AFRICAN JOURNAL FOR PHYSICAL, HEALTH EDUCATION, RECREATION AND DANCE (AJPHERD)

The African Journal for Physical, Health Education, Recreation and Dance (AJPHERD) is a refereed journal published quarterly (March, June, September and December) by LAM Publications Limited. The Editor-in-Chief and the Editorial Committee serve as reviewing board in conjunction with appointed reviewers throughout Africa and overseas for special topics. Subscribers should send their requests and papers to the Editor-in-Chief.

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African Journal for Physical, Health Education, Recreation and Dance (AJPHERD) Volume 21(1:1), March 2015, pp. 69-80.

Changes in renal and hydro-electrolytic parameters induced by the 30-15 Intermittent Fitness Test (IFT) among female Division 1 handball players in the Republic of Benin.

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(Received: 19 June 2014; Revision accepted: 11 March 2015)

Abstract

This study aims at assessing the changes in renal parameters induced by the 30-15 Intermittent Fitness Test (IFT) in female handball players of the Republic of Benin. The study sample was categorised as experimental (EG: $n = 7$) and control (CG: $n = 6$) groups. Glomerular filtration rate (eGFR) with two formulas, urine specific gravity (USG), fractional sodium excretion (FeNa), urinary sodium-potassium ratio (Na/K) and plasma volume variation (PV) were determined before, just at cessation and three hours after the test. In the end, eGFR and PV decreased by at least 17.2% ($p < 0.05$) according to the formula and 9.2% in the EG group while in CG, FeNa and PV increased, respectively by 39% ($p = 0.017$) and 1.7%. Three hours after the test, eGFR and PV increased by 10.5% ($p = 0.02$) and 1.4%, while FeNa decreased by 25% ($p = 0.02$) in EG. In CG, FeNa decreased by 12.5% and PV increased by 2.7%. Urinary Na/K ratio remained unchanged ($p > 0.05$) in both groups. The 30-15 IFT induced in hot environment, a transient reduction of eGFR and a decrease of FeNa during recovery in female handball players.

Keywords: Kidney function, 30-15 IFT, handball, girls, hot environment.

How to cite this article:
Tonon, B.A., Gouthon, P., Agboton, B., Bio Nigan, I., Falola, J-M. & Agboton, H. (2015). Changes in renal and hydro-electrolytic parameters induced by the 30-15 IFT test among female Division 1 handball players in the Republic of Benin. *African Journal for Physical, Health Education, Recreation and Dance*, 21(1:1), 69-80.

Introduction

The practice of high performance sport requires from athletes intensive training and regular participation in both national and international competitions. In order to compete with the best chance of success, it is essential to submit the athletes to careful preparation based on meticulous performance analysis in the targeted sport. This preparation includes among others, good planning of training

sessions, periodic evaluation of the critical performance capacities and of the test matches. Physical and physiological tests play a critical role in this preparation, particularly in capacity assessment because they facilitate the measurement of the impact of training programme and on the basis of which any necessary adjustments could be made (Haydar & Buchheit, 2009). In team sports such as handball, the VO_2max evaluation has been until now particularly focused, with the use of continuous, progressive and maximal laboratory (Milenković et al., 2013) and field tests (Cazorla & Léger, 1993). The continuous, progressive and maximal tests are increasingly abandoned for intermittent tests such as the Yo-Yo Intermittent Recovery Test (Bangsbo, Iaia & Krustrup, 2008) and the 30-15 Intermittent Fitness Test (IFT) (Buchheit, 2005). They are maximum incremental tests whose protocols make provision for incomplete recovery periods. Intense strain as imposed by these tests may disturb the functioning of the kidneys, because of redistribution of cardiac output and subsequent reduction in renal blood flow.

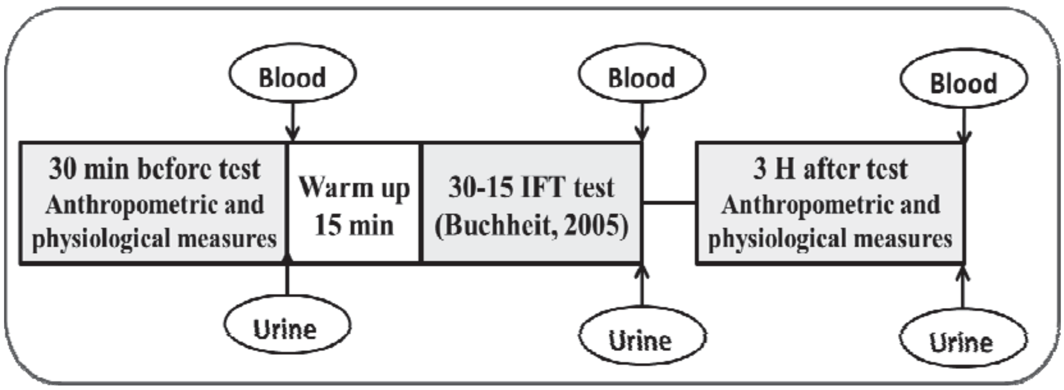
As a matter of fact, physical strain actually causes a redistribution of cardiac output in favor of the active muscles and at the expense of the inactive muscles and organs of the splanchnic area, including the kidneys (Mc Allister, 1998). Renal blood flow then undergoes a steady decline according to the intensity of exercise. Under these conditions, transitory changes in renal hemodynamics and in the excretion of electrolytes and proteins are likely to appear (Poortmans, 1984). Also, a reduction in the glomerular filtration rate (GFR), hematuria, proteinuria and decreased diuresis and electrolyte excretion may occur (Poortmans, 1995). As the kidneys are not directly involved in athletic performance, very few studies have examined the effect of intense physical activity on renal function. Research on the issue has been carried out in African athletes, especially in Benin handball (Tonon et al., 2012; Tonon et al., 2011) and basketball (Gouthon, Tonon, Ouendo, Falola et al., 2009) players. These studies have also reported transitory modifications in renal function during competitions. The realization in Benin of the 30-15 IFT progressive, maximal and intermittent test (Buchheit, 2005) exposed the subjects to physical stress coupled with a thermal stress induced by hot and humid sub-Saharan climate. This climate, characterized by an ambient temperature between 29 °C and 34 °C in the shade and a relative humidity between 70% and 90% (Encarta, 2008) during the day, is indeed likely to exert strenuous conditions on all functions that contribute to homeostasis. This hot climate could induce very high levels of dehydration, with serious consequences for the health of athletes (Maughan, 2012). The objective of this study is to measure the changes in renal and electrolyte parameters that occur within the three hours following a 30-15 IFT test carried out by female Division 1 amateur handball players, in the hot and humid climate of Porto-Novo, southern Benin.

Methodology

Study Design and Participants

A pre-and-post-test control group design was used in this study. The sample consisted of 13 senior female handball volunteers (22.8 ± 0.7 years, 56.6 ± 6.3 kg, 165.3 ± 4.8 cm) who were preselected for the 2012 Zone 3 Challenge Trophy tournament in Ghana. Out of a total of 20 preselected players, only the 13 gave written informed consent to participate in the study. The players were randomly divided into two groups, i.e experimental (EG: n = 7) who performed the 30-15 IFT test (Buchheit, 2005) and a control group (CG, n = 6) which did not participate in the fitness test.

The day before the test and warm-up, anthropometric and physiological parameters were measured in all players, and then blood and urine samples were taken. The EG players warmed up for 15 minutes and subsequently took the 30-15 IFT test. At the end of the test and three hours later, the same measurements were repeated for the whole sample (Figure 1). The study received authorization from the Ministry of Public Health, after approval for the study granted by the National Provisional Committee for Ethics in Health Research (N° 009 of 28 March 2012).



H: hour; min: minute; samples.

Figure 1: Schematic representation of the study design.

Measurements

The measurements were taken at rest, at the end of the test and after three hours. Glomerular filtration rate (GFR) was estimated (eGFR) using the Cockcroft and Gault (1976) and the Modification of Diet in Renal Disease (Levey, Coresh, Greene, Stevens et al., 2006) equations. eGFR was normalized to standard body surface area (Sc) for the Cockcroft and Gault equation to allow comparisons, using the ANAES (2002) formula. Renal function was considered as altered for any value of eGFR less than 90 mL/min/1.73 m^2. The urine specific gravity

(USG) was determined and any person presenting USG > 1.020 was considered dehydrated (Armstrong et al., 2010). The fraction of sodium excretion (FeNa), the variation of plasma volume (ΔPV) and physiological strain index (PSI) were calculated using respectively the formulas of Carvounis, Nisar and Guro-Razuman (2002), Dill and Costill (1974), and Moran, Shitzer and Pandolf (1998). The urinary sodium/potassium ratio (urinary Na/K) was also calculated (Frey et al., 2001).

In each subject, heart rate (HR) and rectal temperature (Trec) were measured using respectively Accurex heart rate monitors (Polar, Finland) and automatic thermometers MT-101R (Hangzhou Sejoy, China). The ambient temperature and relative humidity were recorded using a MeteoStar multi-function device. The heart rate was measured in subjects at rest for at least 15 minutes. All blood samples were taken from the antecubital vein at the fold of the left elbow, then preserved at ambient temperature and transported quickly to the laboratory for analysis. Before, during and after the test, players were allowed to drink still water at their convenience. The last meal was consumed more than four hours before the test.

RT-9200 spectrophotometer (Rayto, Germany) was used to measure creatinine with the Jaffé (1886) kinetic method. The hemoglobin and hematocrit rates were determined using an M-Series (Medonic, Sweden) Automat Counter. An ISE 4500 (SFRI, France) Electrolyte Analyser was used to determine sodium and potassium by reference electron photometry. A Master-SUR/Nα clinical refractometer (Attago, Japan) was used to determine the urine specific gravity (USG). Dry (urine) and EDTA (hemoglobin and hematocrit) test tubes and burettes of 500 mL maximal capacity (consumed water) were also used in this study. Anthropometric measurements were taken according to the techniques recommended by McDougall, Wenger and Green (1988). Whenever it was necessary, the measurement devices were calibrated before analysis.

30-15 IFT Test

Each player in the experimental group has undertaken the 30-15 IFT field test (Buchheit, 2005) which is a maximum and intermittent progressive test, carried out in a shuttle race to estimate intermittent maximum aerobic speed (IMAS) and VO_2 max. It consists of 30 second running periods interspersed with 15 second recovery periods. During periods of efforts, the player runs a shuttle race over a distance of 40 m at a speed indicated by a soundtrack that emits periodic beeps. At recovery periods, the player walks to join the nearest line in front of her, in order to wait for the next run. A period of race and the subsequent recovery constitute a level. This test starts at a speed of 8 km/h with increments of 0.5 km/h at each level and ends when the athlete is unable to follow the rhythm. The last level announced is the player’s result, which is the IMAS, expressed in km/h

and used to estimate VO_2max in mL/min/kg: $VO_2max_{30\text{-}15IFT}$ = [28.3 – (2.15 x 2) – (0.741 x age) – (0.0357 x Weight) + ((0.0586 x age) x $IMAS_{30\text{-}15IFT}$) + 1.03 $IMAS_{30\text{-}15IFT}$] (Buchheit, 2005). The test was performed in groups of three or four players, under an ambient temperature of 33-41 °C and a relative humidity of 42-56%.

Statistical analysis

The data were processed with the Statistica (Stat Soft Inc., Version 7.0) software. Descriptive statistics as a percentage (%), mean (m) ± standard deviation (s) were calculated for each variable after checking the normal distribution using the Kolmogorov-Smirnov test. The interaction of *Time of measure* x *Group* was investigated with the two-way analysis of variance (ANOVA). A one-way ANOVA or Friedman ANOVA was used, followed by Tukey or Wilcoxon rank test to compare the results at different measurement times. The Student t test or the Mann Whitney U test was used as appropriate to compare the experimental and control groups. The significance level for the statistical tests was set at $p < 0.05$.

Results

Anthropometric and physiological characteristics of the handball players

VO_2max of players from the EG group was estimated at 46.8 ± 2.7 mL/kg/min. At the end of the test, the PSI average was 8.4 ± 1.0 and the EG group players drank an average of 607.1 ± 283.4 mL of water against 375.0 ± 136.9 mL in CG ($p = 0.13$) during the three hours of recovery. In the EG group, body weight decreased by 0.7% ($p = 0.02$) while Trec increased to an average of 38.7 °C (2.9%, $p = 0.001$) at the end of the test (Table 1).

Three hours after the test, Trec decreased by 1.6% ($p < 0.001$) below the mean value of rest (Table 1). No significant change was recorded in the CG group ($p > 0.05$), at different times of measurement. Observations on ΔPV showed a disparity for both EG and CG groups at the end of the test (9.2% against 1.7%, $p = 0.004$), but the variations were evenly oriented between rest and three hours after the test (1.4% against 2.7%, $p = 0.63$), with significant differences found between groups ($p < 0.01$).

Changes in renal parameters

At rest, whatever the formula, 61.5% of players presented an eGFR < 90 mL/min/1.73 m^2. Eleven (84.6%, including six of the EG group) out of the 13 studied players showed USG > 1.020 at rest and at the end of the test, against eight (61.5%, including five of the EG group), three hours after the test. In the

EG group, eGFR decreased by 17.2% (CG: p = 0.01) and 19.3% (MDRD: p = 0.04) at the end of the test (Table 2), while three hours after, only the Cockcroft and Gault eGFR increased (10.5%, p = .02). In the CG group, changes in eGFR were not significant (p > 0.05).

Table 1: Changes in anthropometric and physiological parameters during 30-15 IFT in female handball players (n = 13).

Variables	At rest (M1)	At cessation of exercise (M2)	3H after cessation of exercise (M3)
Height (cm)			
EG	165.7 ± 5.7	-	-
CG	164.8 ± 4.2	-	-
Weight (kg)			
EG	57.3 ± 6.0	56.9 ± 6.0*	57.3 ± 6.0
CG	55.8 ± 7.2	55.7 ± 7.3	55.7 ± 7.2
Rectal temperature (°C)			
EG	37.6 ± 0.1	38.7 ± 0.3***	37.0 ± 0.1***†††
CG	37.4 ± 0.2	37.2 ± 0.1#	36.9 ± 0.4*#
HR (bpm)			
EG	70 ± 6	192 ± 7***	70 ± 9†††
CG	70 ± 5	72 ± 4#	67 ± 8#
ΔPV (%)			
EG	-9.2 ± 2.5		+1.4 ± 4.6**††
CG	+1.7 ± 5.4#		+2.7 ± 5.3#

Values in cases represent mean ± standard deviation ; H : hour ; HR : heart rate ; ΔPV : variation of plasma volume ; EG : experimental group ; CG : control group ; * : difference with M1, significant at p < 0.05 ; *** : difference with M1, significant at p < 0.001 ; ††† : difference with M2, significant at p < 0.001 ; # : difference between EG and CG, significant at p < 0.05.

Table 2: Changes in renal parameters during 30-15 IFT in female handball players (n = 13).

	Rest (M1)	At cessation of exercise (M2)	3H after cessation of exercise (M3)
eGFR C-G (mL/min/1.73 m^2)			
EG	91.193 ± 17.117	75.583 ± 10.815*	83.554 ± 9.049†
CG	87.074 ± 10.743	86.039 ± 8.357#	85.610 ± 11.061
eGFR MDRD (mL/min/1,73 m^2)			
EG	91.387 ± 18.104	73.625 ± 9.418*	82.430 ± 7.388
CG	88.174 ± 12.701	87.050 ± 10.764#	86.809 ± 15.288
FeNa (%)			
EG	0.849 ± 0.260	0.842 ± 0.415	0.592 ± 0.292*†
CG	0.580 ± 0.200#	0.817 ± 0.354*	0.749 ± 0.265*
Urinary Na/K			
EG	5.879 ± 2.882	5.250 ± 3.159	4.969 ± 2.478
CG	5.213 ± 2.274	6.694 ± 2.331	6.615 ± 2.882
USG			
EG	1.022 ± 0.010	1.026 ± 0.008	1.020 ± 0.006
CG	1.024 ± 0.007	1.021 ± 0.006	1.019 ± 0.011

Values in cases represent mean ± standard deviation ; H : hour ; eGFR : estimated glomerular filtration rate ; C-G : Cockcroft and Gault (1976) formula normalized ; MDRD : Modification of Diet in Renal Disease (Levey et al. (2006) ; FeNa : fractional excretion of sodium ; urinary Na/K : urinary sodium and potassium ratio ; USG : urine specific gravity ; GE : experimental group ; CG : control group ; * : difference with M1, significant at p < 0.05 ; † : difference with M2, significant at p < 0.05 ; # : difference between EG and CG, significant à p < 0.05.

FeNa increased non-significantly at the end of the test ($p > 0.05$) before decreasing by 25% ($p = 0.02$) after three hours in the EG (Table 2) group. On the contrary, in the CG group, an increase of 39.6% ($p = 0.02$) of FeNa was recorded at the end of the test and followed three hours later by a non-significant reduction of 12.5% ($p = .46$). Variations of urinary Na/K and USG recorded at different times of measurement were not significant ($p > 0.05$) in both groups.

Discussion

This research is based on the assumption that, when gradually increased to the maximum value imposed by the 30-15 IFT test, intensity, combined with the hot and humid climate of southern Benin, can induce transient disturbances in renal function in athletes. The mean VO_2max recorded in this study, which was 46.8 mL/min/kg, appears to be higher than those reported in non-professional Serbian and Brazilian players (Zapartidis et al., 2009; Vargas et al., 2008). However, it is lower than that found in the female Danish or Norwegian elite handball players which ranged between 47.5 mL/min/kg and 57.6 mL/min/kg (Manchado et al., 2013; Ogueira & Dantos, 2005). The differences between these results and those of other authors may be related to the relatively lower level of practice among Benin players and/or high thermal strain experienced during the experiment.

The hypothesis related to the negative effect of heat stress on performance (Gonzalez-Alonso, 1998) is the most plausible, because while the recorded physiological strain index was high (Moran et al., 1998), the players were very motivated and ready to give the best of themselves. Therefore, this strengthens the reliability of the 30-15 IFT test results and reflects the maximal character of the test, the maximal registered heart rate being close to the values generally observed in laboratory reference tests, even in adolescents (Sunberg & Elovainio, 1982).

The high dehydration rate observed at rest in this sample may be associated with the high thermal stress imposed by the hot and humid climate, and inadequate hydration of players, during both effort and recovery periods. It should be noted that even in temperate climates, and as recently indicated by Gibson, Stuart-Hill, Pethick and Gaul (2012), and Arnaoutis et al. (2013), a high incidence of dehydration was reported in young soccer players, regardless of gender. It is therefore necessary for the players involved in this study to drink fluide well before, during and particularly after every training session or competition to reduce the risk of dehydration. It may then be possible to improve their performances of which dehydration is a major limiting factor, particularly in a hot environment. As a matter of fact, it is generally assumed that an approximate 2% decrease in body weight through sweating reduces performance by 3 to 10% (Shirreffs, 2009).

Whatever the formula used to estimate GFR, most players showed values of eGFR between 89 and 60 mL/min/1.73 m^2. Compared to the International classification of chronic kidney disease (Kidney Disease Improving Global Outcomes AKI Work Group, 2012), these players were at stage 2. This stage corresponds to a lower reduction in GFR, due to the intervention of mechanical and/or hemodynamic factors that are likely to be at the origin of a reduction in renal blood flow. The first factor in question is a reduction in renal blood flow triggered by the observed high dehydration rate in the studied series, which may cause renal ischemia. The lack of reference values in athletes and the absence of formulas that are specific to people of African origin make it difficult to interpret these results. It is noteworthy that abnormally low eGFR values have been reported in sedentary women in Ghana (Eastwood et al., 2010), among Benin female Division 1 amateur handball (Tonon et al., 2011) and basketball players (Gouthon et al., 2009) and in semi-marathon runners in Italy (Lippi et al., 2008).

At the end of the test, a transient reduction in eGFR was recorded in our study. This predictable phenomenon, often attributed to the reduction in renal blood flow was indeed reported in Europe (Poortmans, 1995; Colombini et al., 2012) and in Africa, particularly in Benin (Tonon et al., 2011; Gouthon et al., 2009). This is true regardless of the formula used, which supports the idea that the different formulas used to estimate GFR are applicable to our study. In both groups, the FeNa is less than 1% at rest, at the end of the test and three hours later, reflecting a reduction in renal blood perfusion (Bazari, 1994). This reduction in renal blood flow may be associated with the hydration state of the players. The steeper decrease of FeNa three hours after the test in the experimental group is an indication of sodium retention as a result of a decrease in the recorded plasma volume (Carvounis et al., 2002) after the test.

The reduction in plasma volume marks the delayed effect of antidiuretic hormone and aldosterone (Brooks & Mercier, 1994), tending to reduce sodium excretion in case of hypovolemia. Similar observations were recorded in Europe after a marathon (Mydlík, Derzsiová & Bohus, 2012) and an ultramarathon (Neumayr, Pfister, Hoertnagl, Mitterbauer et al., 2005) and in Africa after handball (Tonon et al., 2012) and basketball (Gouthon et al., 2009) matches. Kawasaki et al. (2012), however, did not observe any significant FeNa variation after two hours of ergometer exercise at 60% of VO_2max.

The differences between our results and those of Kawasaki et al. (2012) are therefore probably related to the intensity and nature of the effort in each study. In fact, it is admitted that the reduction of GFR and secretion of aldosterone are proportional to the intensity of effort (Sims, Rehrer, Bell & Cotter, 2007) and the relative intensity was high in the female handball players who performed the maximal intermittent 30-15 IFT test.

Non variation of USG and urinary Na/K can be attributed to the nature of the test. A continuous, not intermittent maximum test would have had a greater impact on both parameters. Until this hypothesis is verified, it is safe to realize that this field test which is increasingly used in handball, does not have a deep and lasting disturbing impact on the renal function of handball players, even under strenuously high thermal conditions.

Conclusion

The results of this study indicate that the majority of the female handball players presented an abnormally low eGFR at rest and were in a state of dehydration. Despite the high thermal stress, players hydrate badly. This intermittent test induces a transient decrease in eGFR and a slight decrease in FeNa. The starting urinary Na/K ratio and dehydration status remained almost unchanged after the test. Renal function was only slightly affected by the high thermal strain imposed on players during the maximal and intermittent field test. Nonetheless, the study hypothesis according to which, the increased speed up to the maximum imposed by the 30-15 IFT, when combined with the hot and humid climate of southern Benin, may cause transient modifications in the renal function of athletes can be considered partially verified.

Acknowledgments

The authors thank the management of the Fitness and Cardiovascular Centre *VITA FORM* of Porto-Novo, for their technical support during study design and data processing. We express our deep gratitude to all the handball players who volunteered to participate in the study. This study was partially funded by the University of Abomey-Calavi, Republic of Benin.

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