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RENAL RESPONSE TO A HANDBALL MATCH PLAYED IN A HOT ENVIRONMENT BY DIVISION 1 OF FEMALE PLAYERS OF BENIN REPUBLIC

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ABSTRACT

This casual comparative study aims at evaluating the changes of renal parameters during a championship handball match played in the heat, in 13 senior female players (Age: 5.6 ± 5.7 years; Weight: 56.4 ± 6.0 kg; Height: 165.6 ± 5.2 cm) of an amateur team (Division I) of Benin Republic. The team was divided into two groups of Starters (ST: N = 7) and Nonstarters (NS: N = 6). The glomerular filtration rate (eGFR) estimated from two formulas (C-G and MDRD) based on serum creatinine, the fractional sodium excretion (FeNa), the urinary sodium and potassium ratio (Na/K), the hemoglobin (Hb) and hematocrit (Hte) rates were assessed before, at the end and 26 hours after the match. At the end of the match, the eGFR decreased significantly in ST (C-G: -16.5%; MDRD:-18.8%, $p < 0.05$) but not in NS ($p > 0.05$). Twenty-six hours after the match, the eGFR from C-G and MDRD increased by more than 18.6% in ST, and more than 13.7% in NS ($p < 0.05$), while the FeNa decreased respectively by 85.9% ($p = 0.04$) and 88.8% ($p = 0.02$) in the two groups. At different times of measurement, the Na/K has not varied in any group ($p > 0.05$). So, a match of handball played in the warm environment of the sports hall, induces a transient decrease in glomerular function in the most requested players, while the tubular function seems to have been a little bit disturbed.

Keywords: renal function, electrolytes, handball, women, hot environment.

INTRODUCTION

The transition from rest to physical exercise can cause physiological and/or pathological changes in different organs including kidneys, as a result of the redistribution of cardiac output (Mc Allister, 1998). This redistribution of cardiac output leads indeed to a progressive decrease of the renal blood flow as the exercise intensity increases (Poortmans, 1995). Renal hemodynamic alterations including a temporary decrease in glomerular filtration rate, the stimulation of electrolytes excretion may then happens (Poortmans, 1984), especially with a high-intensity exercise. Handball is a sport for which the players must, while playing, repeat actions at very high intensities (Buchheit, 2005) and the average heart rate (HR) reached being about 85% of HRmax. This suggests that a handball match induces high constraints on the functions that ensure homeostasis, particularly on renal function. The constraints will be high, as the game takes place in hot and wet environment, as it is often the case in the South

of Benin Republic. In fact, this environment is characterized in the day, by a temperature that varies between 29 °C and 34 °C and a relative humidity between 70% and 90% (Encarta, 2008). Such an environment is likely to induce a high level of dehydration, with potential health risks for athletes. The assessment of cardiovascular risk associated with physical exercise in the heat was conducted in different sports and the results widely reported in the literature (Melin, Savouray & Launay, 2007; ACSM, 2006). The same is true for the study of the interaction physical exercise-kidneys in male athletes practicing individual sports (Mingels, Jacobs, Kleijnen, Wodzig & Dieijen-Visser, 2009; Lippi *& al.*, 2008). Studies seeking the interaction exercise-kidneys in sportswomen are rather rare (Machado, Zini, Valadão, Amorim, Barroso & de Oliveira, 2011; Endo *& al.*, 2008) and those concerning the African players practicing game sports are almost inexistent. One of the few available studies is that of Gouthon *et al.* (2009) carried out during a match of Basketball in Benin Republic, while the practice of other game sports such as handball is widespread among young girls. During handball matches, some players, the starters, are generally the first inbound players and the most requested, while the others, i.e. the Nonstarters, sitting on the reserve bench, just go up the field for three to five minutes per halftime. Thus, it is inferred that the impact of the game on the renal function of the players, will be different depending on their status of Starter or Nonstarter in the team.

The objective of this study is therefore to compare the changes of renal parameters, during, and 26 hours after a match of handball Division 1 amateur championship of Benin Republic, in Starters (ST) and Nonstarters (NS) of the same female team.

MATERIAL AND METHODS

Nature of the study and setting

It is a casual comparative study carried out at Cotonou (Benin Republic), with female handball players of an amateur team-Division 1. It was undertaken in the Laboratory *APS et Motricité* of the National Institute of youth, physical education and sport (INJEPS), with the collaboration of the Department of Nephrology of the National Universitary Hospital Centre H.K. Maga of Cotonou (Benin Republic).

Study subjects

The study sample consists of 13 senior female handball players, members of the ASO Modèle team (M ± s: 25.6 ± 5.7 years; 56.4 ± 6.0 kg; 165,6 ± 5.2 cm; 20.5 ± 2.0 kg/m^2), selected among the 14 listed to take part in the first game of the preliminary round of the 2009 championship. The study sample was divided into two groups of Starters (ST: N = 7) who are the first seven inbound players, the most requested on the ground during the match and the Nonstarters (NS: N = 6), which are more often on the reserve bench.

To be included in the study sample, each player must meet the following criteria: she must be black and resident in Benin Republic for at least a year because of food habits; she must also be 18 years old or more and listed to take part in the match for the account of *ASO Modèle* team; she is asked to give her detailed and written consent to participate in the study; and not be under medication (anti-malaria, anti-inflammatory, anti-hypertensive, *etc.*) likely to influence renal parameters. The only player under anti-inflammatory treatment has been excluded from the study.

Materials and measurements

The distances covered during the match were measured, using manual pedometers Y-2028 (Geonaute Decathlon, China). EDTA (for [Hb] and Hte) tubes and dry tubes (for creatinine, electrolytes), made it possible to collect 10 mL of blood or urine sample for creatinine and

electrolytes proportioning. Test tubes (sensitivity 10 mL) were used to measure the amount of water drunk by player during the match. A spectrophotometer Kenza Max (Bio ChemisTry) was used to measure blood and urinary creatinine by the method of Jaffé (1886). Urinary sodium and potassium were measured by reference electron photometry with an Electrolyte Analyser SFRI ISE 4500. A Counter automat (Medonic) was used to assess [Hb] and hematocrite (Hte).

Study design

The study was conducted among the players at rest, during the game and recovering period. The day before the match, all the13 players answered a questionnaire related to their sport practice patterns, their personal history of cardiovascular and renal disease, and their menstrual status. The day of the match, before the players listed for the match warm-up, the first measures were made in all the players. After a 20 min warm-up, they played their first match of the championship in two 30 min-half times, with a 15 min break (IHF, 2010). The match took place in a sport hall, between 12 and 2 pm, at respective temperature and relative humidity of 32 °C - 34 °C and 58 mm Hg - 62 mm Hg. Just at the end of the match, the second measures were carried out and the total amount of water drunk by players was measured. The same operations and procedures of measurement were taken 26 hours after the end of the match.

Blood samples were taken by venipuncture at the antecubital fold of the left elbow. Blood and urine samples were kept cold in a cooler for less than two hours before being tested by technicians. Pedometers have been programmed and read by persons familiar with their use. During and after the match, players were allowed to drink water at their convenience, without specific instruction on how much to drink. The composition in mg/L of the available water is as follows: calcium, 3.1; magnesium 1.5; potassium, 0.4; sodium, 5.8; bicarbonate, 9.8; sulphates, 1.2; chlorides, 10; nitrates < 3. The last training session in the team took place 48 hours before the match and the last meal was taken at least four hours before.

Study variables

The glomerular filtration rate was estimated (eGFR) using plasma creatinine and the formulas of Cockcroft-Gault (1976) corrected to the standard of body surface (Sc) = 1.73 m^2 (ANAES, 2002) and that of MDRD (Levey *et al.*, 2006). The glomerular function is considered altered for any value of eGFR less than 90 mL/min/1.73 m^2. The fractional sodium excretion (FeNa) and the ratio of urine sodium/potassium (Na/K) were used to assess tubular function. For FeNa in %, the formula of Carvounis, Nisar and Guro-Razuman (2002) was used as FeNa = 100 x (Urine Na [mmol/L] x Serum creatinine (mg/dL)/(Blood Na [mmol/L] x Urine creatinine [mg/dL]), a resting FeNa value > 2 suggesting a renal functional failure (Fesler & Mimran, 2007). It is the same for any value of Na/K < 1 (Frey *et al.*, 2001). An [Hb] < 12 g/100 mL is considered abnormal (Janssens, 2009), that is associated with anemia.

At the end, and 26 hours after the match, the variation in plasma volume (ΔVP) was determined by the formula of Dill and Costill (1974): $\Delta VP\ (\%) = 100 \times (Hb_{before}/Hb_{after}) \times \{[1-(Hte_{after}/100)]/[1 - (Hte_{before}/100)]\} - 100$. In this equation, Hb_{before} and Hte_{before} represent respectively [Hb] and Hte at rest, then Hb_{after} and Hte_{after} measured at the end of the match.

Ethical considerations

All the players were informed about the interest, the objective of the study, and the security measures taken, before giving their detailed and written consent to take part in it. The study received the approval of the Sectorial Scientific Committee of the Sports Sciences and

Physical Activities called (CSS/STAPS) of the University of Abomey-Calavi (UAC), setting as Ethics Committee.

Statistical analysis

The software Statistica (Stat Soft Inc., Version 8.0) was used for data processing. The results are presented as mean values (M) ± standard deviations (s) for each studied variable. After verification of the normality of distribution of the variables (Kolmogorov-Smirnov test), comparisons between ST and NS players for times of measurements was carried out by two-factor repeated analysis of variance (Anova) (measurement time x status), followed by a one factor Anova. When the distribution of the variable was not normal, appropriate non-parametric tests were used. The significance level of all statistical tests was set at $p < 0.05$.

RESULTS

Biometric characteristics, menstrual status and data of the match

Taken together, the players of this study are 25.6 ± 5.7 years [19 - 37 years] old, being trained for an average of 5 ± 1 hours weekly, over an average of 10 ± 5 years. Whatever the biometric variable considered may be, no significant differences ($p > 0.05$) appears between the ST and NS players (table 1).

Table 1: Biometric characteristics and estimated glomerular filtration rate among handball Division 1 of female players in Benin Republic (N = 13).

	Whole sample (N = 13)	Starters (N = 7)	Nonstarters (N= 6)
Age (years)	25.69 ± 5.76	25.85 ± 6.46	25.50 ± 5.43
Weight (kg)	56.44 ± 6.03	56.37 ± 6.00	56.53 ± 6.63
Height (m)	1.65 ± 0.05	1.65 ± 0.06	1.66 ± 0.04
Body mass index (kg/m^2)	20.56 ± 2.02	20.64 ± 2.04	20.46 ± 2.20
Body area (m^2)	1.61 ± 0.10	1.60 ± 0.10	1.61 ± 0.10
Resting heart rate (bpm)	76 ± 12	76 ± 13	75 ± 10
[Hb] (g/100 mL)	10.84 ± 0.56	10.78 ± 0.62	10.91 ± 0.53
eGFR with C-G (mL/min/1,73 m^2)	81.72 ± 11.62	85.46 ± 8.17	77.36 ± 14.25
eGFR with MDRD (mL/min/1,73 m^2)	82.26 ± 13.95	86.82 ± 12.24	76.93 ± 14.96

The values in the cases are mean values ± standard deviation; N: study sample; eGFR of C-G: glomerular filtration rate estimated with the formula of Cockcroft and Gault (1976); eGFR of MDRD: glomerular filtration rate estimated by the Modification of Diet in Renal Disease formula of Levey *et al.* (2006).

None of the players has a personal or family history of hypertensive or renal disease. Three players out of 13 including one ST were in menstrual phase (first to second days), four out of the 13 including three ST were in post-menstrual or follicular phase (sixth to 14th days of the menstrual cycle) and six girls out of the 13 including three ST, in the pre-menstrual or secretory phase (17th to 23th days).
The experimental team (*ASO Modèle*) won its first match of the preliminary round of the championship with 26 goals *vs* 24. The ST players and the NS played respectively at an average heart rate (HR) of 129 ± 15 bpm (66% HRmax) and 113 ± 33 bpm (58% HRmax), with a significant difference (p = 0.016) between the two groups of players (table 2).

Table 2: Data recorded during a handball match in Starters and Nonstarters of a Division 1 female team of Benin Republic (N = 13).

		Starters (N = 7)	Nonstarters (N = 6)
Exercise heart rate (bpm)		129 ± 15	113 ± 33
Distance covered (km)		3.60 ± 2.41	1.34 ± 0.94‡
Water drunk during the match (L)		0.92 ± 0.39	0.57 ± 0.37
Plasma volume variation (%)	ΔVP1	-8.90 ± 8.15	-12.81 ± 6.29
	ΔVP2	-9.33 ± 7.58	-2.75 ± 13.85
	ΔVP3	-0.12 ± 8.22	+11.80 ± 15.93

The values in the cases are mean values ± standard deviation; N: study sample; H: hour; ‡: difference between Starters and Nonstarters, significant at p < 0.05. VP1: measure at rest – measure at the end of the match; VP2: measure at the end of the match – measure 26 H after the match; VP3: measure at rest – measure 26 H after the match.

Significant differences were recorded between ST and NS players for the mean distance covered (3602.8 ± 2411.1 m *vs* 1342.1 ± 945.5 m, p = 0.034) and the amount of water drunk (923.5 ± 393.8 mL *vs* 574.1 ± 370.0 mL, p = 0.0015).

Renal parameters during the match

At rest, respectively 10 to 11 players (C-G and MDRD) out of the13, including seven ST had a GFRe < 90 mL/min/1.73 m^2. At the end of the match, the plasma volume (PV) of the ST players decreased by 8.9%, and 26 hours after, it continued decreasing by 0.12%. During the same time, that of the NS players decreased by 12.8% before increasing by 11.8%, 26 hours after the match, without a significant difference between the two groups (figure 1).

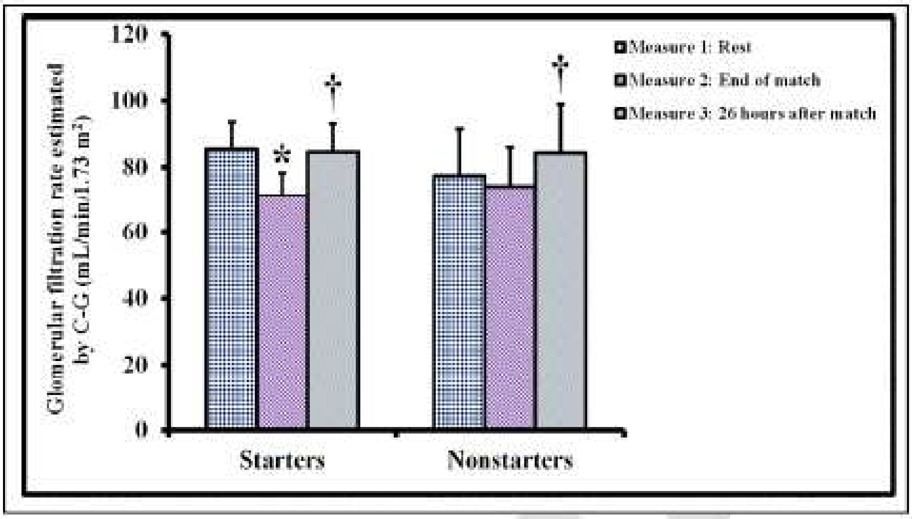

Figure 1: Glomerular filtration rate estimated with the Cockcroft & Gault (1976) formula, corrected to the standard of body surface area (1.73 m^2) during a handball match, in Starters and Nonstarters of a female team of Benin Republic. Interaction (*measurement time* x *status*, $p = 0.44$); Anova of Friedman for measurement time, $p = 0.005$ (Starters) and $p = 0.141$ (Nonstarters).

At the end of the match, the eGFR according to C-G and MDRD was reduced by 16.5% ($p = 0.017$) for C-G and 18.8% ($p = 0.017$) for MDRD in the ST group (figure 2), but no significant change was recorded in NS ($p > 0.05$).

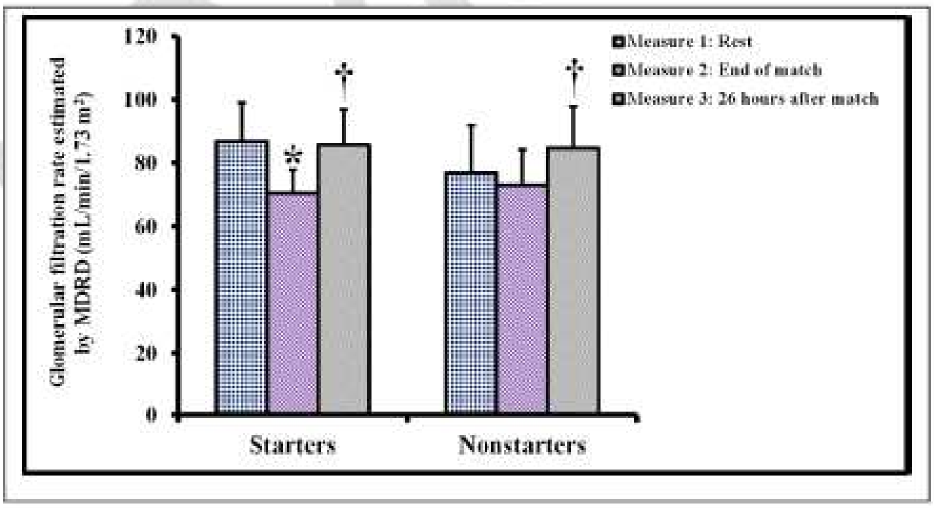

Figure 2: Glomerular filtration rate estimated with MDRD (Levey et al., 2006) during a handball match, in Starters and Nonstarters of a female team of Benin Republic. Interaction (*measurement time x status*, $p = 0.39$); Anova of Friedman for measurement time, $p = 0.005$ (Starters) and $p = 0.141$ (Nonstarters).

During the 26 hours following the end of the match, the eGFR (C-G and MDRD) increased by 18.6% and more (p = 0.017) in the ST group and 13.7% (p = 0.043) in the NS group, without reaching resting values. Furthermore, the standard deviations are greater in the NS group than in ST.

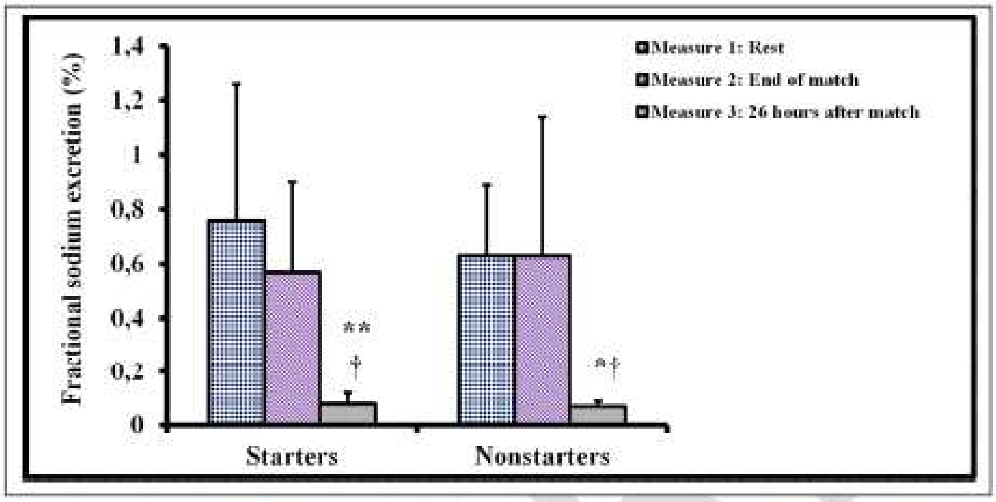

Figure 3: Fractional sodium excretion during a handball match, in Starters and Nonstarters of a female team of Benin Republic. Interaction (*measurement time x status*, p = 0.78); one factor Anova for measurement time, p = 0.005 (Starters) and p = 0.014 (Nonstarters).

At the end of the match, the FeNa (figure 3) has not varied in the two groups (p > 0.05) but 26 hours after the end, it decreased by -85,9% (p = 0.041) in the ST players and by -88,8% (p = 0.027) in the NS group, without a significant difference between the two groups.

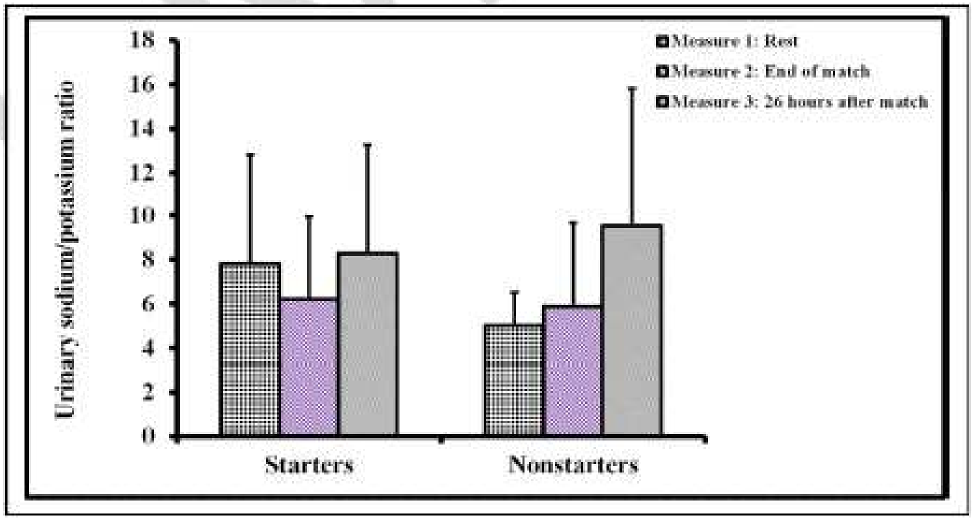

Figure 4: Urinary sodium/potassium ratio during a handball match, in Starters and Nonstarters of a female team of Benin Republic. Interaction (*measurement time x Status*, p = 0.52); one factor Anova for measurement time, p = 0.68 (Starters) and p = 0.19 (Nonstarters).

At the different times of measurements, no significant change of Na/K (figure 4) was recorded in the groups and between them ($p > 0.05$).

DISCUSSION

This study was conducted hypothesizing that the impact of a handball match played in the heat on renal parameters of the players, depends on their status of Starter or Nonstarter in the team. The seven Starters have covered during the match, an average total distance of 3600 m *vs* 1340 m for the Nonstarters (i.e. 37.2% less), which shows clearly that the former have been much more requested during the match. The HR data of the ST recorded during the match (between 159 and 100 bpm), representing 66% of their HRmax, are rather below the usual values, i.e. 85% HRmax (Gallet, 2001). While recognizing that HR and distance covered could be underestimated, because of the limitations inherent to the pedometers used, it must be accepted that these data shed light on effort loads, including the distance covered, below the usual values of 4000 m, reported in the literature for the best women's teams.
Most of the players (77%) were in the post-menstrual period, i.e. in luteal or secretory phase. The first phase (follicular) may generate an increase in the blood concentration of estrogen, favorable to the retention of water, a reduction in the sodium and potassium excretion (Szmuilowicz *et al.*, 2006; Pechère-Bertschi, Maillard, Stalder, Brunner & Burnier, 2002). According to these authors, the high concentration of progesterone often observed during the secretory phase, compete with aldosterone, causing a urine sodium hyper excretion.
The temperature and the relative humidity recorded during the match suggest that the players have made an effort under high thermal stress, likely to make physiological adaptations difficult. Indeed, during a physical exercise in hot and wet environment like that of this study, the thermal stress and subsequent water loss can cause dehydration, a potential source of cardiovascular drift, tiredness and accident (Melin *et al.*, 2007). The plasma volume reduction found at the end of the match in the two groups reflects well the effect of the thermal stress on the body fluid compartments.
The amount of water drunk by the Starters appears to have had beneficial impact on their body, since the variation of plasma volume at the end of the game is less important in this group. However, the Nonstarters recovered better than the Starters in 26 hours, from the point of view of the plasma volume, probably because of a better post-effort rehydration in the former group.
The anemic state observed at rest in all the players may be associated with a nutritional deficiency or a negative parasitic state (high plasmodia load, helminthiasis) or a pseudo-anemia induced by the pre-competition training, or both the three factors. Anemia of black Africans results indeed in the association between nutritional deficiency, iron loss due to intestine warms (helminthiasis), hemolysis due to plasmodia infections and genetic factors (Nussenblatt & Semba, 2002; Stoltzfus, Chway, Montresor, Albonico, Savioli & Tielsch, 2000). However, the hypothesis of a nutritional deficiency associated with an increase in plasma volume before the competition, remains the most plausible in our players.

Ten to 11 players have a eGFR less than 90 mL/min/1.73 m^2, regardless of the formula C-G or MDRD. The discussion of these results seems difficult since the absence of reference values for sub-Saharan Africans and normative resting values for athletes make the interpretation of these data less reliable. It appears hazardous to refer to international classifications proposed for sedentary populations by K/DOQI (2002) and ANAES (2002), in studies with black athletes. It must however be indicated that frequencies of abnormally low

values of the resting eGFR, close to those recorded in this study were already reported among female basketball players in Benin (Gouthon *et al.*, 2009) and among semi-marathon runners in Italia (Lippi *et al.*, 2008).
The eGFR reduction recorded at the end of the match can be attributed to that of renal blood flow to the benefit of the active muscles, as a result of the cardiac output redistribution (Poortmans, 1984). This reduction of renal blood flow is proportional to the exercise intensity (Poortmans, 1995). It probably explains the significant reduction of the GFRe in the Starters that have made a more intense effort over a longer total distance. This is not the case in the group of Nonstarters who played for a little time during the match.

The decrease in eGFR is however transient, regardless of the formula, since 26 hours later, the trend reversed. This phenomenon is known and reported by several authors (Machado *et al.*, 2011; Gouthon *et al.*, 2009). Poortmans *et al.* (1990) have however found no change in the eGFR after a rowing test. The differences between our results and those of Poortmans and his contributors may be in relation to the intensity, duration and nature of the efforts which the subjects were subjected to in each study. Rowers have probably produced a continuous low intensity, but long-term effort, while the female handball players made an intermittent effort at high intensity.
The fractional sodium excretion has not significantly varied at the end of the match while it considerably decreased 26 hours after. The non-variation of the fractional sodium excretion despite the hemoconcentration recorded, can be associated with the hypothesis related to the possible effect of the preparation phase, put forward earlier. We must have in mind that after a training period at high frequency, the body tends to retain sodium during exercise, in order to limit dehydration and protect the kidneys. This result could be also associated with an increased secretion of vasopressin and aldosterone during the match, and with the slight decrease in the observed eGFR. Sodium excretion depends on glomerular filtration rate and aldosterone secretion (Marshall & Bangert, 2005). However, the sodium retention recorded 26 hours after the match in the two groups may be attributed to an inadequate electrolytes and water intake during the 26 hour-recovery.

In these conditions, a tubular reabsorption of sodium is jointly stimulated by increased production of aldosterone and vasopressin, both induced by the decrease in plasma volume. Gerth *et al.* (2002) have also reported a decrease in the FeNa, six hours after a race, but Kawasaki *et al.* (2011) recorded no change of the FeNa after two hours of exercise on ergometer, at 60% of the VO_2max. Cohen, Roussel, Lumsden, Cohen, Grift *and* Lewis, (1993) found however an increase of the FeNa after an intense exercise. As the eGFR reduction and the secretion of aldosterone are proportional to the exercise intensity, the differences between our results and those of Kawasaki *et al.* (2011) and Cohen *et al.* (1993), are probably in relation to the intensity of the effort in each study.
Non-significant and opposite changes of urinary Na/K were found in both the two groups at the end of the match. This trend may be associated with the movement of electrolytes, especially sodium and potassium, during the match. The retention of sodium tended indeed to be higher in the Starters than in the Nonstarters, while the reverse phenomenon was observed for potassium. This finding may be associated with increased secretions of aldosterone and vasopressin that promote the excretion of potassium, while they induce a greater reabsorption of sodium (Fumeaux & Stoermann Chopard, 2005).

CONCLUSION

A decrease in renal parameters was expected in Starters (the most requested) after the handball match played in the heat, but not in the Nonstarters of the same team. This was the case for the eGFR regardless of the status, although all the players had mild anemia at rest. In the conditions of this study, the status of Starter or Nonstarter in the team does influence renal glomerular response during the match, but not that of the tubules. Glomerular response was however transient, since after a 26 hour-recovery, the eGFR tends towards the resting value. Thus, for this level of competition, a unique handball match, even played in moderate heat, does not appear to cause a sustainable renal dysfunction. The reduction of urinary sodium excretion recorded during the recovery period suggests that these female handball players drink more and compensate for the loss of electrolytes as early as the end of a match, to protect their kidneys.

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