European Review for Medical and Pharmacological Sciences 2022; 26: 6896-6903

Evaluation and education of hydration and sodium status in a cool environment among Chinese athletes

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Abstract. – OBJECTIVE: The aim of the study was to find the significance of several factors with parameters of urine tests and blood tests. Finally, we aimed at evaluating the percentage of athletes from the study sample regarding their hydration level.

SUBJECTS AND METHODS: The current study is the prospective type and was conducted on Chinese athletes between June 2021 to April 2022. The study was done in 2 parts for obtaining measurements in the summer season and the winter season and then they were correlated between them. Urine and blood samples were evaluated for determining the required parameters. The parameters of the physical environment like temperature, relative humidity, precipitation, etc. were obtained from the concerned weather station for each day.

RESULTS: It was observed that 14.5%, 59% and 26.5% of the female participants were found to have hyper-hydrated, euhydrated and dehydrated, respectively. While 17.57%, 69.69% and 12.74% of the males were classified as hyper-hydrated, euhydrated and dehydrated, respectively. The participants with hyper-hydrated were found to have increased urine volume (*p*<0.001), reduced specific gravity (*p*<0.001) and reduced-sodium level (*p*<0.001).

CONCLUSIONS: The study found that there is a significant difference in sodium levels between gender and seasons. The level of serum osmolality is also significantly different between the whole study populations concerning combined seasons. In this way, many other parameters are evaluated by correlation with seasons and gender. Hence, this study has brought forward various important findings and gives an overall evaluation of hydration status.

Key Words:
Athletes, Hydration, Poor hydration, Sodium level, Serum osmolality.

Introduction

Throughout the training, the body of athletes secretes fluid and salts as a result of thermoregulatory perspiration. This is supported by studies that the rate of secretion and the replacement of fluid loss varies greatly amongst and throughout people. Sweat depletion can indeed be likely to elicit severe water/electrolyte deficits and impede performance in key scenarios, particularly while exertion is lengthy, high-intensity, and/or in such a hot climate. Sweat examinations are used by many academia and practice to evaluate how much fluids and electrolytes are lost by athletes throughout competition and training. Sweat sampling data is frequently used to assist athletes' tailored fluid and electrolyte replacement suggestions; nonetheless, unstandardized scientific techniques and difficult fieldwork circumstances might lead to conflicting findings. Sweat dispersion is critical for dissipating energy metabolism heat generation, which could jump ten-fold to twenty-fold throughout the activity. Evaporative sweat cooling seems to be the primary source of heat dissipation in hot temperatures, limiting fast increases in core body temperature[1,2].

Hypohydration, caused by sweating, increases physiological stress and the sense of exertion, lowering stamina and aerobic capacity. Furthermore, electrolyte imbalances, such as hyponatremia, may happen as a consequence of perspiration evaporation following exercising. As a result, replacing electrolyte depletion as a component of the rehydration phase following exertion seems critical. Individualised features, kind and degree of activity, clothes, gear donned, and weather circumstances all influence each athlete's sweat rate and sweat ionic balance[2,3]. For designing cus-

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tomised rehydration plans, it is indeed essential to analyse specific sweat rate and sweat electrolytes deficits for various activities and climatic situations. The above method may help to lower the risk of heat sickness while also enhancing productivity. It is said that everyone's sensitivity to dehydration seems different. So, current standards recommend keeping fluid imbalances while training to below well over 2% of body weight to prevent impaired brain abilities and aerobic activity effectiveness[4].

Elevated levels of hypohydration (3-10%) are linked to worsening performances, especially in hot temperatures, such as those found in tropical climes. Individualised drinking regimens could also help to prevent the possibility of excessive drinking and hyponatremia exercise-induced muscle. Sportsmen who reside in cool or chilly climates are much more prone to be heat-acclimatised than those who inhabit tropical climates[5]. People who have become accustomed to the heat exhibit temperature regulation adjustments, such as a reduced core body temperature, a reduced heart rate, a faster beginning of sweat, and then, a greater sweat rate. Differences in body mass while exercising are the easiest and perhaps most effective way to estimate the entire body SR; nevertheless, non-sweat causes of mass change and retained sweat in clothes are staggering variables points to consider. Furthermore, variables in the kind of collection equipment employed (full body or localised), the scheduling of sweat gathering, skin cleansing process, specimen storage/handling, as well as research methodology might cause variation in sweat Na^{+}[3,6].

Fitness level, ambient circumstances, heat acclimatisation, aerobic fitness, body size/composition, donning of safety clothing, sex, maturation, age, nutrition, and/or hydration levels are all variables that influence intra/interindividual heterogeneity in SR and sweat Na^+ during activity. Sweat analysis could be a valuable technique for estimating athletes' SR and sweat Na^+ loss and guiding fluid/electrolyte substitute methods if the information is retrieved, processed, and understood properly. Sweat output typically surpasses fluid consumption whilst activity in the heat, resulting in an electrolyte imbalance or hypohydration. The above condition is likely to have a detrimental impact on aerobic activity routines[5,7].

Consequently, large-scale competitions such as the Olympics, the World Cup, or maybe even a funded solitary event cannot be delayed again until the temperature is ideal. Problems are bound to emerge whenever an athlete practices or participates in a somewhat more temperate zone. Individuals do not consume enough liquids following the sport to re-establish fluid equilibrium. Earlier research referred to this as "voluntary dehydration"[8]. Nonetheless, this name has indeed been altered to "involuntary dehydration" to reflect the fact that somehow a hypohydration person seems to have no desire to replenish also when fluids, as well as opportunities, remain accessible. The sportsmen's responses to the pressure of training in the heat are perhaps the most essential component affecting the influence of climatic stress on their performances. The winner will have devised a recovery solution that outlines acclimatisation, replenishment, as well as social and cognitive elements[7-9].

This study intends to find out the present status of hydration among the athlete's population and the factors influencing the hydration status of the athletes. This would give us an idea of mitigation of the negative effects of poor hydration status.

Subjects and Methods

Study Type and Source of Data

The current study is a prospective type and was conducted on the Chinese population between June 2021 to April 2022. The study was conducted in two halves. Firstly, the study measurements were taken from June 2021 to September 2021 for measurements in summer and again, the same process was repeated from November 2021 to April 2022 for obtaining the measurements in winter. The study was carried out on Chinese athletes who were professionals for the last 10 years. The subjects were aged between 18 years and 35 years old, comprising both males and females (Figure 1). The athletes were from the same type of sports and had been playing for almost the same period in their lives. After applying inclusion and exclusion criteria, the study finally considered 325 athletes (165 males and 160 females).

Inclusion Criteria

The athletes were selected based on the criteria that they are all full-time basketball players, they have been playing for 9 to 10 years, they were aged between 18 years and 35 years old, they had no chronic disease, their BMI was in the range of 20 kg/m^2 to 24.99 kg/m^2.

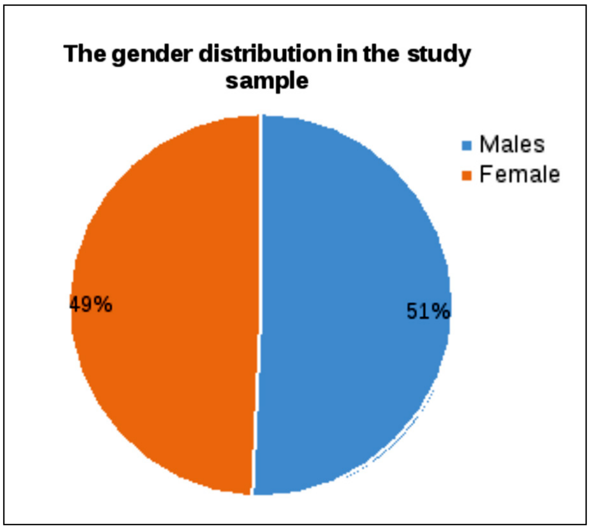

Figure 1. Gender distribution in this study.

Exclusion Criteria

The athletes could not cooperate with both the phases of the study. The athletes whose BMI were not within the specified range were mentioned, the athletes who became sick or had a physical injury, etc.

Data Collection and Preparation

The data were collected four times. For collecting the measurements in the summer, the data was collected in the first week of June 2021 and again in the last week of September 2021. For winter measurements, the first collection was done in the first week of November 2021 and the second one was done in the last week of April 2022. From each athlete, urine samples and blood samples were obtained. The study considered the following indices of urine samples, namely, sodium (mEq/day), urine volume (L) and specific gravity of urine. The blood samples were evaluated for hemoglobin (g/dL), glucose (mmol/L) and sodium (mEq/L). In addition to this, each athlete was given a notebook to record the amount of water they are consuming within the study timeframe. They were also asked questions about their daily activities and diet. As they were enrolled in the same sports academy, their diet was controlled and the same.

Procedure for Sampling

The athlete who took part in this study was given instructions regarding the process of the study thoroughly. Urine was by each athlete by themselves. They were given a urine storage container in which they brought urine from their home. They were asked to bring at least 10 mL of urine in the storage container. Blood was drawn by the volunteers. 5 mL of venous blood was drawn from each participant's forearm. This was done in the first week of each study timeframe. The participants were told to come on an empty stomach (NPO) in the early morning between 7 am and 8 am. Their height and weight were measured with only underwear and even without shoes. Then, they were asked a few questions regarding their knowledge about hydration and their eating and drinking behavior.

Urine and blood samples were evaluated for determining the required parameters in the study as mentioned above. Urine and serum sodium was assessed by the ion-selective electrode method. The specific gravity of urine was determined with a pen refractometer and the volume of urine was measured with a digital scale. The parameters of the physical environment like temperature, relative humidity, precipitation, etc. were obtained from the concerned weather station for each day.

Statistical Analysis

The study considered the expression of continuous variable as mean±standard deviation. The significance between genders concerning the seasons was obtained by conducting Pearson's correlation coefficient. Student *t*-test was conducted for normally distributed variables. The multivariate association test was carried out between variables. All the statistical analyses were done using SPSS 25 software (IBM Corp., Armonk, NY, USA) at α=0.05.

Results

The study considered 325 athletes (165 males and 160 females). Their Body Mass Index (BMI) was found to be 22.2±0.4 kg/m^2 for males and 20.1±0.8 kg/m^2 for females (p=0.014). The age of the males is 28±8.1 years old while the mean age of females is 27±7.5 years old (Figure 2).

Result of 24-Hours Urine Analysis

The study evaluated hydration indices like sodium concentration, the volume of urine, specific gravity and color of the urine, for each season (summer phase study and winter phase study). The detailed findings are shown in Table I.

Table II shows the significance of several parameters. The study found that the urine osmo-

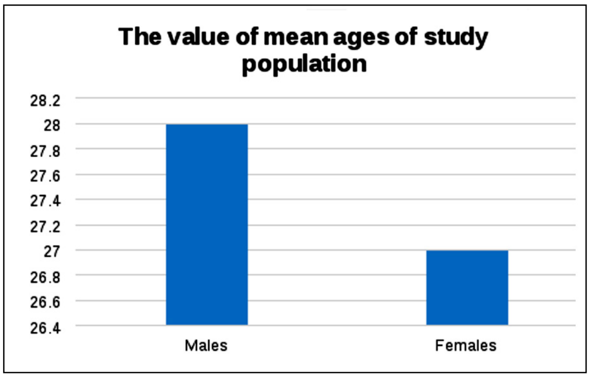

Figure 2. The mean ages of males and females.

lality is highly significant between males and females both during summer and winter time individually (p=0.000) while the specific gravity of urine is highly significant only during summertime (p<0.001). The study further found out that there is a significant difference between gender and both the seasons combined in terms of sodium level, the specific gravity of urine and urine osmolality.

Blood Indices Analysis

The study considered blood determining hemoglobin, glucose, serum osmolality and sodium, separately in the summer phase, winter phase and both phases. This measurement has been done in males and females separately and is also considered a combined measurement. The statistical analysis has shown that glucose and hemoglobin level have a significant difference in males and females during the winter season and summer season separately. But in combined (summer and winter), serum osmolality is significantly different. The study further found significant differences between gender and both phase (winter and summer combined) in hemoglobin level, glucose level and serum osmolality. Table III shows the detailed findings while Table IV shows the result of significant tests of a blood sample.

Further, it was observed that 14.5%, 59% and 26.5% of the female participants were found to have hyper-hydrated, euhydrated and dehydrated, respectively, while 17.57%, 69.69% and 12.74% of the males were classified as hyper-hydrated, euhydrated and dehydrated, respectively. The participants with hyper-hydrated were found to have increased urine volume (p<0.001), reduced specific gravity (p<0.001) and reduced-sodium level (p<0.001).

The study has highlighted important findings regarding the hydration status involving various parameters. Several parameters have been compared and have been shown to have significance in the above tables. Urine osmolality has significant differences between males and females during the winter season and again summer seasons. Again, there is a significant difference in sodium levels between males and females during the summer season but not in the winter season. However, the difference in urinary sodium levels between males and females is significant, when it comes to both the seasons combined. The level of serum osmolality is significantly different between the whole study populations concerning combined seasons.

Discussion

A major goal of this study is to give an overview of both the study on the influence of con-

Table I. The findings of 24-hours urine hydration indices in athletes in the summer and winter phase.

	Sodium (mEq/day)	The volume of urine (L)	The specific gravity of urine	Urine osmolality (mOsmol/kg.H_2O)
Summer Phase				
Male	179.5 ± 47.25	1.62 ± 0.71	1.017 ± 0.004	696 ± 197
Female	144.63 ± 51.21	1.65 ± 0.79	1.014 ± 0.005	599 ± 234
Total	160.35 ± 49.65	1.63 ± 0.74	1.015 ± 0.006	656 ± 231
Winter Phase				
Male	179.23 ± 49.5	1.65 ± 0.65	1.019 ± 0.004	644 ± 212
Female	161.5 ± 51.2	1.71 ± 0.73	1.015 ± 0.005	568 ± 195
Total	172.31 ± 53.6	1.69 ± 0.67	1.017 ± 0.004	616 ± 210
Both Phase				
Male	181.2 ± 51.2	1.62 ± 0.65	1.017 ± 0.005	676 ± 202
Female	154.1 ± 56.2	1.65 ± 0.75	1.016 ± 0.005	586 ± 227
Total	167.5 ± 55.2	1.66 ± 0.71	1.017 ± 0.004	632 ± 224

Table II. The result of the significance test between parameters measured in 24-hours urine.

	Sodium (mEq/day)	Volume of urine (L)	Specific gravity of urine	Urine osmolality (mOsmol/kg.H_2O)
Significance between gender and winter phase (p1)	0.022	0.587	0.0036	0.000
Significance between gender and summer phase (p2)	0.000	0.745	< 0.001	0.000
Significance between total sample and summer and winter phase (p3)	0.066	0.372	0.675	0.110
Significance between gender and both phase (winter and summer combined) (p4)	< 0.001	0.618	< 0.001	< 0.001

Table III. Findings of Blood indices in athletes in the Summer and Winter phase.

	Hb (g/dL)	Glucose (mmol/L)	Serum osmolality (mOsmol/kg H_2O)	Sodium (mEq/L)
Summer Phase				
Male	15.6 ± 1.4	4.99 ± 1.01	292 ± 6	142.9 ± 4.8
Female	14.2 ± 1.5	4.92 ± 1.12	293 ± 7	144.3 ± 7.6
Total	14.9 ± 1.5	4.94 ± 1.08	293 ± 7	143.9 ± 8.6
Winter Phase				
Male	15.6 ± 1.3	4.66 ± 1.15	293 ± 6	143.5 ± 4.8
Female	14.3 ± 1.4	4.65 ± 0.99	293 ± 5	142.6 ± 4.7
Total	14.9 ± 1.4	4.66 ± 1.07	293 ± 6	142.9 ± 4.4
Both Phase				
Male	15.5 ± 1.5	4.83 ± 1.25	295 ± 6	143.4 ± 5.2
Female	14.3 ± 1.4	4.81 ± 1.28	294 ± 6	143.6 ± 6.7
Total	14.9 ± 1.3	4.82 ± 1.27	294 ± 6	143.1 ± 6.3

flicting findings on Sweating Rate (SR) and sweat makeup (mostly sodium concentration [Na^+]) on SR and sweat composition (particularly sodium level [Na^+]). Hygrometry and gravimetry are two approaches for measuring SR. Dry air with such a specified temperature is blasted at a steady rate of flow throughout a capsule adhered to the surface using hygrometry, or even the ventilated sweat capsule method[9,10]. The difference in temperature and evaporation level of something like the outflow relative to the inlet air of the capsule determines local SR (LSR) onto the skin surface underneath the capsule (about 1-20 cm^2)[9].

Hygrometry, on the other hand, might exaggerate sweat flow rates in certain cases due to the forced ventilation as well as the preservation of dry skin (that aids sweating) beneath the capsule may not always be indicative of ambient circumstances. Filter paper, absorbent patches, Parafilm-M pouches, cotton gloves/socks, latex gloves, or plastic sweat collectors are being used in gravimetric techniques to extract perspiration straight from the surface of the skin. For sweat-testing sportsmen inside the arena, gravimetric methods, especially absorbent patches, are much more feasible than hygrometry[10,11].

Variations in naked bodyweight from well before to after exercising are the easiest and also most effective way to quantify WBSR; nonethe-

Table IV. The significance test between parameters measured in blood test.

	Hb (g/dL)	Glucose (mmol/L)	Serum osmolality (mOsmol/kg H_2O)	Sodium (mEq/L)
Significance between gender and winter phase (p1)	< 0.001	< 0.001	0.014	0.016
Significance between gender and summer phase (p2)	< 0.001	< 0.001	0.078	0.159
Significance between total sample and summer and winter phase (p3)	0.833	0.395	< 0.001	0.006
Significance between gender and both phase (winter and summer combined) (p4)	< 0.001	< 0.001	< 0.001	0.702

less, adjustments for non-sweat causes of bodily change in mass should indeed be addressed[3,4,7]. Specifically when activity will only last many hours, is high-intensity, and/or is undertaken in a cool/dry environment. SR estimations relying upon the change in physical mass must be modified for metabolic mass loss and respiratory moisture loss. Ion chromatography (IC), inductively-coupled plasma mass spectrometry (ICP-MS), flame photometry (FP), ion-selective electrode (ISE), and conductivity are some of the methods used to quantify sweat (Na^+)[12].

Athletes are recommended to consume certain quantities of water, carbs, and sodium throughout training depending on their ability to reduce weariness and sickness caused by hyperthermia, dehydration, or hyperhydration. Hydration should be consumed at intervals that are as near to perspiration as feasible. Whenever the surroundings are chilly or moderate, certain sportsmen may endure water and electrolyte reduction of up to 2% of body mass without considerable damage to bodily well-being or ability when this is not realistic, feasible, or adequately high-performance[13,14]. Water intake really shouldn't exceed sweating levels, since this will cause body water and body weight to rise throughout the activity. Exhaustion could be decreased by mixing glucose with the liquids taken, consuming 30-60 g of quickly digested carbohydrates every hour of an athletic event. Furthermore, salt must be incorporated in liquids ingested throughout the long-duration activity or by persons participating in just about any activity that causes significant sodium depletion (more than 3-4 g of sodium). Consuming glycerol, proteins, or purported neurotransmitter antecedents has little advantage for sportsmen. Most chemicals, with the probable exception of coffee, should not be consumed while activity. Athletes can gain the best if they customize their particular hydration, calorie, and sodium demands to particular sport's specific obstacles, particularly given the environment’s influence on perspiration as well as temperature changes[15,16].

The research included a combination of more than a hundred subjects. For 30-100 minutes, individuals sprinted through at their speed. Age, weather circumstances, running patterns, sweat rates, and sweat sodium information have all been taken into account. Age, running length, range, and speed, as well as physiological differences between men and women, have been investigated. Many studies have shown that males exhibited a lower comparative water intake and a proportionately larger liquid imbalance than females. Males sweated more than females throughout the body. Males sweated more sodium than females, on average. The sweat profile, as well as content among tropical native runners match, published values. The state of hydration can indeed be thought of as a performance that is mostly dependent on intentional consumption[17,18].

There is a need to assess the time an additional amount of fluid an athlete should consume for rehydration. There are certain health drinks or supplements which can support an athlete to recover from the acute deficiency of electrolytes and fluid. Refreshments containing electrolytes increase the desire to consume by retaining plasma osmotic concentration, resulting in larger quantity consumption. Refreshments including carbohydrates (CHO) are beneficial because they stimulate hunger. The product's pleasant flavour also is beneficial, as seen by the fact that orange juice is consumed in greater quantities compared to other beverages. Some of the surveys conclude that cool water is chosen over warmer one by the athletes. It's been stated that serving gradually cooler drinks reduces the amount drunk[19,20].

There seem to be a variety of techniques that span in accuracy and consistency, from complex and intrusive approaches (such as neutron activation analysis and stable isotope dilution) to tolerably intrusive blood, urinalysis, and salivary parameters. Again, it adds non-invasive indicators like tear osmolality, body weight, bioimpedance assessment, and hydration sensory perception[21,22]. The best way is to employ a variety of methods that complement each other and improve reliability and completeness. Because of their low sensitivity, dependability, and/or accuracy, measures including such salivary parameters, urine colours, vitals, and thirsty feeling should be used with caution. Comprehensive evaluations like neutron activation and stable isotope dilution studies have shown remarkable results but they are also costly. One of the drawbacks is substantial time constraints owing to data analysis limiting the ability to respond quickly[23,24].

Sweat examinations must be understood in their proper perspective, which means that the findings are only relevant to the particular contexts like location, and aerobic capacity in which they were done; comparisons across sweat tests are only acceptable whether the similar methodologies were employed. Sweat analysis, in conclusion, might be a valuable method for estimating participants' WBSR and sweat Na^+ depletion, therefore, guiding fluid or electrolyte replenishment regimens[25,26].

Conclusions

The findings of the current study have shown detailed hydration and sodium status of the young athlete, from which, it can be considered that, although the training facilities are equipped with drinking water and other drinks, there is a considerable amount of dehydration among the athletes when the training is held throughout the day. It is essential to keep hydration level steady and prevent dehydration. The current study contributes by showing the probability and prediction of failure of maintenance of hydration among the athletes, leading to the reduction of their performance. Especially, this current study also presents the need to keep these athletes hydrated during the summer and winter. Therefore, there is a need to educate the athletes to keep them hydrated all the seasons appropriately. Although there are enough supplies of drinks in the training facilities, the lack of awareness among the athletes can be the primary reason why the athletes are still not hydrated sufficiently. Hence, this study has brought forward various important findings and gives an overall evaluation of hydration status. This current study also recommends educating the athletes about the strategies to hydrate themselves and also solving difficulties like tight burdening schedules of practice which can potentially affect their hydration status.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Informed Consent

The participants, who gave the consent were only included. The whole study was conducted according to the declaration of Malaysia promulgated in 1964 as amended in 1996.

Authors' Contribution

We declare that this work was done by the authors named in this article, and the authors will bear all liabilities claims relating to the content of this article.

Ethics Approval

All the procedures and the investigation in human subjects were conducted based on the Malaysian Guideline for Independent Ethics Committee Registration and Inspection, and National Statement on Ethical Conduct in Human Research.

Funding

None.

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