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Post-match hydration in west African wheelchair basketball athletes: A preliminary study

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Abstract

Wheelchair basketball is a major paralympic sport that's getting more and more popular across sub-Saharan Africa, mainly in Benin and Togo. It is a high-intensity, intermittent sport that subjects athletes to demanding physiological and environmental conditions. The objective of this study was to assess the hydration status of wheelchair basketball players after an international match, conducted in a hot and humid sub-Saharan climate, based on changes in the variation in urine specific gravity (USG) and urine color. A prospective cohort of 23 international players was evaluated (mean age: 32 ± 7.5 years; competitive experience of 7.7 ± 4.6 years). Their mean body mass index (BMI) was 22.3 ± 4.1 $kg{\cdot}m^{-2}$. Participants were monitored during an international wheelchair basketball camp in Porto-Novo, Benin. Urine samples were analyzed using reagent and color charts at three key intervals: baseline (pre-game), immediately post-game, and 24 hours post-game. To isolate the physiological effects of match play, participants were stratified into two main groups: Players Group (N=15) and Control Group (N=8). Active players showed a significant post-game increase in urine specific gravity (USG) (ranging across subgroups from 1.020 ± 0.005 to 1.027 ± 0.003; $p<0.01$), whereas the control group remained stable (1.023 ± 0.003). Before the match even began, urine color tests had indicated signs of dehydration (light-yellow) in most players. In fact, 6 of the 7 players in the Control Group and 5 out of 8 players from the Players Group had light-yellow urine. Fluid intake, quantified by residual volume measurement, ranged from 0.14 L (controls) to 0.97 L (high-playtime players). This preliminary study reveals a high prevalence of pre-exercise hypohydration and highlights inadequate rehydration strategies among players during and after competitive events. The international match induced an acute fluid deficit. While average USG values returned to baseline within 24 hours, visual urine color profiling suggested a multi-stage recovery process for individual players. Implementing routine non-invasive hydration monitoring such as urine color charts, alongside tailored hydration protocols, is critical to safeguard athletes' health and optimize inclusive performance in tropical regions.

Keywords: Wheelchair Basketball, sub-Saharan Africa, Urine specific gravity, Inclusive Development, Hydration status, Benin.

Introduction

Disability sport has transitioned from a clinical tool to a core component of a global inclusive development and social integration framework (Molina et al., 2024). A large majority of West African athletes consider participation in para-sports to be a major driver of empowerment and the acceptance of disability (Ian, 2015). However, sustaining high-level athletic performance in wheelchair sports requires significant cardiovascular and muscular endurance, which is heavily challenged under environmental stress. However, to maintain elite performance in wheelchair sports, athletes need strong cardiovascular and muscular endurance, but environmental stress makes it much more challenging. In some parts of sub-Saharan Africa, like Benin and Togo, there is a frequent rise of temperature above 35^0C with humidity over 80%. Such extreme conditions act as a severe environmental stressor that increases sweating and fluid loss. This can quickly disrupt cellular function (Robin et al. 2024; Casa et al. 2012). As a result, many players begin games or training already dehydrated (Philippe, 2011). This poses a serious risk and makes it harder to control body temperature, increasing cardiovascular strain and decreasing performance quality during long games (Weissland et al., 2015).

Despite these risks, most research on hydration still focuses on able-bodied athletes, leaving a considerable gap in adaptive athletics. Para-athletes encounter unique physiological challenges. Athletes with spinal cord injuries, for example, go through disrupted automatic thermoregulation and sweat less below the lesion level. They may not even feel thirsty as needed. Wheelchair basketball has also become very demanding. With the recent progress in tactics, including full-court pressing, quick short-clock play, and constant wheelchair maneuvering, athletes now face much higher physical and cardiovascular demands than before (Pierret, 2012). Consequently, relying on voluntary fluid intake (*ad libitum*) often fails to prevent significant plasma volume depletion during match play.

Furthermore, field research in developing nations faces major logistical hurdles: restricted access to advanced biomedical laboratories, high costs of precise hydration monitoring tools (such as osmometers), and material limitations, especially the reliance on heavy, non-standardized wheelchairs (averaging 11.5 kg), which drastically increase metabolic cost (Ouedraogo et al., 2022).

Therefore, this preliminary study aimed to determine the impact of an international wheelchair basketball match, played under tropical conditions, on the longitudinal hydration status of West African players. To this end, we monitored changes in urine specific gravity (USG) and urine color (U_{COL}) across three key time points—pre-match, immediately post-match, and 24 hours post-match—in order to provide accessible data to optimize hydration strategies in resource-limited settings and to promote evidence-based sports guidelines that support the sustainable and inclusive development of adaptive athletics in local communities. We hypothesized that match play under tropical conditions would induce a significant acute increase in USG compared to baseline and that 24-hour post-match values would return to pre-match levels.

Methods

Study design and population

This prospective study was conducted in Porto-Novo, Benin, during an international wheelchair basketball tournament held as part of the *'Enfants du Bénin debout camp'*. A cohort of 23 elite wheelchair basketball players from the national teams of Benin and Togo was recruited via purposive sampling. All participants provided free, written, and informed consent prior to data collection. Athletes taking medications known to alter renal function or those with pre-existing renal pathology were excluded.

The Laboratory of Biomedical Analysis «Toxi-Labo» located in Cotonou (Benin), and the Research Unit: Disabilities, Adapted Physical Activities, and Rehabilitation (UR DAPAR) of the National Institute of Youth, Physical Education, and Sport (INJEPS) of the University of Abomey-Calavi (UAC) also served as research settings.

Data collection and experimental protocol

Following inclusion, clinical (body temperature, heart rate) and anthropometric data were collected 1 hour before the start of the match. A *Dighealth* electronic thermometer (32°C to 42°C) was used to determine body temperatures by contact in the axillary fossa for 5 minutes, with the arm held close to the abdomen (Flamant et al., 2010). Cardiovascular strain was tracked throughout the match using Polar heart rate monitors. Microclimate metrics (ambient temperature and relative humidity) were logged using a *Testo 810* infrared thermometer.

During the game, each player was provided with five 0.5-liter bottles of water, uniformly branded and individually labeled with the players' names and jersey numbers. These were all mineral water of the same brand. Each player drank the water intended for them, and all bottles were removed at the referee's final whistle and put away. Fluid consumption was not measured directly. To account for field constraints in this setting, individual fluid intake was indirectly quantified post-match by measuring the residual fluid volume remaining in the assigned personal bottles. To find out how much water each athlete actually drank during the game, we considered the quantity that was given to them before the match and then subtracted whatever amount was left in the bottles after the game.

Urine samples were collected in sterile and labeled containers at three different levels: 15 minutes before the match (baseline); immediately post-match (acute impact); the following morning using the first void (24-hour recovery phase).

These anonymously labeled bottles were sent directly to the Biomedical Laboratory for analysis. Urine Specific Gravity (USG) was measured with reagent strip testing (DUS-10). At the same time, urine color (UCOL) was assessed using the validated 8-point linear scale from Armstrong et al. (2010; 1994). This visual scale classifies hydration status based on urine pigment: scores of 1-3 mean euhydration, scores of 4-5 mean dehydration, and scores of 6-8 point to severe hyperhydration. This gives a reliable field estimate of hydration without lab testing. To minimize observer bias, all of the evaluations took place in a dedicated room under uniform white light and a white background and were reviewed by two researchers to ensure accuracy.

Group stratification

To examine the specific physiological impact of a match, participants were divided into two main groups:

- Players group (N=15): athletes actively engaged in match play;
- Control group (N=8): roster athletes who did not log active playing time during the match

For the 24-hour follow-up, the players group was divided based on sample compliance and sample availability:

- Players with complete follow-up (PCF, N=8): players who provided samples at all the three time points.
- Players with incomplete follow-up (PIF, N=7): players who provided only baseline and immediate post-match samples.

To determine individual playing time, data were collected on the substitutions and ejections based on table officials. These data were used to obtain the actual time spent by each player on the court. Ethical approval for this study was granted by the Sectoral Scientific Committee on Science and Technology of Physical and Sports Activities (CSS-STAPS) at the University of Abomey-Calavi (Ethics approval ID:0714-2019/UAC/INJEPS/CSS-STAPS/SP).

Data processing and analysis

All statistical analyses were conducted using SPSS (version 21). Considering the fact that the sample size was small and the violation of normality assumptions based on the Shapiro-Wilk test, non-parametric tests were used. Descriptive statistics were reported based on variable type. The Friedman test was used to assess differences between the various measurement time points, and the Wilcoxon test was used for post hoc comparisons. Inter-group differences were evaluated using Mann-Whitney U tests. For all statistical analyses, the significance level was set at $p < 0.05$.

Results

Characteristics of the wheelchair basketball players (N = 23)

The study sample consisted of 22 male and 1 female participants. The mean age of the participants was 32.0 ± 7.5 years (range: 19–43 years). Their mean body mass index (BMI) was 22.3 ± 4.1 $kg \cdot m^{-2}$, and they had an average of 7.7 ± 4.6 years of wheelchair basketball experience (Table 1). During the international fixture, the mean ambient temperature was 29.1 ± 0.1 °C. The players' overall mean baseline body temperature (BT) was 36 ± 0.4 °C, and their mean heart rate (HR) was 78.5 ± 8.0 bpm.

The game wheelchairs weighed between 11 kg and 15 kg (mean: 12.9 kg). A comparison between groups revealed that the Players Group (N=15) was significantly older (37 ± 5.6 vs. 24.5 ± 2.9 years; $p < 0.05$) and had more playing experience (10.1 ± 4 vs. 3.4 ± 1.9 years; $p < 0.05$) than the control group (N = 8). No significant baseline differences were observed for HR (79.5 ± 9.2 vs. 78 ± 7.6 bpm) or BT (35.9 ± 0.6 °C vs. 36.1 ± 0.4 °C). Poliomyelitis was the most prevalent disability among the participants (86.9%), followed by paraplegia (8.6%) and limb amputations (4.3%).

Table 1. Baseline characteristics of the study cohort (N = 23).

Variables		Not having played (N1 = 8) (Control group)		Having played (N2 = 15)		Total sample, N = 23		Frequency (%)
		m ± s	Min – Max	m ± s	Min – Max	m ± s	Min – Max	
Age		24.5 ± 2.9	21.0 - 29.0	37.0 ± 5.6	19.0 - 43.0	32.0 ± 7.5	19.0 - 43.0	
BMI (kg/m²)		23.4 ± 5.3	18.0 - 35.4	21.7 ± 3.4	16.3 - 27.6	22.3 ± 4.1	16.3 - 35.4	
HR (bpm)		78 ± 7.6	64.0 - 90.0	79.5 ± 9.2	62.0 - 92.0	78.5 ± 8.0	62.0 - 92.0	
BT (°C)		35.9 ± 0.6	34.6 - 36.6	36.1 ± 0.4	35.3 - 36.7	36 ± 0.4	34.6 - 36.7	
T_{Amb} (°C)						29.1 ± 0.1	29.0 - 29.5	
Experience (years)		3.4 ± 1.9	1.0 - 7.0	10.1 ± 4.0	3.0 17.0	7.7 ± 4.6	1.0 - 17.0	
Chair weight (kg)		12.8 ± 1.5	11.0 - 14.0	13 ± 1.5	11.0 - 15.0	12.9 ± 1.5	11.0-15.0	
Type of Handicap	Poliomyelitis	7		13		20		86.9%
	Amputees	0		1		1		4.3%
	Paraplegics	1		1		2		8.6%

m: mean; s: standard deviation; N: effective; Min: minimum; Max: maximum, BMI: Body Mass Index; HR: heart rate; BT: body temperature; T_{Amb}: ambient temperature

Acute physiological and biometric variations

In the non-playing group (N = 8), body mass index did not vary significantly between the pre- and post-match ($p > 0.05$, Table 2). However, their heart rate increased significantly from 78.0 ± 7.6 bpm to 88.6 ± 12.9 bpm ($p = 0.012$), and their body temperature rose significantly from 35.91 ± 0.6 to 36.4 ± 0.2 °C ($p = 0.017$).

In contrast, the Players Group (N = 15) also demonstrated a significant post-match increase in heart rate (79.5 ± 9.2 bpm to 94.6 ± 15.8 bpm; $p = 0.002$).Body temperature, however, increased non-significantly (36.1 ± 0.4 °C to 36.4 ± 0.5 °C; $p = 0.062$). No significant acute modifications in BMI were observed for the active players ($p > 0.05$).

Table 2. Acute anthropometric and cardiovascular responses pre- and post-match

Variables	Not having played (N1 = 08) (Control group)			Having played (N2 = 15)		
	Pre-game	Post-game	p-value	Pre-game	Post-game	p-value
	m ± s	m ± s		m ± s	m ± s	
BMI (kg/m²)	23.4 ± 5.3	23.4 ± 5.3	0.593	21.7 ± 3.4	21.7 ± 3.4	0.803
BT (°C)	35.9 ± 0.6	36.4 ± 0.2	0.017	36.1 ± 0.4	36.4 ± 0.5	0.062
HR (bpm)	78.0 ± 7.6	88.6 ± 12.9	0.012	79.5 ± 9.2	94.6 ± 15.8	0.002*

m: mean; s: standard deviation; N: effective; BMI: body mass index; HR: heart rate; BT: body temperature; *: statistically significant difference to $p < 0.05$

Hydration status of players as a function of time played

Descriptively, voluntary *ad libitum* fluid intake increased alongside effective playing time. The control group consumed an average of 0.14 L of water. In contrast, active players who clocked between 10 and 19 minutes of playing time consumed 0.37 L, those with 20-29 minutes of playing time consumed 0.52 L, and players with maximal game exposure (30-40 minutes) consumed an average of 0.97 L (Figure 1).

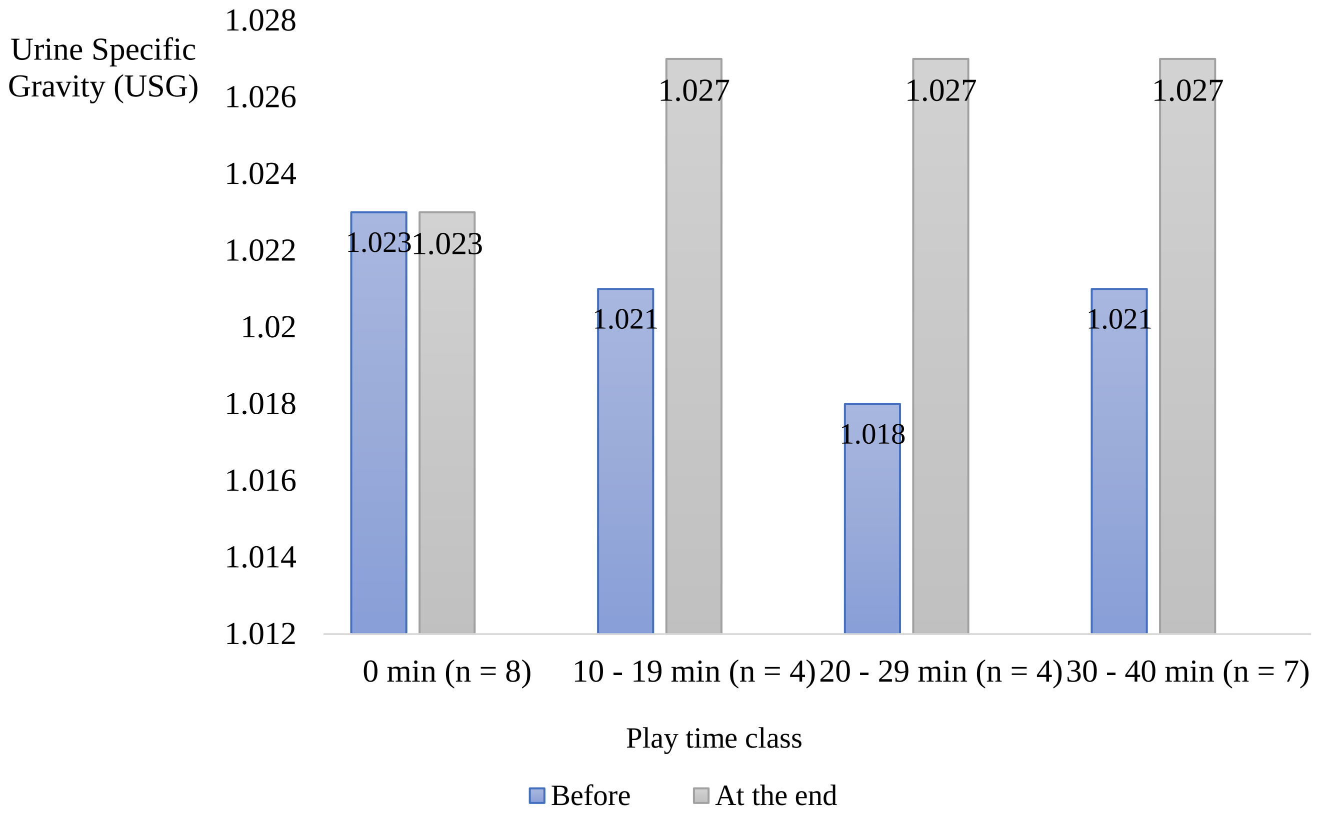

Figure 1. Post-match evolution of Urine Specific Gravity (USG) across playing time classes (Note: Due to the very small sample sizes within each localized playing time division (N=4 to 8), formal inferential inter-group statistical comparisons (e.g., Kruskal-Wallis test) were not computed across classes to avoid power inflation, and trends are limited to descriptive analysis).

Longitudinal urine specific gravity (USG)

In the control group (N = 8), urine specific gravity stayed unchanged before and after the match (1.023 ± 0.003 vs. 1.023 ± 0.002; $p = 0.300$). This shows that environmental conditions without physical activity have no immediate effect on hydration (Table 3). However, both active payer subgroups showed a significant increase in USG. In the incomplete follow-up group (PIF, N = 7), USG increased from 1.020 ± 0.005 to 1.027 ± 0.003 ($p < 0.001$). In the complete follow-up group (PCF, N = 8), USG increased from 1.020 ± 0.007 to 1.026 ± 0.002 ($p = 0.010$). At the 24-hour mark, the PCF subgroup demonstrated a significant decrease in USG (1.026 ± 0.002 vs. 1.021 ± 0.002; $p = 0.05$), successfully returning to their baseline physiological profile.

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Table 3. Variation in urine specific gravity (USG)

Variables	Not having played (N1 = 08) (Control group)	p-value	PIF sub-group (N = 7)	p- value	PCF sub-group (N = 8)	p- value
	m ± s		m ± s		m ± s	
Pre-match	1.023 ± 0.003		1.020 ± 0.005		1.020 ± 0.007	
Immediately post-match	1.023 ± 0.002	0.3	1.027 ± 0.003	0.000*	1.026 ± 0.002	0.01*
24-hour Post-Match					1.021 ± 0.002	0.05*†

m: mean; s: standard deviation; *: statistically significant difference compared to baseline ($p < 0.05$); †: statistically significant difference between post-match and 24-hour post-match ($p < 0.05$); PIF: Players - Incomplete Follow-up**,** PCF: Players - Complete Follow-up

Urine color (UCOL) distribution

Active players exhibited concentrated urinary profiles prior to the match, with dehydrated (light-yellow) or hyper-dehydrated (dark yellow) statuses characterizing 6 out of 7 players in the PIF subgroup and 6 out of 8 players in the PCF subgroup (Table 4). Immediately, post-match, despite acute fluid loss, 6 out of 7 players from the PIF subgroup and all 8 players from the PCF subgroup shifted toward or maintained a light-yellow profile. At the 24-hour follow-up, 7 out of 8 players from the PCF subgroup presented a light-yellow or dark-yellow profile, reflecting the standard concentrated physiological pattern for first morning urine voids.

Table 4. Longitudinal distribution of players' urine color profiles

Variables	PIF sub-group (N=7)		PCF sub-group (N=8)		
	Pre-game	Post-game	Pre-game	Post-game	24 hours
Colorless (hydrated)	1	0	2	0	0
Light yellow (dehydrated)	4	6	5	8	7
Dark yellow (hyper dehydrated)	2	1	1	0	1

N: effective, PIF: Players - Incomplete Follow-up, PCF: Players - Complete Follow-up

Discussion

Pre-match hydration status

The objective of this study was to investigate changes in the longitudinal hydration status of elite West African wheelchair basketball players following an international match played in a hot and humid environment, primarily through urine specific gravity (USG) variations and secondarily by urine color (U_{COL}) distribution.

Our findings revealed that USG underwent significant variations only in the subgroup of players who actively played in the game. The baseline USG of these players stood at an average of 1.020, which rose acutely increased to 1.026 ± 0.002 (PCF subgroup) and 1.027 ± 0.003 (PIF subgroup) immediately post-match. In sports science, hydration is categorized into two levels: euhydration or normal hydration (USG 1.010-1.020) and hypohydration or dehydration (USG >1.020) (Lopez et al. 2024; Klimesova et al., 2022; Casa et al., 2010; Volpe et al., 2009). Based on that, our baseline results indicate that West African para-athletes began the international match already close to dehydration. By the end of the game, this progressed to severe acute hypohydration. This post-match rise in urine concentration aligns with previous research in elite sports (Adams et al., 2021; Wardenaar et al., 2021), which shows that basketball players dehydrate more than players of other sports because of the intermittent, high-intensity nature of the game. Nevertheless, the average pre-game USG (1.020) was lower than baseline values reported in similar tournament studies, where athletes started with USG between 1.023 and 1.025.

Acute hydration impact and mechanical load

In addition to the pre-match dehydration observed in our participants, there are some other factors that may explain these differences and the acute hydration stress observed during a single match. These include differences in the characteristics of the participants between studies, the athletes' specific physical impairments, the high metabolic requirements of elite competition, and the complex biomechanics related to wheelchair basketball. Moreover, our players' game wheelchairs weighed an average of 12.9kg, which is considerably heavier than the 11.5kg average reported in earlier regional studies (Ouedraogo et al., 2022). Due to the logistical difficulty of directly measuring oxygen consumption (VO_2), whole-body sweat rates, or energy expenditure in the field, the physiological impact of wheelchair weight remains partly speculative, but such biomechanical demands logically accelerate metabolic heat production.

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Southern Benin (Porto-Novo) has a tropical climate with temperatures approaching 30°C and high humidity. In such conditions, the heat produced by a player during a game caused heavy sweating. This overwhelmed the renal fluid preservation mechanisms and led to very concentrated post-match urine. It is recognized that heat and humidity are factors that can impair sports performance (Hargreaves and Febbraio, 1998).

Importantly, *ad libitum* water consumption during the match failed to mitigate this post-match increase in USG. Although basketball inherently provides many opportunities to drink due to the proximity of fluids and the large number of breaks (time-outs, halftimes, substitutions) (Bloxham et al., 2001), players did not consume enough water even though they had water bottles available and enough opportunities to hydrate. The post-game elevation in urine concentration is consistent with the small amount of fluid consumed (0.97 L at most). The data suggests that the amount of water consumed depends on the game's duration. It is possible that players only feel the need to drink when they perceive the sensation of thirst. However, the sensation of thirst is usually less than the water deficit when dehydration occurs. Dehydration can reach 2% to 3% of body mass before the thirst mechanism is triggered (Deshayes, 2022). Players should not wait until they feel thirsty before hydrating. Fluid replacement remains a challenge for para-athletes because of their intense physical commitment.

Control group environmental dynamics

Interestingly, the control group showed an important increase in both heart rate and body temperature before and after the game, even though they did not play. This was probably caused by the high temperature and emotional stress from watching the match. It is also worth mentioning that the control group was not tested in a standardized, temperature-controlled setting. This limitation must be acknowledged as a logistical challenge of this study.

24-hour recovery kinetics and field monitoring tools

An assessment of the hydration status of the same data has also been done using urine color (U_{COL}). The cross-biological validity of U_{COL} *against quantitative USG has been firmly established across diverse athletic populations* (Kavouras et al., 2016), rendering it a highly reliable, low-cost field screening tool where advanced laboratory infrastructure is absent. Colorless urine is a sign of good hydration; light yellow urine is a sign of dehydration, and dark yellow urine is a sign of extreme dehydration. The Players - Incomplete Follow-up subgroup (N=7) and the Players - Complete Follow-up subgroup (N=8) started the match with concentrated profiles (4 out of 7 and 5 out of 8 presenting light yellow urine, respectively). This descriptive proportion increased at the end of the match (6 out of 7 and 8 out of 8, respectively) and remained elevated 24 hours after the match for 7 out of 8 in the complete follow-up subgroup. While this trend could visually suggest a slow return to a fluid balance, it must be carefully contextualized. Because these samples consisted of the first morning urine void, they are naturally and physiologically highly concentrated due to a standard nocturnal fluid restriction. This interpretation is further validated by the fact that their quantitative USG values significantly dropped back to baseline (1.021 ± 0.002) in Table 3. Therefore, these data should not be overinterpreted as a definitive persistent fluid deficit, but rather as an expected physiological pattern that indicates a gradual and multistage return to baseline hydration levels.

Limitations of the study

Despite the novel insights provided regarding para-athletes in sub-Saharan Africa, several methodological limitations must be acknowledged. First and foremost, the total sample size is small (N=23), which inherently restricts the generalizability of our findings. The near-exclusively male composition of this sample (22/23 participants) limits the extrapolation of findings to female para-athletes, who may differ in thermoregulatory responses and sweat rates.

This cohort was further fragmented for analytical purposes into an active players group (N=15) and a non-playing control group (N=8). Furthermore, longitudinal 24-hour hydration tracking could only be completed for a subgroup of players (PCF subgroup, N=8). The sample size used in the course of this study was so small and split into groups. So, it is more difficult to detect real differences and increases the risk of missing important effects (Type II errors). As a result, our conclusions from the longitudinal data are weak, and so the observed trend should be treated with caution. We needed these subgroups to clearly identify the match-related effects. At the same time, they limited our capacity to draw firm conclusions about the 24-hour recovery.

Second, because of logistical and material constraints in this resource-limited setting, the calculation of fluid intake was made indirectly from residual bottle volumes instead of using more accurate gravimetric measurements standard for calculating exact sweat rates. As we did not take nude body mass measurements before and after the match, we could not determine individual sweat rates per hour or express fluid loss as a percentage of body mass, which is an important measure for assessing clinical risk. Moreover, the use of reagent strips for urine specific gravity (USG), although highly practical and accessible for field research in developing regions, offers less precision than digital refractometry. Furthermore, strict controls over pre-game confounding variables- such as a standardized diet, physical exertion tracking, and prior 24-hour fluid intake- were not implemented, introducing potential confounding factors. Future studies utilizing larger, multi-center cohorts and gold-standard hydration biomarkers are critically needed to validate these preliminary observations and firmly guide international para-sport policies in tropical environments. Furthermore, strict controls over pre-game variables -such as standardized diet and prior 24-hour fluid intake- were not implemented, introducing potential confounding factors. Additionally, due to the cohort size, formal statistical correlation analyses (Pearson or Spearman coefficients) between playing time, fluid volume, and USG changes could not be robustly computed, limiting our capacity to confirm these descriptive trends statically.

Conclusions

This preliminary study demonstrates that international wheelchair basketball is played in a hot and humid sub-Saharan environment, placing para-athletes at high risk of severe and prolonged dehydration. Poor hydration before matches and insufficient rehydration during and after play make the fluid deficit worse. With heavy wheelchairs and a hot local climate, drinking only when they are thirsty is not enough. For adaptive sports in Africa to grow safely, organizations and coaches should adopt structured hydration protocols instead of ad libitum drinking. A urine color chart is a low-cost tool to monitor hydration in resource-limited contexts. These guidelines and monitoring methods should be shared with the International Wheelchair Basketball Federation and the National Para-Sports Federations of Benin and Togo. This will help to develop policies that improve safety and performance. Future studies should aim to measure exact sweat rates and examine how differences in wheelchair weight impact the metabolic and thermoregulatory loads on African para-athletes.

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Conflicts of interest

The authors declare no conflicts of interest.

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