BIOLOGY OF EXERCISE
VOLUME 11.2, 2015

Changes and Recovery in Fitness Capacities following a series of Handball matches played in the Sub-tropical climate by Division 1 amateur players

D.O.I: http:doi.org/10.4127/jbe.2015.0089

NOUATIN KB[1], GOUTHON P[1], AMOUSSOU-GUÉNOU D[2], DANSOU HP[3], MESSAN F[1], FALOLA J-M[4, 5], TONON BA[1], BIO NIGAN I[1], ARÈMOU M[1].

[1] Laboratory of Physical and Sportive Activity and Motricity. National Institute of Youth, Physical Education and Sport (INJEPS). University of Abomey-Calavi (Benin). 01 PO Box 169 Porto-Novo.
[2] Unity of Training and Research in Endocrinology. Faculty of Health Science, University of Abomey-Calavi, (Benin).
[3] Laboratory of Exercise Physiology (LAPHE). National Institute of Youth, Physical Education and Sport (INJEPS). University of Abomey-Calavi (Benin). 01 PO Box 169 Porto-Novo.
[4] Laboratory of Biomechanics and Performance. National Institute of Youth, Physical Education and Sport (INJEPS). University of Abomey-Calavi (Benin). 01 PO Box 169 Porto-Novo.
[5] Laboratory of Human Motor, Education, Sport, Health (LAMHESS). Faculty of Sports Science. University of Nice Sophia Antipolis (France). 261 Boulevard du Mercantour 06205 Nice.

ABSTRACT

The objective of this study was to determine in amateur handball players, the changes in fitness capacities and physiological data, during a series of three consecutive matches, as well as the rates of restoration reached after a 24-hour recovery. The study sample included 17 senior players (23.5 ± 0.7 years; 176.4 ± 6.7 cm; 73.4 ± 9.2 kg). They were randomly distributed in two teams A and B, to play the series of experimental matches, 24 hours apart. The players ran a 30-m sprint and took repeated sprint ability test, before the first and at the end of the third match. We measured the squat and counter movement jump heights, the physiological parameters before and just at the end of all the matches. The performances at the 30-m sprint and jump tests decreased non-significantly ($p > 0.05$) between the beginning and the end of the three matches. The repeated

Key Words: *Handball, Fatigue, Recovery, Repeated sprint ability, Jump.*

sprint ability was reduced by 9.3% between the initial measurement and that of the end of the 3rd match. After a 24-hour recovery, the difference with the initial performance was always of the same order as that of the end of the 3rd match. In the context of this study, there was no cumulated effect of the matches on the fitness capacities measured. The results suggest that the trainers systematically integrate in the training schedules of these handball players, physical preparation and fitness work items that favour fast inter-efforts recovery.

INTRODUCTION

For two decades, team handball has become increasingly popular as well in the world as in Africa, because of its high strong mediatisation. Except for the Maghreb, handball is practiced on amateur level in most African countries, particularly in those of the sub-Saharan region. In these countries, as at the international level, most competitions are played as grouped tournaments in a preliminary round, followed by a final phase. The matches of the preliminary round opposing three or four teams by pool are often scheduled every 24 hours. Each team plays at least three consecutive matches and the best ones play up to six matches during the competition. The recovery time between the matches of the preliminary round and those of the final phase is generally 24 or 48 hours. Consequently, the handball trainers need to prepare the teams for a fast recovery, for achieving good performance, in spite of fatigue (2, 5).

Handball is in fact an intermittent sport, played at high intensity corresponding to 82-85% of the maximum heart rate of the players (13), which requests ATP-CP anaerobic metabolism first (22). During a match lasting 60 minutes, the playing intensity decreases from the first to the second half-time in most players, which suggests the occurrence of a neuromuscular and/or metabolic fatigue (30, 27). For budgetary reasons, the organizers of handball competitions usually provide for a maximal duration of 24 hours as recovery period between matches. Therefore, it is reasonable to think that during a series of handball matches, players, whatever their positions on the field, are likely to find their performance capacities decreasing gradually, if the recovery time between two consecutive matches is not appropriate. To avoid such decrease in fitness capacities or in sports performance resulting from repeated effort, separated by less than 48 hours, high level players use various strategies and procedures such as inter-alia therapy, balneotherapy, massage and dietetic techniques to accelerate recovery (7).

In spite of the possibility of using these techniques, the preparation schedule of the handball players who aspire to elite level should include activities or sequences aiming at developing the capacity of fast inter-efforts recovery. In the particular

context of tropical countries in sub-Saharan Africa like the Republic of Benin, such preparation is not rational, since the integration of fitness capacities to the training schedules does not constitute a major concern in junior and senior players (20). The changes in physiological parameters and fitness capacities induced by a series of handball matches played in hot climate sub-Saharan Africa, are not known. On the other hand, such data were reported among European elite males (21) and females (23), respectively engaged in handball and tennis tournaments. If such studies are carried out in handball players from sub-Saharan Africa, they will make it possible to define more adapted preparation strategies for the competition formulas and context of amateur players. Since these results are not yet available, this study is undertaken with an aim of determining in amateur handball players, the changes in fitness capacities and physiological data during a series of three consecutive matches, as well as the rates of restoration reached after a 24-hour recovery.

MATERIALS AND METHODS

Experimental approach of the research

We undertook this study, using a before and after intervention design, during which handball players were subjected to measurements and fitness tests, before, just at the end and 24 hours after a series of three consecutive matches separated each by a 24-hour recovery. One week before the matches, all the players took a 30-15 intermittent fitness test (30-15 IFT), followed 48 hours later by anthropometric measurements, 30-m sprint and repeated sprint ability (RSA) tests. On the day of each match, we drew in all the players 5 mL of blood from the alnar fold of the left elbow, 45 to 40 min before warm up, then just at the end of the match, for glucose assessment. The players took the jump tests (squat and counter movement) at least 10 minutes before the beginning of each of the three matches. Before, just at the end of each match and 24 hours after the third one, we measured rectal temperature (Trec). We collected the urine for urinary specific gravity (USG) assessment and to appreciate the hydric status of the players. The heart rate (HR) was also measured at rest and just at the end of the match, to calculate the physiological strain index (PSI) suggested in the literature (18) according to the formula: $\mathbf{PSI = 5\ (Trec_1 - Trec_0\ x\ (39.5 - Trec_0^{-1} + 5\ (HR_1 - HR_0\ x\ (180 - HR_0^{-1})}$ in which $Trec_0$ and $Trec_1$, are respectively the rectal temperature before and at the end of the match; HR1 and HR0, are the heart rate before and at the end of the match. We used the PSI estimation scale proposed by the authors of the formula (18) to determine the level of thermal strain in the players during matches. During the matches, we evaluated the total distance covered by each player. The players drank as much

water they like from bottles that were marked with their names and the quantity drunk was measured. At the end of the 2nd and the 3rd matches and 24 hours later, the players agreed to take the 30-m sprint and the RSA tests. They also took the squat and counter movement jump tests at the end of the three matches, then after the 24-hour recovery.

Participants

We constituted the study sample with 17 Division 1 (D1) male senior handball players, of which nine took part in the 2011 World Junior championship (Greece) or the 2012 World Challenge Trophy (India). We randomly divided the front and the back players in two teams A (n = 8) and B (n = 9) for the experimental matches. They trained three to five times per week and each session was made up of traditional specific handball drills (warm up, skill and/or tactical drills, topic game all over the ground). To be included in the sample, the players had to: hold a valid sporting licence as a member of a D1 team; be between 18 and 34 years old; have a seniority of at least five years in the practice of competition handball and a weekly training duration (WTD) of six hours or more. Those who had suffered from a fever or debilitating disease during the 15 days preceding the start of the study were rejected. All the players gave their informed written consents to take part in this study which was approved by the Scientific Committee of the Physical Activities and Sports Sciences and Techniques named CSS/STAPS, of the University of Abomey-Calavi, sitting as Ethics committee.

Materials and techniques

We used FT4 heart rate monitors (Polar, Finland) to measure the resting heart rate and that reached during matches, as well as the total distance covered by player. We used a spectrophotometer RT-9200 (Rayto®, Germany) to assess glycaemia by the method in final point. A clinical Sur-Ne refractometer (Atago, Japan) permitted to determine the urine specific gravity (USG). The lactate (La) was assessed after blood micro-sampling of 5 µL from the fingertip, using a lactatometer (Lactate Pro, Urkray, Japan). We measured rectal temperature with MT 101R electronic thermometers (Hangzou Sejoy, China), the 30-m sprint time and the repeated sprint ability (RSA) with photo cells (Brower Timing System, USA). We used the OptoJump Next system (Microgate, Italia) to measure the jump heights, then a DVD/CD tape recorder and a pre-recorded protocol of the 30-15 IFT test (5) to estimate VO_2max on the field.

Matches and tests

The participants played all the matches outdoors in Porto-Novo, according to the official match-play time (12) between 4 and 5.30 pm, in an ambient temperature of 33.4 ˚C - 35.6 ˚C, and a relative humidity of 67% - 70%.

The players performed the squat and counter movement jump tests one after the other, with at least 3 minutes of post-match recovery and we recorded the best height (in cm) out of five. They ran the three 30-m sprints separated each by 30 s recovery and we recorded the best time (in seconds). The test of repeated sprint ability (RSA) used in this study consists in performing six shuttle-sprints at maximal speed, on a distance of 15 m x 2, with 14 s of active recovery between two sprints (25). The performance criterion was the mean running time of the six sprints (Tm) expressed in seconds i.e. the time cumulated at the six sequences of 15 m x 2 shuttle divided by six. The 30-15 IFT used for estimation of the $VO_2max_{30\text{-}15IFT}$, is an intermittent and maximal field test, currently used in handball (5).

Statistical analysis

The descriptive data are presented as mean value (m) ± standard deviation (s). We used a one-way analysis of variance (ANOVA) followed, according to the case, by the Tukey HSD post hoc test, to compare measurements at different times. The data were processed using the Statistica software (Stat Soft Inc., Version 5.5). The level of significance of the statistical tests was set at $p < 0.05$.

RESULTS

Anthropometric and physiological characteristics.

Table 1 summarizes the general characteristics of the studied handball players. The respective mean resting heart rate and $VO_2max_{30\text{-}15IFT}$ of the players were 70 ± 8 bpm and 57.2 ± 3.1 mL/min/kg.

Table 1.
Biometric and sportive practice characteristics of the studied handball players (n = 17).

	m ± s
Age (years)	23.5 ± 3.2
Height (cm)	176.4 ± 6.7
Weight (kg)	73.4 ± 9.2
BMI (kg/m^2)	23.5 ± 2.3
Seniority in the practice (years)	9.5 ± 2.4
WTD (hours)	9.8 ± 2.5
VO_2max (mL/min/kg)	57.2 ± 3.1
HR (bpm)	70 ± 8

m ± s: mean value ± standard deviation; BMI: body mass index;
HR: heart rate; WTD: weekly training duration;
VO_2max: maximum oxygen intake estimated from the results of the 30-15 IFT.

Changes recorded during the series of matches

The performance at the 30-m sprint measured before Match1 had a non-significant difference with those recorded at the end of the two following matches ($p > 0.05$). A decrease of 9.3% in the performance of the RSA test (Table 2) was observed between the measurement before Match1 and the one at the end of Match3 ($p < 0.001$). The respective reductions of 13.1% and 10.6% (the most important of all) compared to the initial values recorded for squat and counter movement jumps at the end of Match3 were non-significant ($p > 0.05$).

The changes recorded in physiological parameters from Match1 to the end of Match3 relate to Trec, La, glycaemia and USG (Table 3).

Table 2.
Changes in fitness capacities before and at the end of the matches in African Division 1 amateur handball players (n = 17).

	30-m sprint (s) m ± s	Tm (s) m ± s	SJ (cm) m ± s	CMJ (cm) m ± s
Match 1				
Before	4.2 ± 0.1	5.7 ± 0.2	36.1 ± 4.6	41.0 ± 4.4
At cessation	–	–	31.2 ± 5.3	36.1 ± 4.4
Match 2				
Before	4.2 ± 0.1	6.1 ± 0.3*	36.1 ± 4.6	39.2 ± 4.4
At cessation	–	–	31.2 ± 5.3	36.6± 4.6
Match 3				
Before	4.3 ± 0.2	6.3 ± 0.3***	35.1 ± 3.7	39.5 ± 5.1
At cessation	–	–	32.9 ± 4.4	36.6 ± 4.2
After 24-H	4.3 ± 0.1	6.3 ± 0.4***	33.1 ± 4.8	36.4 ± 5.5

Match 1: first match of the series; Match 2: second match of the series; Match 3; third match of the series; ***: difference significant at $p < 0.001$ between the value recorded before Match 1 and that of the end of Match 3; *: difference significant at $p < 0.05$ between the value recorded at the end of Match2 and the one before Match 1; ***: difference significant at $p < 0.001$between the value recorded 24 hours after Match 3 and the one before Match 1; RSA: repeated sprint ability; Tm: it is the mean running time of the six shuttle-sprints calculated for the RSA test; s: second; SJ: squat jump: CMJ: counter movement jump.

Trec and La respectively increased on average by 2.8% and 55.9% ($p < 0.001$) from the end of Match1 to that of Match3. No player presented at the beginning a Trec ≥ 38 °C, but at the end of Match2, Trec was 40.5 °C in one of them. At the end of the matches, La was always lower than 11 mmoles/L. In the studied group, four players had a glycaemia value > 1.10 g/L just before Match1 and < 0.70 g/L at the end of Match2. All these four players have a family history of diabetes. Following the data processing and fifteen days after the matches, the fasting glycaemia measured in three among the four players who formerly presented abnormal resting and effort values, was between 0.86 and 0.98 g/L.

Before Match1, 11 players had an USG value > 1.020, but at the end, they were 16. On the other hand, there were only six, then 10 players who had an USG value > 1.020 respectively before and at the end of Match2.

Table 3.
Changes in physiological parameters during matches among African Division 1 amateur handball players (n = 17).

	Blood lactate sanguin (mmol/L) m ± s	Glycaemia (g/L) m ± s	Rectal temperature (˚C) m ± s	USG m ± s
Match 1				
Before	2.95 ± 1.19	0.99 ± 0.13	37.49 ± 0.27	1.023 ± 0.010
At cessation	4.28 ± 1.35	0.94 ± 0.08	38.84 ± 0.65***	1.029 ± 0.000
Match 2				
Before	3.49 ± 2.48	0.77 ± 0.08	37.18 ± 0.21	1.024 ± 0.010
At cessation	6.35 ± 3.66 ††	0.70 ± 0.08***	38.76 ± 0.75***	1.028 ± 0.000†
Match 3				
Before	2.05 ± 1.65	0.99 ± 0.13	37.01 ± 0.30	1.018 ± 0.010
At cessation	4.60 ± 2.70 **	0.85 ± 0.10†††	38.54 ± 0.55***	1.022 ± 0.010†††
After 24-H recovery	–	–	37.05 ± 0.35	1.019 ± 0.010$

Match 1: first match; Match 2: second match; Match 3: third match; USG: urinary specific gravity; **: difference significant at $p < 0.01$ between the value recorded before Match 3 and the one at the end; ***: difference significant at $p < 0.001$ between the value recorded before and the one at the end of Match1; ††: difference significant at $p < 0.01$ between the value recorded at the end of Match1 and the one at the end of Match2; †††: difference significant at $p < 0.001$ between the value recorded at the end of Match1 and the one at the end of Match2 and Match 3; †: difference significant at $p < 0.05$ between the value recorded before Match1 and the one at the end of Match2; $: difference significant at $p < 0.05$ between the value recorded at the end of Match2 and the one 24-hour recovery after Match 3.

The average distance covered and the percentage of HRmax reached by the players (Table 4) did not vary significantly during the series of matches ($p > 0.05$). The amount of water drunk by the studied handball players was more important during Match3 (3.91 ± 1.20 L; $p < 0.001$). The PSI recorded for Match3 was weaker than that of the others two (3.86 ± 1.11; $p < 0.001$). A player had a Trec value of 40.5 ˚C and a PSI of 12.5 at the end of Match2, although he drank three litres of water.

Table 4.
Changes in match data in African amateur Division 1 handball players (n = 17).

	Match 1	Match 2	Match 3
Percentage of HRmax (%)	82.74 ± 3.64	84.90 ± 4.53	83.98 ± 4.74
Distance covered (km)	4.25 ± 0.92	4.38 ± 0.90	4.79 ± 0.74
Water drunk (L)	1.38 ± 0.41	2.55 ± 0.63***	3.91 ± 1.20***
PSI	7.23 ± 1.75	7.40 ± 1.85	3.86 ± 1.11***

Match 1: first match of the series; Match 2: second match of the series; Match 3: third match of the series; HRmax: maximal heart rate; PSI: physiological strain index (Moran et al., 1998); ***: difference significant at $p < 0.001$ between the amount of water drunk during match 1 and that of matches2 and 3; ***: difference significant at $p < 0.001$ between the PSI recorded during match 1 and that of match 3.

Changes recorded after 24 hours of recovery

After the 24-hour recovery, the performance in the RSA test was restored to 90.4% of the initial value, the difference of 9.5% being significant ($p < 0.001$). On the other hand, the SJ and the CMJ jump heights varied non-significantly ($p > 0.05$).

The mean value of the USG accounted for 99.6% of the initial value and nine players had an USG > 1.20. No player presented a Trec value > 38 °C, 24 hours after the end of Match3.

DISCUSSION

African Division 1 amateur handball players were subjected to a series of three matches separated each by 24 hours, in order to appreciate the impact of associated physical load on their fitness capacities. The resting heart rate of these players appears higher than that reported in the literature for the highly trained athletes. Indeed, the resting heart rate reported in athletes is in general lower than 60 bpm, showing a tendency to bradycardia (24). On the other hand, the values of VO_2max recorded in this group of handball players are close to those of the international handball elite, i.e. between 50 and 60 mL/min/kg (26, 31).

The performances at the 30-m sprint and jump tests decreased non-significantly between the beginning and the end of the three matches. So, there was no cumulated effect of the loads associated with the three matches on these performances. The performance of the repeated sprint ability test was reduced by

9.3% between the initial measurement and the one at the end of the last match. After the 24-hour recovery, the difference with the initial performance is always of the same order as that at the end of the third match.

The absence of change in the performance of the 30-m sprint was unexpected, since the players' actions during the handball match are mainly associated with short accelerations (29). According to this author, acceleration capacity – defined as the rate of speed change – is more significant in the realisation of a good performance in team handball than maximum speed that cannot be reached during a match (14). The decrease of 3.7 ± 0.4% in the 20-m sprint performance in the Norwegian female handball elite following a series of three matches confirms this position (23). This contradicts the results of our study and reveals the distance of 20 m as the one on which more strain is put on the players during a handball match. Although the players reached on average 82-84% of their HRmax during matches, it is likely that their low performances, compared to the international elite, did not enable them to repeat a significant number of maximum sprints during these experimental matches. In these conditions, the players were certainly unable to perform accelerations at the rate of 2 or 3 sprints per minute during each match. In the case of such hypothesis, it is not possible to observe a decrease in sprint performance at the end of the matches (1), in relation with the depletion of phosphagen (ATP-PCr) and muscle glycogen reserves (15). It is worth mentioning that the phosphagen reserves are depleted only to a maximum of 35-55% during 6 second sprints and are very quickly restored after exercise cessation, i.e. after a 5-min recovery (6). The 24 hours of recovery should consequently be largely sufficient to ensure almost complete restoration of the single sprint performance in these players during the series they run while playing.

The lack of variation in jump heights between the beginning and the end of the three matches can be explained by the same arguments related to the 30-m sprint, since they are both efforts of same nature, i.e. explosive and strongly correlated effort (3). However, we know that after a drill of high intensity, the capacity of the muscles to generate force-speed decreases (17). We can then assume that at the end of the three matches, the excitation-contraction couple of lower limb muscles preserved its contractile qualities.

This could partly justify the stability in jump performances observed in the current study. It is however necessary to point out that a reduction of 5.2% of the jump performance has been reported after a match, in top handball players. The decrease observed in the counter movement jump at the end of the three-day tournament was 4-7% in the female handball players of the Norway national elite (23).

Although there was no cumulated effect, the reduction of the repeated sprint ability was expected in spite of the relatively high level of VO_2max in this study sample. In fact, VO_2max and repeated sprint ability are not strongly correlated (3), even if a high level of VO_2max allows a fast inter-efforts recovery, after a repetition of sprints. The intervention of VO_2max during recovery is rather associated with an

increased O2 consumption supporting a fast re-synthesis of PCr, a key factor of recovery after a repetition of sprints (16, 10). On the basis of the data collected, it can be assumed that for each match, repeated sprint ability shows an important decrease, that the 24-hour recovery contributes to partial restoration (23), so that there was no more than a residual gap of 9% at the end of Match3. It is worth mentioning that in spite of the high level of thermal strain suffered by the players during the first two matches, the value of blood lactate remained moderate (4 – 6 mmoles/L), i.e. largely below the 11 mmoles/L reported at the end of maximum incremental laboratory tests (11). The La concentration recorded at the end of the match in this study is still on average lower than the 8.9 mmoles/L registered after a 4 against 4 handball side-game (4).

The absence of complete restoration of repeated sprint ability after a 24-hour recovery was not expected, since a high level of VO_2max facilitates recovery after high intensity and intermittent exercise (28), as is not the case in this study. According to these authors, this is made possible by an increase in oxidative processes, La elimination and the restoration of PCr.

The data processing revealed in the study sample, the presence of four players having at the same time a resting hyper-glycaemia and a significant decrease in blood glucose during the matches. This may seem all the more surprising as the players are young, but can be explained by an association of resting hyper-insulinism with a hyper-glucidic diet. In these conditions, the decrease recorded in these players at the end of the match could correspond to the phenomenon of hypo-glycaemia reaction as a result of increased insulin secretion in the blood flow, after an important consumption of food with high glycaemic load. It is necessary to specify that sub-Saharan African athletes, like the players in the study sample, generally eat hyper-glucidic food such as cereals (corn, sorghum, millet) and roots like cassava and yams (9). Such hyper-glucidic food can expose them, in the long term, to insulin-resistance, hyper-insulinism and type 2 diabetes (19). A periodic screening of metabolic parameters including glycaemia, as suggested in tennis, seems to be necessary in these players so as to reduce the risk of sudden hypoglycaemia at the beginning of exercise, i.e. at the start of warming up (8). The glycaemia data recorded in this study underline the need for a biomedical follow-up of the whole population of handball players who practice in the sub-Saharan environment, throughout the sports season.

CONCLUSION

This study was undertaken on the basis of the statement that in amateur players, a cumulated effect of physical loads, associated with three handball matches

separated each by 24 hours, is observed on the decrease in fitness capacities. The results recorded do not confirm this assumption for the performances of 30-m sprint, squat and counter movement jumps. For the first time however, this study showed that repeated sprint ability is affected during a series of three handball matches played in the tropical climate of sub-Saharan Africa. Moreover, it revealed in amateur players, that a 24-hour recovery following a series of three matches, are not enough to ensure the restoration of repeated sprint ability.

The results suggest that trainers should systematically integrate physical preparation, especially fitness sequences supporting fast recovery, in the training schedules of handball players. The most effective way of integrating this preparation in the training schedules of amateur-level players, who have little time for training, must be determined beforehand by an experimental-designed study.

ACKNOWLEDGEMENTS

We thank all the players who took part in this study for their availability, and the persons in charge of *Vita Forme, a* Centre for muscular and cardiovascular maintenance in Porto-Novo, for their technical support during the data processing.

REFERENCES

1. Balsom P, Seger J, Sjödin B, Ekblom B. Maximal-intensity intermittent exercise: effect of recovery duration. Int J Sports Med, 13(7): 528-33, 1992.
2. Bishop D, Girard O, Mendez-Villanueva A. Repeated-Sprint Ability - Part II: recommendations for training. Sports Med, 41: 741-56, 2011.
3. Buchheit M, Delhomel G. Déterminants de la capacité de répétition de sprint chez des footballeurs adolescents de haut niveau. Poster 3ème Edition Science & Foot,. Available at: http://www.martin-buchheit.net. [Downloaded on 29 March 2013], 2008.
4. Buchheit M, Lepretre PM, Behaegel AL, Millet GP, Cuvelier G, Ahmaidi S. Cardiorespiratory responses during running and sport-specific exercises in handball players. J Sci Med Sport, 12(3): 399-405, 2009. Doi: 10.1016/j.jsams. 2007.11.007.epub 2008 Mar 20.
5. Buchheit M. Le 30-15 Intermittent Fitness Test: un nouveau test de terrain spécifiquement dédié aux joueurs de sport collectif pour la détermination d'une vitesse maximale aérobie intermittente. Approches du handball, 87: 27-34, 2005.
6. Dawson B, Goodman C, Lawrence S, Preen D, Polglaze T, Fitzimons M,

Fournier P. Muscle phosphocreatine repletion following single and repeated short sprint efforts. Scand J Med Sci Sports, 7: 206-13, 1997.
7. Décombaz J. Nutrition and recovery of muscle energy stores after exercise. Schweizerische Zeitschrift für «Sportmedizin und Sporttraumatologie», 51(1): 31-38, 2003.
8. Ferrauti A, Pluim BM, Busch T, Weber K. Blood glucose responses and incidence of hypoglycaemia in elite tennis under practice and tournament conditions. J Sci Med Sport, 6(1): 28-39, 2003.
9. Food and Agriculture Organization of the United Nations (FAO). Aperçu nutritionnel par pays – Bénin. ESNA-FAO, Roma Italia, 2003.
10. Haseler LJ, Hogan MC, Richardson RS. Skeletal muscle phosphocreatine recovery in exercise-trained humans is dependent on O_2 availability. J Appl Physiol, 86: 2013-8, 1999.
11. Haydar B, Al Haddad H, Ahmaidi S, Buchheit M. Assessing inter-effort recovery and change of direction ability with the 30-15 Intermittent Fitness Test. J Sports Sci Med, 10: 346-54, 2011.
12. International Handball Federation (IHF). Handball. Rules of the game. Basle, 9-13, 2010.
13. Loftin M, Anderson P, Lytton L, Pittman P, Warren B. Heart rate response during handball singles match-play and selected physical fitness components of experienced male handball players. J Sports Med Phys Fitness, 36(2): 95-9, 1996.
14. Manchado C, Pers J, Navarro F, Han A, Sung E, Platen P. Time-motion analysis in women's team handball: importance of aerobic performance. J Hum Sport Exerc, 8(2): 376-390, 2013.
15. Medbo JI, Gramvik P, Jebens E. Aerobic and anaerobic energy release during 10 and 30 s bicycle sprints. Acta Kinesiol Univ Tartuensis, 4: 122-46, 1999.
16. Mendez-Villanueva A, Edge J, Suriano R, Hamer P, Bishop D. The recovery of repeated-sprint exercise is associated with PCr resynthesis, while muscle pH and EMG amplitude remain depressed. PLoS ONE, 7(12): e51977: 1-10, 2012. Doi: 10.1371/journal.pone.0051977.
17. Miles MP, Ives JC, Vincent KR. Neuromuscular control following maximal eccentric exercise. Eur J Appl Physiol, 76(4): 368-74, 1997.
18. Moran, DS, Shitzer A, Pandolf KB. A physiological strain index to evaluate heat stress. Am J Physiol Regul Integr Comp Physiol, 275(1 Pt 2): R129-34, 1998.
19. Moreira PI. High-sugar diets, type 2 diabetes and Alzheimer's disease. Cur Opin Clin Nutri Metab Care, 16(4): 440-45, 2013. Doi: 10.1097/MCO.0b013e328361c7d1.
20. Nouatin BK, Gouthon P, Messan F, Dansou HP, Amoussou-Guénou D, Bio Nigan I, Attiklémé K, Gouda S. Context of handball practice and level of integration of fitness capacities to training schedules among players in southern Benin. JPES, 14(3): 371-81, 2014.
21. Ojala T, Häkkinen K. Effects of the tennis tournament on player's physical

performance, hormonal responses, muscle damage and recovery. J Sports Sci Med, 12: 240-48, 2013.
22. Povoas SC, Seabra AF, Ascensao AA, Magalhaes J, Soares JM, Rebelo AN et al. Physical and physiological demands of elite team handball. J Force Res Cond, 26(12): 3365-75, 2012.
23. Ronglan LT, Raastad T, Borgesen A. Neuromuscular fatigue and recovery in elite female handball players. Scand J Med Sci Sports, 16: 267-73, 2006.
24. Scheuer J, Tipton CM. Cardiovascular adaptations to physical training. Annu Rev Physiol, 39: 221-251, 1977.
25. Spencer M, Fitzsimons M, Dawson B, Bishop D, Goodman C. Reliability of a repeated-sprint test for field-hockey. J Sci Med Sport, 9 (1-2): 181–4, 2006.
26. Sporis G, Vuelta D, Vuelta D Jr, Milanovic D. Fitness profiling in handball: physical and physiological characteristics of elite players. Coll Antropol, 34(3): 1009-14, 2010.
27. Thorlund JB, Michalsik LB, Madsen K, Aagaard P. Acute fatigue-induced changes in muscle mechanical properties and neuromuscular activity in elite handball players following a handball match. Scand J Med Sci Sports, 18: 462-472, 2008.
28. Tomlin DL, Wenger HA. The relationship between aerobic fitness and recovery from high intensity intermittent exercise. Sports Med, 31(1): 1-11, 2001.
29. Upton DE. The effect of assisted and resisted sprint training on acceleration and velocity in Division IA female soccer athletes. J Strength Cond Res, 25(10): 2645-2652, 2011.
30. Zebis MK, Bencke J, Andersen LL, Alkjær T, Suetta C, Mortensen P, Kjær M, Aagaard P. Acute fatigue impairs neuromuscular activity of anterior cruciate ligament-agonist muscles in female team handball players. Scand J Med Sci Sports, 21(6): 833-40, 2011. DOI: doi: 10.1111/j.1600-0838.2010.01052.x.
31. Ziv G, Lidor R. Physical attributes, physiological characteristics, on-court performances and nutritional strategies of female and male basketball players. Sports Med, 39(7): 547-68, 2009. DOI: 10.2165/00007256-200939070-00003.

Address for correspondence:

Gouthon Polycarpe. National Institute of youth,
Physical Education and Sport,
University of Abomey-Calavi,
01 PO Box 169 Porto-Novo (Republic of Benin).
Phone: (229) 90 03 98 70/ (229) 61 76 74 34.
E-mail: goupoly@yahoo.fr