Repeated-sprint ability and its correlates among handball players in Porto-Novo, Republic of Benin

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Aim. This cross-sectional study aims at identifying, by age groups, the factors which contribute most to the prediction of repeated sprint ability (RSA) among handball players in Porto-Novo, Benin.

Methods. The study was carried out with 208 players aged 10 to 25, who practise handball at school and/or in civil clubs. Total running time (Tt) and fatigue index (FI) at the RSA test were the dependent variables. Gender, seniority in handball practice, performance at the squat jump, 30-15 IFT, motor coordination test of Illinois, sprint on 30 m tests were the independent or predictive variables.

Results. In minim players, the performance at the Illinois test was the first predictive variable of Tt (r^2=0.42; P=0.002). In the cadet, junior and senior categories, the performance at sprint on 30 m presented the highest r^2 of 0.60, 0.45 and 0.40 (P<0.0001).

Conclusion. From the two performance criteria of the used RSA test, Tt varied most according to age group and was more associated with other studied variables. Moreover, the factors which contributed more to the prediction of RSA in the Porto-Novo minim handball players (10-12 years) differed from those identified for older groups.

KEY WORDS: Oxygen consumption - Athletic performance - Exercise test

H andball is an increasingly popular team sport in the world and even in Africa.

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In Benin, the number of competitions increased, as well as that of practitioners whose Division 1 club number increased from four in 1970, to 17 in 2013.[1] The results of the Beninese clubs and national junior teams during continental and world competitions from 2011 to 2012 are promising.

However, the performance of the Benin handball players has to be improved, and this cannot happen, above all, without the improvement of the main performance determining factors in this sport. Repeated sprint ability (RSA) which is the issue of this study constitutes one of the performance determining factors in team sports like handball.[2, 3]

Data from the literature relating to conceptual aspects, assessment methods and RSA training techniques allow considering RSA as a multifactorial entity.[4-6] Factors like strength, speed, VO2max, CPK enzyme activity, blood lactate, are the main determi-

nants identified in professional team sport players.[7]

It seems however that the contribution of each factor (VO_{2max} for example) to the prediction of RSA in professional or elite players varies according to authors.[8, 9] In addition, we do not know if this contribution is the same according to age group in the population of African handball players and particularly in Benin. Knowledge of RSA level and its interrelationship with other factors among handball players will allow the Benin trainers to better define the physical abilities which they must develop first, by age group. This study was thus undertaken with the aim of: 1) comparing in the Porto-Novo handball players, the values of RSA and its associated factors among age groups; 2) identifying in the same sample, the factors which contribute mostly to the prediction of RSA, by age group.

Materials and methods

Type of study and setting

This cross-sectional study was carried out with handball players in Porto-Novo, the administrative Capital of the Republic of Benin, West Africa, according to the recommendations of Helsinki.[10] The authorization of the heads of the school (Secondary and Primary schools) and that of the people in charge of the civil clubs were requested and obtained for players' participation. The study was approved by the Sports Science Council (named CSS/STAPS) of the National Institute of Youth, Physical Education and Sport (University of Abomey-Calavi).

Study sample

This study included an exhaustive sample of 208 school or civil club players from Porto-Novo and surrounding areas. The players had to satisfy the following criteria: to hold a valid sporting licence for the current season, for the account of a school or civil club; to be 10 to 25 years old; to give a writ-

ten informed consent (juniors and seniors) or oral consent (minims and cadets). The players taking anti-inflammatory, anti-malarial drugs, or under any other treatment likely to influence muscular parameters or who, for one reason or another, gave up during tests, were excluded.

Materials and techniques

A survey form was used to collect information about the socio-demographic characteristics and the sporting practice of the players. Photo cells (Brower System Timing, USA) were used to measure race speed at the single sprint on 30 m, RSA and Illinois tests. The Optojump Next system (Microgate, Italy) was used to measure performance at the squat jump test. A DVD/CD tape and a pre-recorded 30-15 IFT [11] were used to estimate VO_{2max} and maximum aerobic speed (MAS) on the field.

Physical tests

The RSA test used consisted in running six shuttle sprints at maximal speed, on a distance of 15 m x2, with 14 s of active recovery between two races. The performance was appreciated as the total running time (Tt), *i.e.* the time cumulated for the six race bouts of 15 m x2, expressed in seconds and the fatigue index (FI) during the six passages, expressed as percentage.

$$FI = (\text{ideal average time/temps}) \times 100 - 100$$

Ideal time is the best time of race multiplied by six.[12]

The test of single sprint on 30 m, consists in running at maximal speed on a distance of 30 m, three times separated each by a 30 s-recovery period. The best race time (in seconds) of the three tests constitutes the performance.

The 30-15 IFT is an intermittent and maximum field test which was validated for handball players.[11] It is carried out in the form of sprints in 30 s, intersected with periods of 15 s-active recovery. The number of stages completed was used to determine the $MAS_{[30 - 15\ IFT]}$ in each player. The VO_{2max}

was calculated using the formula purposed by the same author: $VO_{2max[30 - 15 IFT]} = 28.3 - 2.15 - 0.741 \times age - 0.0357 \times weight + 0.0586 \times age \times MAS_{[30 - 15 IFT]} + 1.03 \times MAS_{[30 - 15 IFT]}$ where MAS is the maximal aerobic speed.

At the squat jump test, the player jumps the highest possible, starting from a motionless position of the knees at 90°, with his hands on his hips. The recorded performance in cms is the best jump height out of five tests.

The Illinois Agility Test is carried out with four blocks forming a rectangular space of 10 meters long and 5 meters wide. A cone is put at point A to mark the beginning of the test, at points B and C to mark the return points and at point D to mark the end of the test. Four other cones, separated from each other by a 3.3 meter space, are put at the centre of the test zone. At the starting command, the stop-watch of the photo-electric cells is started and the player follows the course of the test at maximal speed (from left to right or from right to left). In turns B and C, he must touch the cone with his hand. The stop-watch is stopped as soon as the player crosses the finishing line and his performance is recorded in seconds.

Data collection

The data were collected in three sessions. At the first session, the information about socio-demographic and sporting practice history was collected and anthropometric measurements were taken three times according to the recommendations of Mc Dougall *et al.*,[13] then the average values were recorded. After a 15-minute warm-up, the players took the single sprint test on 30 m, the Illinois Agility Test, as well as the RSA test. At the second session, they took the 30-15 IFT and at the third, the squat jump test. Small groups of 10 to 16 players were scheduled to take the tests in the morning each time, before 11 o'clock.

Study variables

The identified dependent variable in this study was the RSA which was expressed in

terms of performance at the shuttle sprint test of 15 m x2, repeated six times. The performance criteria were the total running time (Tt) and the fatigue index (FI).

Two groups of independent or predictive variables were used:

The first refers to the age groups adopted by the Beninese Handball federation (BHF). They were expressed as follows: minims (10 to 12 years), cadets (13 to 15 years), juniors (16 to 18 years), seniors (more than 18 years).

The other independent variables were: socio-demographic characteristics (age, gender), anthropometric measures (body mass index) and sporting practice (seniority in handball practice, weekly training time), performances at the 30-15 IFT (MAS and VO_{2max}), squat jump (height) and single sprint on 30 m (race time).

Statistical analysis

The data were processed using the SPSS software (version 18.0). The normality of variable distribution was checked by using the Kolmogorov Smirnov test, and variance homogeneity, by the Levène test. An analysis of variance (Anova) was also used to compare data between age groups. A correlation analysis (coefficient r of Bravais-Pearson) was carried out to identify the independent variables that had a significant correlation with each of the two performance criteria of the RSA, *i.e.* Tt and FI. Only these independent variables were integrated to a stepwise multivariate linear regression presented by category of age group and in which each performance criterion was the dependent variable. The significance level of the statistical tests was settled at $P<0.05$.

Results

Biometric and sportive practice characteristics

The studied players were 18.3±3.6 years old (10-25 years), with an average weekly training time of 6.7±2.3 hours (Table I).

TABLE I.—*Biometric and training characteristics in studied handball players (N.=208).*

	Whole sample (mean±SD)	Male players (mean±SD)	Female players (mean±SD)
Age (years)	18.3±3.6	19.2±3.6	17.2±3.4***
Height (cm)	168.1±10.1	173.3±9.1	161.7±7.1***
Weight (kg)	58.6±12.1	63.8±11.7	52.1±9.2***
BMI (kg/m²)	20.5±2.8	21.1±2.7	19.9±2.7***
WTH (hours)	6.7±2.3	6.9±2.2	6.5±2.4*

Whole sample: N.=208; male players: N.=115; female players: N.=93.
BMI: Body Mass Index; WTH: weekly training hours.
* Difference between men and women, significant for P<0.01; *** difference between men and women, significant at P<0.0001.

TABLE II.—*Comparison by gender, of performances at physical tests among age groups.*

	Male players				Female players			
	Minims (mean±SD)	Cadets (mean±SD)	Juniors (mean±SD)	Seniors (mean±SD)	Minims (mean±SD)	Cadets (mean±SD)	Juniors (mean±SD)	Seniors (mean±SD)
Total time (s)	40.3±1.8	**37.8±1.6***	**35.7±4.8*†††**	**30.5±8.3†††‡**	42.1±2.1	41.6±1.6	42.4±1.9	41.3±2.6
Fatigue index (s)	4.0±1.2	5.1±4.4	5.7±4.1	5.6±2.4	3.7±1.8	4.6±4.0	4.6±2.0	5.0±2.3
30-m sprint (s)	4.8±0.3	**4.5±0.3***	**4.3±0.1#***#†**	**4.3±0.2***†**	5.1±0.3	5.1±0.2	5.0±0.2	5.0±0.1
VO$_{2max}$ (mL/min/kg)	51.3±4.5	52.6±3.8	**50.5±4.5†††**	**46.6±4.6††**	40.5±3.1	**42.1±2.8***	**42.7±3.0***	**44.3±2.9***
MAS (km/h)	17.4±1.5	18.7±1.1	19.0±1.5	18.9±1.4	15.4±1.8	16.2±1.4	16.3±1.4	16.6±1.2
Illinois Test (s)	17.4±0.6	16.7±0.8	16.9±4.7	15.8±0.7	18.2±1.0	18.1±1.0	18.3±1.1	17.7±0.8
Squat jump (cm)	25.3±2.1	**30.6±4.7***	**33.4±4.5***†**	**34.3±4.9***†**	22.3±4.1	23.4±3.9	23.7±3.3	23.2±1.9

Total time: cumulated time during the six 2x15 m race sequences; senior boys (N.=32); senior girls (N.=15); junior boys (N.=44); junior girls (N.=36); cadet boys (N.=33); cadet girls (N.=29); minim boys (N.=6); minim girls (N.=13); fatigue index: appreciation criterion of the repeated sprint ability (RSA), corresponding to the percentage of decrease in sprint performance; VO$_{2max}$: maximal oxygen consumption; MAS: maximal aerobic speed; Illinois test: used for the assessment of the agility, considered as a component of motor coordination. * Comparison between minims and all the other categories; † comparison between cadets and the two other categories (junior and senior); ‡ comparison between juniors and seniors.

They had an average seniority of 4±3 years for males and 3±2 years for females, in the practice of competition handball.

Comparison among age groups

In males, only Tt and squat jump height improved from the minim to the senior groups (P<0.05). The weakest VO$_{2max}$ average was recorded in the senior groups (46.6±4.6 mL/min/kg) who also presented the smallest Tt average (30.5±8.3 s). In females, the difference among age groups was significant only for VO$_2$max and the lowest value (40.5±3.1 mL/min/kg) was observed in minims (Table II).

Correlations between performances at the RSA test and independent variables

In minims, the highest coefficient of correlation with Tt was observed at the Illinois test (r=0.67; P<0.0001) followed by the VO$_{2max}$ (r=-0.59; P<0.0001). On the other hand in seniors, the highest correlation was observed for the level of practice variable (r=0.80; P<0.0001). In all the categories, the performance with the sprint on 30 m was strongly correlated with Tt (r=0.51 to 0.78; P<0.05). In no category did the playing position present a significant correlation with Tt (Table III). No variable was significantly correlated with FI in minims and juniors (P>0.05). The level of practice variable was significantly correlated with FI: r=-0.44 (P<0.0001) and r=-0.38 (P<0.0001), respectively in juniors and seniors.

Multivariate regression

In minims, the performance at the Illinois test was the best predictive variable for Tt at the first step of the multivariate regression. After adjustment with MAS whose contribution is significant, r²=0.56. Among cadets, juniors and seniors, it was rather the performance at the single sprint on 30 m which constituted the best predictive vari-

TABLE III.—*Correlation coefficients between the total running time at the RSA test and the independent variables, in the studied handball players.*

	Total running time				Fatigue index			
	Minims (N.=19)	Cadets (N.=62)	Juniors (N.=80)	Seniors (N.=47)	Minims (N.=19)	Cadets (N.=62)	Juniors (N.=80)	Seniors (N.=47)
Age	r=-0.15	**r=-0.47*****	**r=-0.33*****	**r=-0.30***	r=0.02	r=0.24	r=0.13	r=0.18
Sex	r=0.38	**r=0.75*****	**r=0.65*****	**r=0.58*****	r=-0.07	r=-0.05	r=-0.18	r=-0.08
Level of practice	r=-0.17	r=0.18	**r=0.59*****	**r=0.80*****	r=-0.10	r=0.08	**r=-0.44*****	r=-0.14
Playing position	r=0.37	r=0.08	r=0.003	r=0.28	r=-0.22	r=-0.08	r=-0.06	r=-0.04
30-m sprint	**r=0.51***	**r=0.78*****	**r=0.67*****	**r=0.64*****	r=0.22	r=-0.21	r=-0.16	r=0.006
VO_{2max}	**r=-0.59*****	**r=-0.76*****	**r=-0.54*****	r=-0.11	r=-0.08	r=0.08	r=0.04	**r=-0.38*****
Illinois test	**r=0.67*****	**r=0.69*****	r=0.20	**r=0.55*****	r=0.10	r=-0.04	r=-0.10	r=0.02
Squat jump	r=0.08	**r=-0.70*****	**r=-0.61*****	**r=-0.56*****	r=0.08	r=0.08	r=0.20	r=-0.00

VO_{2max}: maximal oxygen consumption; Illinois Test: test assessing agility considered as a component of motor coordination; playing position: front and back playing positions, and that of goal keepers have been retained as modalities; correlation coefficients significant at $P<0.05$ are highlighted; the total time corresponds to the cumulated running time; * correlation coefficient significant at $P<0.05$; *** correlation coefficient significant at $P<0.001$.

TABLE IV.—*Synthesis of the multivariate regression by age groups of handball players between the total running time at the RSA test and the fatigue index on one hand, and the independent variables on the other one (N.=208).*

	Steps	Independent variables	β coefficient	B constant	Estimated SE	r²	Adjusted r²	P
Minims Tt	1	Illinois Test	0.67	15.32	1.65	0.45	0.42	0.002
	2	Illinois Test	0.47	31.00	1.44	0.61	0.56	0.015
		MAS	-0.44					0.022
Cadets Tt	1	30-m sprint	0.78	17.36	1.56	0.61	0.60	0.0001
	2	30-m sprint	0.50	33.75	1.29	0.73	0.73	0.0001
		VO_{2max}	-0.45					0.0001
	3	30-m sprint	0.41	25.00	1.19	0.78	0.77	0.0001
		VO_{2max}	-0.35					0.0001
		Illinois Test	0.26					0.002
Juniors Tt	1	30-m sprint	0.67	-2.96	3.86	0.45	0.45	0.0001
Seniors Tt	1	30-m sprint	0.64	-30.94	6.58	0.42	0.40	0.0001
Seniors FI	1	VO_{2max}	-0.39	15.77	2.24	0.15	0.13	0.008

MAS: maximal aerobic speed; Illinois test: test assessing agility considered as a component of motor coordination; VO_{2max}: maximal oxygen consumption; Tt: total running time during the six sprints of the repeated sprint ability (RSA) test; FI: fatigue index, representing the performance decrease during the six sprints of the RSA test.

able (Table IV). Among cadets, after adjustment with VO_{2max}, r²=0.73 for both variables. Thus, the part of RSA predicted by VO_{2max} corresponded to r²=0.13. As far as FI is concerned, only VO_{2max} and in seniors, had a significant r² in the multivariate regression (Table IV).

Discussion

This study aimed at identifying, by age groups, the factors that contribute most to the prediction of repeated sprint ability (RSA) in handball players in Porto-Novo, Southern Benin. The data collected revealed that in the youngest players (minims), the performance at the motor coordination Illinois test constitutes the best predictor, whereas in the oldest, it is rather the performance at the sprint on 30 m.

In this study, the mean value of VO_{2max} recorded in minim boys, cadets and juniors are ranged within the values reported in the literature, *i.e.* 50-60 mL/min/kg.[14-16] It is then right to deduce from this, that these players have a relatively good level of aerobic maximum power, contrary to the seniors whose VO_{2max} is on average lower than that indicated in the literature.[17, 18] In the case of the seniors, the inadequate contents and the weekly relatively low frequency of the training sessions can justify the low values observed. The recorded increase in VO_{2max}

according to age group among the females of this study can be associated with the cumulated effect of the handball practice (training sessions and matches) to which they had devoted themselves for years. It is true that the value of 44 mL/min/kg recorded in senior female players, is lower than the 49.6±4.8 mL/min/kg and the 48.49±4.51 mL/min/kg reported in the literature for this category.[17, 19]

In minims, the performance at the Illinois test is the best predictive variable of the total time of race during the RSA test. This test is used to assess the agility of the players, one of the main abilities of motor coordination such as dexterity, rhythm, segment dissociation, space orientation, differentiation, laterality, balance, etc. This result was expected, since in pre-pubescent children as is the case of minims in this study, motor coordination is often regarded as the main component of physical performance. The evidence is that ability is no more highlighted in the regression models for older players, *i.e.* in juniors and seniors.

It is worth noting that performance at the sprint on 30 m appeared regularly from the category of cadets as the best independent predictive variable of the total race time at the RSA test. This result suggests that speed during the sprint on 30 m is a factor which deserves particular attention from handball trainer who must give it a significant place in the development plan of the players' physical capacities, when they reach the age of 12.

Neither maximal aerobic speed (MAS) nor VO_{2max}, contributed significantly to the prediction of RSA, but they apparently showed in the regression models of minims and juniors as second (a prediction at 13%) or third predictive variables. These observations suggest a first comment as follows: the 12-16 age bracket corresponds to the children's fast growing period during which trainability in aerobic maximum power is probably high.[20-22] It can then be noticed that the literature data do not agree on the question concerning the relation between VO_{2max} and RSA. As a matter of fact, a significant correlation of r=0.62 has been re-

ported between performance at the RSA test and VO_{2max} in professional soccer players [23] and in team sport players.[4] The correlation was on the other hand non-significant and very weak between the two parameters (r=0.03; P>0.05), in the players belonging to the Tunisian handball elite [24] and even in Australia football players.[9] Although in the current study, VO_{2max} seems not to play an important role in the prediction of RSA in senior players, the results suggest the development of VO_{2max} and its maintenance at a high level during the players' training sessions. Indeed, this factor contributes to a significant degree to the prediction of RSA in the studied minims and cadets. The trainers should consequently consider the development of VO_{2max} as a permanent component of the preparation of the young handball players to high-level competition, in order to support a fast inter-efforts recovery.[25]

Height in squat jump which is evidence of power and indirect sign of higher muscular mass of the lower limbs in junior and senior male players, may relate to the increase in protein synthesis during puberty. A significant positive correlation was in fact reported between the values of testosterone and performance at the counter movement jump test, as well in female as in male players.[26] The natural development of power as a result of increased testosterone secretion cannot solely improve power to the level needed for handball players to be effective in competition, particularly during duels and shoots. Therefore, it is necessary to develop muscular force by adequate and well planned techniques of resistance training. This is not always the case among players in the Republic of Benin, as shown by other observations of this study. Indeed, in spite of its significant association with the total time of race at the RSA test (bivariate analysis), the height of squat jump does not contribute significantly to the prediction of RSA among seniors in the final regression model. The heights recorded in this study are however similar to those reported in the literature among handball players in Northern Africa.[24]

On another side, when fatigue index is

taken as a criterion of performance at the RSA test, only VO2max and in seniors is the unique variable that significantly contributes to the prediction of RSA. Under these conditions, it is risky to consider fatigue index as a relevant criterion of appreciation for RSA in this population of handball players whose training level is rather low. A study on a wider and more representative sample of all handball players in the Republic of Benin will certainly make it possible to have more arguments for a final conclusion.

Apart from the interest that they present for the handball players and their trainers, the results of this study open some heuristic prospects. They particularly suggest the implementation, in the near future, of a study: 1) with a probabilistic representative sample of the whole population of Beninese handball players, in order to confirm the current data; 2) involving a record of the lower limbs' muscles EMG activity during the RSA test. It will allow to better understand the neuromuscular mechanisms which induce performance decrease in players; 3) whose design involves the assessment of counter movement jump (CMJ) in addition to that of squat jump, since the RSA test as shuttle-run requests the use of the braking capacities (muscular elasticity) of the lower limbs during direction change.

Limitation to the study

Although the data collected are of great importance, they present two limitations. The first relates to the impossibility to generalize the results to the whole population of amateur handball players, even to those from Sub-Saharan Africa. The second relates to the fact that the neuromuscular factors identified in the literature [7] as limiting for repeated sprint ability were not assessed in the current study.

Conclusions

The realization of this study was founded on the assumption that the factors contributing more to the prediction of RSA vary among age groups. The data recorded mainly confirm this assumption and highlight the high contribution of motor coordination in children and that of performance at the single sprint on 30 m in older subjects, *i.e.* in juniors and seniors. The results of the multivariate analysis confirm the data of the literature according to which, it is necessary to integrate the improvement of race speed into the strategies of development of repeated sprint ability[27]. They especially suggest that the elective development of race speed must be a priority after the age of 11-12. Before this age, most of the working time should be devoted to the development of motor coordination in handball players.

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