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Sweat rate of some professional football players during routine practice in a hot humid environment in Yenagoa, Bayelsa State, Nigeria

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Abstract
Training in hot and humid environments has profound effects on physical and health status of athletes. This study was aimed at evaluating the sweat rate of male and female professional football players in Yenagoa, a hot humid environment in Bayelsa State, Nigeria.120 participants were evaluated, consisting of 30 male and 30 female professional football players and 30 male and 30 female ‘‘active persons’’ who served as control. Sweat rate was calculated using the difference in pre and post exercise body weight adjusted for fluid intake and urine output during training. Fluid intake and urine output were monitored and recorded during the training period at 31.1^{0}C mean atmospheric temperature and 68% relative humidity. Mean value of quantitative data was compared at a significant level of $p<0.05$. Mean sweat rate was 2.14±0.04 litres/hour in male football players, 1.54±0.04 litres/hour in female football players, 1.32±0.04 litres/hour in male active persons and 0.98±0.03 litres/hour in female active persons. The sweat rate of male football players was significantly higher than that of male active persons. Similarly, sweat rate of female football players was significantly higher than that of the female active persons. Linear multiple regression model showed mean sweat rate was significantly higher in males than females [β = -0.25; p=0.01] and to significantly increase with increasing body surface area [β= 0.31; p=0.002] but significantly decreases with increasing age (β= -0.42; p= 0.001). Football players studied have a substantially high sweat rate which can predispose them to becoming dehydrated if sweat lost during training/competition is not properly replaced. Therefore, football players, team physicians and club administrators need to ensure proper replacement of lost fluids and prevent possible dehydration during exercise and competitions.

Keywords: athlete, dehydration, exercise, hydration, health, performance

1. Introduction

Athletes who train or compete in hot and humid environments may be predisposed to significant physical and health challenges resulting from fluid imbalance [1]. Football is a rigorous sport with high demands on energy and fluid reserves which must be adequately replaced subsequently [2]. Recent studies show majority of athletes start training already dehydrated and many do not adequately replace sweat losses during and after training [3]. A knowledge of personal sweating pattern can help an athlete plan fluid requirements taking into consideration environmental conditions, individual differences, intensity and duration of exercise [4]. Sweating is the main physiologic mechanism by which the body regulates body temperature especially when body heat generation exceeds loss by radiation and convection during exercise in the heat [5, 6]. Exercise in the heat causes increased sweating and if there is no commensurate fluid intake may result in some dehydration [7]. Humans can only survive body temperature greater than 41°C for short periods and protein denatures at a body temperature of 45°C [8]. Such elevated body temperature may result in heat illnesses such as cramps, exhaustion and stroke in athletes [8]. Although sweat evaporation is the major means of heat loss during exercise, other means include radiation, conduction, and convection [9-10]. An impairment of thermoregulation can lead to a rise in core body temperature from heat storage and inappropriate dissipation [7].

As environmental temperature and relative humidity rise sweat rate of exercising athletes increases [7]. Sweat rate indicates the amount of fluid loss and shows how much sweat the athlete loses per unit time [9]. The sweat rate for athletes in other environments have been previously reported to be in the range between 0.52 to 2.5 litres/hour [9]. However, the normal insensible fluid losses of about 450 ml/day can increase to 3 litres/hour during exercise in the heat [11]. Regular training increases sweat volume produced by increasing sensitivity of sweat glands [9]. Sweating in the acclimatized and well trained athletes occur earlier; therefore, athletes are likely to have higher sweat rate and are thus at higher risk of dehydration [5]. This makes fluid replacement modalities in the athlete imperative since excess sweating may lead to fluid loss and fluid deficits require adequate replacement to prevent dehydration and ensure optimal performance [9]. For athletes to maintain optimal hydration after training, it is recommended that adequate fluid replacement should be 100% to 150% of sweat loss in 4 to 6 hours [5, 12, 13].

Previous reports on the sweat rate of athletes in our environment has been relatively scanty, underscoring the need to evaluate the sweat rate of professional athletes in our environment. The aim of this study therefore was to evaluate the sweat rate of professional football players in a hot and humid environment in Yenagoa, Bayelsa State, Nigeria. This would provide information to assist coaches and sports physicians in recommending appropriate fluid replacement for football players and possibly other athletes in similar environments.

2. Materials and Methods

2.1 Study Area

The study was conducted in Yenagoa, the administrative, economic and political capital of Bayelsa, a state located in the south of Nigeria. The study was conducted during the dry season between January to February 2018. The climate of Yenagoa is tropical rainforest typical of the Niger Delta with ambient temperature ranging between 24°C and 33°C and average relative humidity of about 59% [14].

2.2 Ethical Approval

Ethical approval was obtained from our Institutional Research Ethics Committee vide a memorandum referenced UPH/R&D/REC/04. Subject participation was entirely voluntary. Informed consent was sought and obtained from each participant before recruitment; study was conducted in accordance with the Helsinki Declaration of 1975 as amended in 2000. Written approval was also obtained from the management of the football teams whose players were used for the study.

2.3 Participants

A total of 120 participants aged between 18 and 35 years were randomly selected for the study. This consisted of 60 professional football players (30 males and 30 females) and 60 active persons (30males and 30 females). All the active persons were apparently healthy with no evidence of metabolic or hematologic diseases likely to influence any of the parameters under investigation and served as control. All professional football players who reported any ill health or conditions that were likely to influence fluid and electrolyte balance were promptly excluded from the study. Pregnant participants were also excluded. Each participant responded to a simple questionnaire to obtain basic socio-demographic data.

2.4 Determination of height, weight, body mass index and body surface area

Height and weight were measured in meters (m) and kilogram (kg) respectively, with all participants barefooted and wearing light clothing, using a standard scale (seca model, Hamburg, Germany). The body mass index was calculated by dividing body weight in kilogram by the square of the height in meters (kg/m^2) [15]. Body Surface Area (BSA) was calculated using the Schlich formula as proposed respectively for both male and female subjects [16].

2.5 Experimental design

Participants were allowed a training session of a total of 2 hours consisting of a 15 minute warm-up period followed by two halves of 45 minutes of play; separated by a 15 minute half-time period. The mean atmospheric temperature and relative humidity all through the training period was 31.1°C and 68% respectively. Water was provided in individually labeled 1.5 litre containers with readily available refills. Participants were instructed to drink only from their assigned water containers; avoid washing their faces with the water and minimize any wastage as much as possible. Participants were also given containers to void urine to ensure accurate estimation of urine output during the entire session. The fluid intake and urine output of each of the players during training was monitored and recorded in a data sheet.

2.6 Determination of sweat rate

Using the formula described by Casa *et. al.,* 2000, [9] sweat rate was calculated as the sum of the difference between the pre-exercise and post-exercise body weight (converted to litres) and the total fluid intake and total urine output (both in litres) divided by the duration of exercise in hours.[9,17] The average human body density was considered to be 985 kg/m^3.

2.7 Statistical analysis

The results are presented in Tables 1 to 4 as mean±standard error of mean (SEM). Statistical significance was determined as appropriate using the student's *t*-test. Association between sweat rate, gender, body mass index and body surface area was determined using a linear multiple regression model. A p-value less than 0.05 was considered statistically significant.

3. Results & Discussion

Table 1: Age, anthropometric indices and sweat rate of all participants

	All professional footballers (n=60)	**Professional male footballers (n=30)**	**Professional female footballers (n=30)**	**All physically active subjects (n=60)**	**Physically active male subjects (n=30)**	**Physically active female subjects (n=30)**
Age (years)	23.10±0.45*	22.07±0.52	24.13±0.70^a	27.30±0.63*	28.00±0.94	26.33±0.91
Body mass index(kg/m^2)	22.75±0.30	22.83±0.32	22.51±0.50	23.33±0.57	23.60±0.56	22.53±0.57
Body surface area (m^2)	1.70±0.03	1.82±0.03^a	1.57±0.03	1.72±0.02	1.79±0.03^a	1.65±0.03
Sweat rate(l/hour)	1.84±0.38*	2.14±0.04^a	1.54±0.04	1.13±0.03*	1.32±0.04^a	0.98±0.03

* indicate significant differences in total population and ^{a}indicate significant gender differences at $p< 0.05$; all values are mean ± SEM

Table 1 shows values for age, body mass index (BMI), body surface area (BSA) and sweat rate of all participants: professional football players and active subjects. The mean age of all active persons: 27.30±0.63 years was higher than the mean age obtained for all professional football players: 23.10±0.45 years. In addition, the mean sweat rate of all professional football players: 1.84±0.38 litres/hour was also higher than the mean sweat rate of all physically active persons: 1.13±0.03 litres/hour. There were no significant differences in body mass index (BMI) and body surface area (BSA) between all active subjects and all professional football players. However, gender differences were found to exist in body surface area and sweat rate amongst professional football players and active subjects: male professional football players and male active subjects were found to have higher values of body surface area and sweat rate compared to their respective female counterparts; similarly, female professional football players were found to be older than their male counterparts. No gender differences were observed for age and body mass index amongst active persons and for body mass index amongst professional football players.

Table 2: Comparison of age, anthropometric indices and sweat rate of professional male football players and physically active male subjects

	All male subjects (n=60)	Professional male footballers (n=30)	Physically active male subjects (n=30)	Significant differences [*t*-test; p= significance level]
Age(years)	25.03±0.66	22.07±0.52	28.00±0.94	5.50; 0.001
Body mass index (kg/m^2)	23.22±0.32	22.83±0.32	23.60±0.56	1.19; 0.24
Body surface area (m^2)	1.71±0.02	1.82±0.03	1.79±0.03	0.53; 0.43
Sweat rate (l/hour)	1.73±0.06	2.14±0.04	1.32±0.04	13.84; 0.001

All values are mean ± SEM

Table 2 shows values for age, body mass index (BMI), body surface area (BSA) and sweat rate of all male participants: male professional football players and active male subjects. Mean age was found to be significantly higher amongst active male subjects: 28.0±0.90 years compared to professional male football players: 22.07±0.52 years (p=0.001). There were no significant differences in body mass index and body surface area between professional male football players and active male subjects (p=0.24). In contrast, mean sweat rate was significantly higher amongst professional male football players: 2.14±0.04 litres/hour compared to the active male subjects: 1.32±0.04 litres/hour (p=0.001).

Table 3: Comparison of age, anthropometric indices and sweat rate of professional female football players and physically active female subjects

	All female subjects (n=60)	Professional female footballers (n=30)	Physically active female subjects (n=30)	Significant differences [*t*-test, p=significance level]
Age(years)	25.23±0.58	24.13±0.70	26.33±0.91	[1.93, 0.06]
Body mass index (kg/m^2)	22.60±0.38	22.51±0.50	22.53±0.57	[0.17, 0.86]
Body surface area(m^2)	1.61±0.02	1.57±0.03	1.65±0.03	2.42; 0.02
Sweat rate(L/hour)	1.26±0.04	1.54±0.04	0.98±0.03	[10.60, 0.001]

All values are mean ± SEM

Table 3 shows values for age, body mass index (BMI), body surface area (BSA) and sweat rate of all female participants: female professional football players and active female subjects. As seen amongst male participants, the mean sweat rate was significantly higher amongst female professional football players: 1.54±0.04 litres/hour compared to active female subjects: 0.98±0.03 litres/hour (p=0.001). No significant differences were observed for age and body mass index amongst the female groups: furthermore, consistent with the male pattern both values were higher for active female subjects as compared to female professional football players. This is unlike the pattern observed amongst male subjects where significant differences were observed for age between professional male footballers and active male subjects. However, unlike the pattern observed amongst males, active female subjects were found to have significantly higher values of body surface area: 1.65±0.03 m^2 compared to professional female football players: 1.57±0.03 m^2 (p=0.02).

Table 4: Multiple regression model of sweat rate with sex, age, body mass index (BMI) and body surface area (BSA)

Model	Unstandardized coefficients		Standardized coefficients β	t value	p value
	B	Standard error			
Constant	1.16	0.54		2.14	0.04
Sex	-0.24	0.09	-0.25	2.62	0.01
Age	-0.04	0.009	-0.42	4.89	0.001
Body mass index	0.01	0.01	0.07	0.81	0.42
Body surface area	0.86	0.28	0.31	3.12	0.002

p= significance value

Table 4 shows a linear multiple regression model showing the influence of sex, age, body mass index (BMI) and body surface area (BSA) on sweat rate amongst our subjects. Amongst our subjects, multiple regression models suggest that overall sweat rate was significantly influenced by age, gender and body surface area but not by body mass index. Mean sweat rate was significantly higher in males than female (β=-0.25; p=0.01) and significantly increase with increasing body surface area (β=0.31; p=0.002), but significantly decreases with increasing age (β= -0.42; p=0.01). However, mean sweat rate was not significantly affected by body mass index (β=0.07; p=0.42).

Findings from our study show that sweat rate of professional football players evaluated in the study environment was relatively high with the football players losing over 1.5 litres/hour of sweat during practice. Yenagoa, Bayelsa State being the study area with a maximum temperature of 33^{0}C and average Relative humidity of 59^{0}C falls under the ‘‘Extreme Caution’’ category of Heat Index with Heat index range of 90^{0}F to 103^{0}F. At this range heat stroke, heat cramps, or heat exhaustion are possible with prolonged exposure and/or physical activity [18]. This underscores the need for adequate fluid replacement during and after training. Although findings in this study are similar to findings in other environments with similar environmental conditions, this study also revealed that sweat rate is significantly increased with increasing body surface area.

Results of present study is in agreement with Maughan *et al*., 2004, who reports similar sweat rate of 2033 ± 413 ml in a male United Kingdom premier league football team [19]. Al-Jaser and Hasan (2006) reported a much higher mean sweat loss of 3.1 ± 1.4 litres in a 90minute training of male Kuwaiti football players V. The difference in sweat rate could be due to much higher temperature of 45.6 ± 2^{0}C in Al-Jaser and Hassan (2006) compared to 31.1^{0}C in the present study. Gibson *et al*., 2012, and Kilding *et al*., 2009, both reported lower sweat rates in their studies [21, 22]. Gibson *et al*., 2012, reported an overall sweat loss of 0.69 ± 0.54 litres and Kilding *et al*., 2009, reported sweat rate of 0.5 ± 0.20 litres/hour and 0.43 ± 0.18 litres/hour in female football players after two friendly matches respectively. The differences can be attributed to differences in environmental temperature which was lower in Gibson *et al*'s study (9.8^{0}C) and cooler in Kilding *et al*., 2009. Ersoy *et al*., 2016, reported a sweat rate of 582.3 ± 232 ml/hour after evaluating male youth footballers [23]. This result also differs from the present study as it is lower and the difference could be due to a much lower temperature of 21.3 ± 2.5^{0}C in the studies of Ersoy *et al*., 2016.

The mean sweat rate was significantly higher in the professional footballers' compared to that of the physically active persons. The difference could be due to higher intensity and level of training in the footballers. In addition, mean sweat rate was significantly higher in males than females and this perhaps is as a result of higher body surface area in the male, higher intensity of training and possibly the effect of the male sex hormones on skin appendages.

4. Conclusion
The sweat rate of professional Football players in the study environment, Yenagoa, Bayelsa State, Nigeria is substantially high. Such significant sweat losses if not adequately replaced can lead to decrease in athletes' performance [24, 25] as fluids provide the needed water to prevent dehydration and also aid exercising muscles [11, 19]. Footballers, team doctors and football administrators therefore need to take necessary steps to ensure adequate fluid replacement of athletes during training and competition in hot humid environments.

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6. References
1. Fallowfield JL, Williams C, Booth J, Choo BH, Growns S. Effect of water ingestion on endurance capacity during prolonged running. J Sports Sci. 1996; 14(6):497-502. PMID: 8981288.
2. Hawley JA, Dennis SC, Noakes TD. Carbohydrate, fluid, and electrolyte requirements of the soccer player: a review. Int J Sport Nutr. 1994; 4(3):221-236. PMID: 7987358.
3. Maughan RJ, Shirreffs SM. Development of individual hydration strategies for athletes. Int J Sport Nutr Exerc Metab. 2008; 18(5):457-472. PMID: 19033609.
4. McGregor SJ, Nicholas CW, Lakomy HK, *et al*. The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. J Sports Sci. 1999; 17(11):895-903. PMID: 10585169.
5. Brouns F. Heat--sweat--dehydration--rehydration: a praxis oriented approach. J Sports Sci. 1991; 9:143-152. PMID: 1895360.
6. Convertino VA, Armstrong LE, Coyle EF, Mack GW, Sawka MN, Senay LC Jr, *et al*. American College of Sports Medicine position stand. Exercise and fluid replacement. Med Sci. Sports Exerc. 1996; 28(1):1-7. PMID: 9303999.
7. Sawka MN, Montain SJ. Fluid and electrolyte supplementation for exercise heat stress. Am J Clin Nutr. 2000; 72(2):564S-572S. doi: 10.1093/ajcn/72.2.564S.PMID: 10919961.
8. Bracker MD. Environmental and thermal injury. Clin Sports Med. 1992; 11(2):419-436.
9. Casa DJ, Armstrong LE, Hillman SK, Montain SJ, Reiff RV, Rich BS, *et al*. National Athletic Trainers' Association Position Statement: Fluid Replacement for Athletes. J Athl Train. 2000; 35(2):212-224. PMCID: PMC1323420. PMID: 16558633.
10. Rodriguez NR, DiMarco NM, Langley S. Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. J Am Diet Assoc. 2009; 109(3):509-527. PMID: 19278045.
11. American College of Sports Medicine. American College of Sports Medicine position stand. Exercise and fluid replacement. Med Sci. Sports Exerc. 2007; 39(2):377-390. PMID: 17277604.
12. Maughan RJ, Leiper JB. Limitations to fluid replacement during exercise. Can J Appl Physiol. 1999; 24(2):173-187. PMID: 10198143.
13. Shi X, Gisolfi CV. Fluid and Carbohydrate replacement during intermittent exercise. Sports Med. 1998; 25(3):157-172. PMID: 9554027.
14. Nigerian Meteorological Agency (NiMet). Average Temperature and Relative humidity of Yenagoa, Bayelsa State, 2018. https://nimet.gov.ng. (Accessed 19 January 2018).
15. Macdonald FC. Quetelet index as indicator of obesity. Lancet. 1986; 1(8488):1043. PMID: 2871329.
16. Schlich E, Schumm M, Schlich M. 3-D Body scan alsanthropometrisches Verfahrenzur Bestimmung der spezifischen Korperoberflache. Emahrungs Umschau. 2010; 57:178-183.
17. Phillips SM, Sykes D, Gibson N. Hydration Status and Fluid Balance of Elite European Youth Soccer Players during Consecutive Training Sessions. J Sports Sci. Med. 2014; 13(4):817-822. PMID: 25435774. PMCID: PMC4234951.
18. United States National Oceanic and Atmospheric Administration/ National Weather Service National Centre for Environmental Prediction Weather Centre 5830. University Research Court College Park, Maryland 20740. Weather Prediction Centre Web Team (2019, March 23). Heat Index. Retrieved from www.noaa.gov.
19. Maughan RJ, Merson SJ, Broad NP, *et al*. Fluid and electrolyte intake and loss in elite soccer players during training. Int J Sport Nutr Exerc Metab. 2004;

14(3):333-346. PMID: 15256693.

20. Al-Jaser TA, Hasan AA. Fluid loss and body composition of elite Kuwaiti soccer players during a soccer match. J Sports Med Phys Fitness. 2006; 46(2):281-285. PMID: 16823359.
21. Gibson JC, Stuart-Hill LA, Pethick W, Gaul CA. Hydration status and fluid and sodium balance in elite Canadian junior women's soccer players in a cool environment. Appl Physiol Nutr Metab. 2012; 37(5):931-937. doi:10.1139/h2012-073. PMID: 22803782.
22. Kilding AE, Tunstall H, Wraith E, Good M, Gammon C, Smith C. Sweat rate and sweat electrolyte composition in international female soccer players during game specific training. *Int J Sports Med*. 2009; 30(6):443-447. doi:10.1055/s-0028-11059. PMID: 19288391.
23. Ersoy N, Ersoy G, Kutlu M. Assessment of hydration status of elite young male soccer players with different methods and new approach method of substitute urine strip. J Int Soc Sports Nutr. 2016; 13(1):34. doi: 10.1186/s12970-016-0145-8. PMCID: PMC5010764. PMID: 27594812.
24. Bandelow S, Maughan R, Shirreffs S, Ozgünen K, Kurdak S, Ersöz G *et al*. The effects of exercise, heat, cooling and rehydration strategies on cognitive function in football players. Scand J Med Sci Sports. 2010; 20(3):148-160.
25. Ali A, Gardiner R, Foskett A, Gant N. Fluid balance, thermoregulation and sprint and passing skill performance in female soccer players. Scand J Med Sci Sports. 2011; 21(3):437-445.