum physiologic state which allows paddle players, a sport little studied until now, to have an adequate performance.
Methods. — Seven urinary trace elements of 16 male high-level players were analyzed using ICP-MS chromatography before and after a paddle competition match. To contrast the results, *t*-Student and Wilcoxon tests were used.
Results. — Copper (Cu), nickel (Ni) and zinc (Zn) increased significantly its urinary excretion ($P < 0.05$). No changes in arsenic (As), molybdenum (Mo) and selenium (Se) were observed and lithium (Li) decreased its values significantly ($P < 0.05$) after the effort.
Conclusions. — The acute effect of a high-level paddle match is not entirely clear, since it has heterogenic effects on the minerals excretion: the biological elimination of some metals involved in antioxidant and energetic functions increased, which seems to indicate a rise in its organic metabolism, whereas other minerals did not seem to be affected by this type of efforts. Li excretion decreased, which might be a sign of a homeostatic retention process of this element.
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MOTS CLÉS
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Résumé
Objet. — Les minéraux trace sont des micronutriments impliqués dans le maintien de l'état physiologique optimal qui permet aux joueurs de padel, un sport peu étudié à ce jour, de développer et maintenir la performance physique adéquate.
Méthode. — Sept éléments trace urinaires provenant de 16 joueurs masculins de haut niveau ont été analysés par chromatographie ICP-MS avant et après un match de compétition. Pour comparer les résultats de l'essai *t*-Student et Wilcoxon ont été utilisés.
Résultats. — L'excrétion urinaire de cuivre (Cu), nickel (Ni) et zinc (Zn) a augmenté significativement ($p < 0,05$). Dans les cas de l'arsenic (As), le molybdène (Mo) et le sélénium (Se) aucun changement survenu ; et dans le cas du lithium (Li) il y avait une diminution significative ($p < 0,05$) pour l'élimination après la fin de l'effort.
Conclusions. — L'effet aigu d'un match de padel de haut niveau n'est pas clair, car il produit des effets hétérogènes sur l'excrétion minérale : l'élimination biologique de certains minéraux impliqués dans les fonctions antioxydants et énergétiques a augmenté, ce qui suggère une augmentation dans le métabolisme organique, tandis que d'autres minéraux ne semblent pas être affectés par ces efforts. La diminution de l'élimination du lithium pourrait être un signe d'un processus de rétention homéostatique de cet élément.
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1. Introduction

Paddle tennis is a relatively recent sport, an implement collaboration—opposition game. It is played on specific 10 m wide and 20 m long courts, divided by a tennis net in the middle with specific areas similar to those in a tennis court. Specific characteristics of paddle courts have just been identified [1,2]. There are two pair teams playing on rotation in separate spaces. It is similar to tennis in the score system, but different to it in its structural elements. A distinctive characteristic of this sport is the implement used: a specific racket which differs from the one used in tennis and badminton. More specific characteristics of paddle rackets were described by Carrasco et al. [1]. Its main game features and the relevant increase in its practice have already been analyzed and described in previous surveys [1]. Since there is little research on paddle in current scientific publications, it is necessary to deepen in the relevant factors of the game in order to improve its teaching, learning and training processes.

Exploratory studies predominate in current literature about paddle temporal structure, external charge and internal charge. Currently there are very few international papers which analyze this sport. Besides, the main percentage of paddle data comes from national studies, since paddle tennis is still an unknown investigation matter in international literature. Nevertheless, there is a recent review on paddle research which recompiles information about this sport [3].

It has not been found yet any previous complete data sets about its structure and game characteristics, so a compilation of paddle matches characteristics has been collected in the present document to analyze the main structural and physiological characteristics of this sport.

Paddle temporal structure data is collected in Table 1. Paddle tennis is an intermittent sport, whose game system allows the distribution of effort and recuperation times alternatively in the different match games and sets.

Certain homogeneity at effort times can be observed at points, games and sets times. However, different previous surveys showed that recuperation times were not homogeneous in their duration or distribution. In the analyzed publications, there is no information about the causes of these differences beyond those due to the intrinsic and individual features of every match.

If this temporal structure data is compared with data from other sports, it can be observed that the percentage of effort time during paddle matches is higher than during tennis matches [4,5] with similar total game [6] and total rally [5,7] times. In the case of squash, it has been observed higher rally times [8] and similar recuperation times within rallies [1,8].

Other external charge factors are movements and motor actions. Table 2 shows data of movement types, their intensity and volume. This data has been compiled from other previous surveys [9—11].

Similar displacement intensity has been observed in tennis and paddle [12]. Also, and considering the difference between the courts sizes, similar distances per game in both sports have been found [10]. However, it has been reported a different displacement pattern in tennis [11].

Internal charge includes three physiologic parameters: heart rate (HR), oxygen uptake (VO_2) and blood lactate concentrations. Table 3 collects data of physiological parameters obtained both in laboratory and real paddle game situations.

It can be stated that energy requirements in terms of VO_2 in paddle are close to those described previously in tennis [1,13,14], but lower than in squash [8]. Slightly upper mean HR values have been registered in tennis [15] and higher HR max values in tennis court situations [14]. In competition squash, HR mean and HR max values are sensibly higher than in tennis and paddle [16]. Anaerobic metabolic systems seem to develop similar roles in tennis and paddle due to the fact that similar lactate concentrations have been registered in both sports [5,17—20], however, squash lactate values are higher than in the two previous ones [21].

From a physiologic perspective, paddle can be classified as a high intensity intermittent sport (HIIS). An important feature of sports of this type is the ''repeated-sprint-ability'' (RSA) that is to say, the capacity to perform high intensity efforts (sprints) intermittently. From an energy requirement point of view, RSA differs from the traditional outline of cyclical sports and seems to depend on a complex interaction of the three systems to obtain energy [22], consequently, the player will have to move in very short time periods with continuous direction and speed changes, using energy of ATP-PC and anaerobic metabolic tracts in the high intensity activities of 10 seconds or less duration [23], and aerobic metabolic tracts in low intensity and recuperation phases, which, as Table 3 shows, are more than 60.3 ± 15.5% of total time game. Thus, the correct energetic regulation of the metabolic systems will be a critical factor in the physical performance of paddle players.

This regulation is strongly related to several trace minerals. There are two general functions which convert minerals into necessary substances for high-level physical practice and which justify metals relevance in these type of sports: The first one is their critical role in energetic metabolism regulation processes; deficiency of certain minerals may cause some adverse effects on the human organism since these aversions may impair the physical exercise capacity and cause serious consequences among high-level athletes [24].

The second essential function of trace minerals is the capacity to get involved in antioxidant processes with different roles; during the exercise, free radicals production and oxidative stress increase drastically causing cells damage. To prevent this damage, the human organism has an antioxidant system which depends on the endogenous production of antioxidant compounds and on the daily intake of antioxidant substances like minerals [24–26].

Can be affirmed that the regulation of the biological mineral ranges is necessary, especially in the high-level sport performance cases; if optimal ranges are altered, harmful physiological alterations can be caused. These alterations can appear both due to conditions of deficiency and, in the case of toxic minerals, to an increase in optimal levels. For this reason, the organic mineral quantification is necessary to guarantee an optimal sport performance from a physiologic point of view and to avoid possible health contraindications as a consequence of overtraining.

In the present study seven trace minerals have been studied; Five essential trace elements with tested essentiality functions: copper (Cu), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn) and two essential minerals classified as elements with suspected essential functions but with an unknown action mechanism: arsenic (As) and lithium (Li) [27,28].

The aim of this research is to test the acute effect of a competition paddle match on the urinary excretion of seven essential trace minerals.

2. Material and method

2.1. Participants

Sixteen male local high-level paddle players took part in the present study. All of them were ranked among Extremadura's top 20 players. Their characteristics were: age: 25.83 ± 5.15 years, height: 179.11 ± 4.05 cm, weight: 75.36 ± 5.76 kg and 23.59 ± 1.73 kg/m^2 BMI. All of them accepted their voluntary participation.

This research was carried out following the Helsinki Declaration ethic guidelines, actualized in World Medical Assembly in Seoul 2008, for the human's investigation.

2.2. Sample collection

Urine samples were taken before and after 2013 Extremadura's absolute championship quarterfinal matches. The total number of matches where urine samples were collected was four. The matches started at 11 am and had an average duration of 86.40 ± 37.77 min with an average of 19.2 ± 3.27 games per match. The court was indoor with stable conditions of temperature (between 24 and 26 °C) and humidity (45 ± 5%). The urine samples were all taken in only one day, the first sample was taken 30–45 min before

Table 1 External charge parameters based on paddle temporal structure.

Duration (s)	Carrasco et al. (2011) [1]	Almonacid (2012) [9]	Amieba and Salinero (2013) [10]	Sánchez-Alcaraz (2014) [32]	Pradas et al. (2014) [49]
Point	$7.24 \pm 8 \times 10^{-4}$	14.65 ± 2.35	–	11.62 ± 10.29	–
Recuperation P	$9.11 \pm 3 \times 10^{-4}$	–	–	24.67 ± 25.26	–
Game	163.06 ± 3.04	–	159 ± 38.2	–	197 ± 25
Recuperation G	$73.40 \pm 7.1 \times 10^{-3}$	–	–	–	–
Set	–	948.54 ± 338.82	–	674.48 ± 215.66	–
Recuperation S	–	932.65 ± 317.21	–	1431.82 ± 507.70	–
Total S	–	–	–	2105.53 ± 723.37	1788 ± 35
Match	–	–	–	–	–
Recuperation M	–	–	413 ± 96.2	–	–
Total time	–	–	2935 ± 493	–	3371 ± 38

Point: effort time in a point; Recuperation P: recuperation time between points; Game: effort time during a game; Recuperation G: recuperation time during a game; Set: effort time during a set; Recuperation S: recuperation time during a set; Total S: total time of set; Match: effort time during match; Recuperation M: recuperation time during the match; Total time: total game time in the match.

Table 2 External charge parameters based on actions and movements in paddle.

Number of strokes per point	8.62 ± 1.80
Number of strokes per set	562.54 ± 226.71
Distance per game (m)	111 ± 24.6
Distance per set (m)	1026 ± 163
Distance per match (m)	2052 ± 327
Average speed (km/h)	2.59 ± 0.40
Maximum speed (km/h)	15.4 ± 1.58
% of distances	
0—3 km/h	32.64
3—6 km/h	47.86
6—9 km/h	14.46
9—12 km/h	4.3
12—15 km/h	0.6
> 15 km/h	0.11
% of sideways movements	52.31
% of forward movements	43.29
% of backward movements	4.40

the corresponding matches, and the second sample was the first urinary excretion after the matches. During the championship and sample collection periods, players did not take any isotonic drinks, food or supplements. These urine samples were collected in 10 mL urine vials and were conserved at −40 °C conditions until their biochemical analysis.

2.3. Urinary concentrations determination

ICP-MS was used to determine As, Cu, Li, Mo, Ni, Se and Zn in urine samples [29,30]. Decomposition of the organic matrix was performed by heating it during 10 h at 90 °C after adding 0.8 mL of nitric acid (HNO_3) and 0.4 mL of hydrogen peroxide (H_2O_2) to 2 mL of urine. The samples were then dried at 200 °C on a hot plate. Samples reconstitution was carried out by adding 0.5 mL of HNO_3, 10 μL of indium (In) (10 mg/L) as internal standard and ultrapure water until getting 10 mL. Reagent blanks (∼1 g of deionized water), element standards and certified reference material (Seronorm™ Trace Elements Urine REF 201205, LOT NO2525 from SERO AS, Billingstad, Norway and Seronorm™ Trace Elements Serum L-1 & L-2 SERO AS Billingstad, Norway) were prepared in the same way and used for accuracy testing. Before the analysis, the commercial control materials were diluted following the manufacturer recommendation. Digested samples in open version (completely clear, colorless, and homogenous solutions) were assayed using an ICP-MS NexION model 300D (PerkinElmer, Inc., Shelton, CT, USA) equipped with a triple quadrupole mass detector and a reaction cell/collision, which allows operation in three modes: no reaction gas (STD), kinetic energy discrimination with helium as the collision gas (KED) or reaction with ammonia as the reaction gas (DRC). Both collision and reaction gases such as argon plasma have a purity of 99.999% and were supplied by Praxair (Madrid, Spain). Gas flows are regulated by two mass flow controllers. The frequency generator is free-swinging and works at 40 Mhz. Three replicates per sample were analyzed. Quantification was performed by In as internal standard. The values of the standard materials of each element (10 μg/L) measured for quality controls were in good agreement with intra and inter-assay variation coefficients of less than 5%.

2.4. Creatinine determination

Creatinine concentrations were measured in all urine samples to take into account the different degree of dilution

Table 3 Paddle internal charge parameters.

Laboratory parameters	Carrasco et al. (2011) [1]		Pradas et al. (2014) [49]
VO_{2max} ($mLkg^{-1}min^{-1}$)	55.64 ± 8.84		47.33 ± 4.57
HR_{max} (ppm)	200.43 ± 15.76		186 ± 5.13
Blood Lactate (mmol/L)	—		11.68 ± 2.14
Real game parameters	**Carrasco et al. (2011) [1]**	**Amieba and Salinero (2013) [10]**	**Pradas et al. (2014) [49]**
Minimun HR (bpm)	—	85.6 ± 22.4	125 ± 9.45
Average HR (bpm)	148.3 ± 16.63	136 ± 9.04	151 ± 8.13
Maximun HR (bpm)	169.72 ± 18.41	176 ± 9.20	177 ± 9.31
% of HR			
0—120 ppm	—	18.4 ± 16.7	—
120—150 ppm	—	60.3 ± 15.5	—
150—170 ppm	—	19.7 ± 15.8	—
170—180 ppm	—	1.36 ± 1.83	—
180—190 ppm	—	0.13 ± 0.24	—
Initial blood lactate (mmol/L)	—	1.9 ± 0.57	1.36 ± 0.33
First set ending blood lactate (mmol/L)	—	2.31 ± 1.32	1.83 ± 0.31
Second set ending blood lactate (mmol/L)	—	2.88 ± 1.32	—

Table 4 Trace minerals in urinary concentrations before and after a paddle match efforts.

	Pre	Post
As (μg/L)	56.91 ± 60.14	52.65 ± 48.82
(μg/g creatinine)	80.15 ± 194	55.42 ± 113.53
Cu (μg/L)	11.40 ± 4.43	17.28 ± 10.61[a]
(μg/g creatinine)	16.05 ± 14.29	18.19 ± 24.67[a]
Li (μg/L)	61.39 ± 71.35	46.96 ± 63.30[b]
(μg/g creatinine)	86.46 ± 230.16	49.43 ± 147.20[b]
Mo (μg/L)	66.96 ± 34.25	71.62 ± 45.08
(μg/g creatinine)	94.30 ± 110.48	75.38 ± 104.84
Ni (μg/L)	1.71 ± 2.45	3.49 ± 4.67[b]
(μg/g creatinine)	2.40 ± 7.90	3.67 ± 10.86[b]
Se (μg/L)	34.40 ± 15.65	45.53 ± 25.98
(μg/g creatinine)	48.45 ± 50.48	47.92 ± 60.41
Zn (μg/L)	356.73 ± 310.39	560.18 ± 311.36[a]
(μg/g CREATININE)	501 ± 1001.25	589.47 ± 724.09[a]

[a] *t*-student ($P < 0.05$).
[b] Wilcoxon ($P < 0.05$).

[31] using Sigma's Creatinine 555 — A kit and a UNICAM 5625 spectrophotometer.

2.5. Statistical analysis

The statistical analysis was carried on with IBM SPSS Statistic software version 19 for Windows. Kolmogorov-Smirnov and Rachas tests were used to contrast the normality and randomness hypotheses. The differences in pre and post urinary concentrations were analyzed using Wilcoxon test for non-parametric variables and *t*-Student test for parametric variables. The results are expressed as mean ± standard deviation (mean ± s); $P < 0.05$ random differences were considered statistically significant.

3. Results

First of all, urinary creatinine concentrations do not suffer significance changes after paddle match efforts (0.95 ± 0.43 g/L) with respect to initial values (0.71 ± 0.31 g/L). Creatinine values are used to correct analyte concentration variations in the urine samples. Obtained values were normal in male's ranges.

Trace elements urinary concentrations are expressed with and without creatinine correction before and after paddle match efforts.

As it can be observed in Table 4, there are significant changes ($P < 0.05$) in Cu, Ni and Zn values, which increase regarding their initial levels, and in the case of Li, whose values decreased.

4. Discussion

Trace minerals metabolization and excretion rates can be affected by the intensity and volume of the exercise practiced, especially in minerals involved in energetic and antioxidant systems. The matches performed by the paddle players studied had an average 86.4 ± 37.77 min duration of interval exercise with lower real effort time and frequent recuperation times between efforts [1,10,32,33]. All matches were played in the last rounds of the regional absolute championship (quarterfinals), so the matches intensity was high, with an average 19.2 ± 3.27 games per match.

Copper (Cu) experimented a significant increase ($P < 0.05$) in comparison with its initial urinary levels. Since this mineral is involved in antioxidant and energetic metabolic tracts [24,26,34,35], the rise in Cu excretion may indicate an increase in the organic process to metabolize this mineral to balance this rising process in the energetic and antioxidant demands as a consequence of an acute physical effort.

Recent findings suggest that these urinary changes are related to the type of exercise, being greater in those physical practices with high impact on muscular tissues [36]. In this sense, paddle is an activity involving frequent mechanical impact due to jumps, turns and explosive actions (Table 2). This fact could explain this significant increase ($P < 0.05$) after the matches (18.19 ± 24.67 μg/g creatinine).

Lithium (Li) experimented a significant decrease ($P < 0.05$) in its final concentrations (49.43 ± 147.20 μg/g creatinine) regarding its initial levels (86.46 ± 230.16 μg/g creatinine) after an acute effort. This fact is crucial because Li is intimately related to energetic metabolism and to the regulation of the adequate function of several biological systems, some of them, like the hormonal system, directly linked to physical activity, so its deficiency may affect negatively to both systems [35]. This significant lessening may indicate a biological retention process of this mineral in the organism to avoid its lack and to ensure an optimal development of protein metabolism and endocrine, cardiovascular, neuromuscular, renal and dermatological systems [37], as well as hormonal, metabolic, neurologic and immunologic processes [38].

Although a clear organic response to an acute effort can be observed, Li's behavior is not entirely clear and it is impossible to draw consistent conclusions, since it would be necessary to know the blood, serum and erythrocyte levels of this mineral before and after performing the efforts.

Nickel (Ni) increased significantly ($P < 0.05$) in final levels (3.49 ± 4.67 μg/g creatinine) in comparison with its initial concentrations (1.71 ± 2.45 μg/g creatinine). Other researchers described Ni as an indirect regulator of lipids' metabolism, and reported that Ni deficit can disturb it [39]. It has also been reported Ni's role as an activator of several enzymes [40], there is, therefore, a true relationship between physical practice and this mineral.

Urinary Ni concentration is markedly lower than its tissue concentrations where levels ascend up to 88 μg/kg [41], which may indicate a scarce Ni's mobilization in the circulatory stream when facing physical stress. This idea is reinforced by other surveys which reported lower concentrations in fluids (2.3 μg/L in blood; 1.2 μg/L in serum and 0.9 μg/L in urine) [42]. The urinary concentrations of paddle players are higher than the data obtained in those studies, and it could be due to the fact that the urine samples were taken after the acute effort and, accordingly, to the effects produced by the catabolism process in the excretion of several substances, like these minerals. Despite this, Ni urinary levels are infinitesimally lower than its tissue

concentrations; this seems to show that Ni is involved in muscles and organic tissues acting locally.

Finally, the results obtained show a significant increase ($P < 0.05$) in zinc's (Zn) urinary excretion after a high-level competition paddle match (589.47 ± 724.09 μg/g creatinine) on regard to its initial concentrations (501 ± 1001.25 μg/g creatinine).

Zn develops role as an antioxidant [26,43,44]. Furthermore, Zn plays an important function in lipid, protein and carbohydrate metabolisms [45]. One of the principal Zn storage in human organism is the skeletal muscle [27] and Zn concentration depends on the muscle's functional activity [45]. It has been reported a rise in Li serum concentration to increase the bioavailability of this mineral to supply the exercise's demands [45]. This increase could be the reason of its increment in urinary excretion, due to the exercise's catabolism. Previous investigations reinforced this idea because it has been observed a quick serum level decrease as a consequence of a high urinary excretion among other factors [46].

A survey among athletes reported a significant increase ($P < 0.05$) in Zn excretion after a six months' endurance training program [45]. These athletes showed urinary concentrations widely lesser (264.75 ± 200.85 μg/g creatinine) than those in paddle players (589.47 ± 724.09 μg/g creatinine). If paddle players urinary Zn concentrations are compared with data obtained from German (269 μg/L) [47] and American (301.4 ± 253.9 μg/L) [48] sedentary population we can observe remarkable differences, because in paddle players the excretion is higher than in those analyzed in other populations.

The explanation of this fact can be based on two possible factors; the first one is the diet. Zn intake and, consequently, Zn excretion can vary with the type of food consumed, because, as some authors have pointed out, one of its principal exposition routes is the diet [39]. The second one is the moment the urine samples were taken because in the case of the athlete's urine analysis, the samples were taken before the effort test [45] and, in the case of the paddle players, the urine samples for the analysis were picked up after the acute effort, with the consequent action of catabolism after an acute effort in the excretion of antioxidant and energetic substances like Zn.

It can be deduced from the previous information that the importance of having optimum trace mineral concentrations in paddle player's bodies resides in assuring a suitable development and maintenance of all metabolic systems in which these essential elements are involved, some of them critically important in the practice of paddle, like energetic and antioxidant ones, due to the marked aerobic energetic base of this sport. This idea has been reinforced by the results obtained in the present survey, in which the excretion increment was a direct consequence of paddle competition matches internal charge.

5. Conclusions

The conclusions that can be drawn from this research are the following: high-level competition paddle matches provoke heterogeneous effects on the excretion of some urinary trace minerals; the metabolic processes of copper (Cu), nickel (Ni) and zinc (Zn) increase as a consequence of their participation in energetic and antioxidant systems when performing this type of efforts; arsenic (As), molybdenum (Mo) and selenium (Se) seems to undergo no changes because of high-level competition paddle matches and, finally, lithium (Li) seems to be a mineral of special organic interest among paddle players, since it increases its organic retention to ensure the correct development of vital functions in which Li takes part.

Disclosure of interest

The authors declare that they have no competing interest.

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