

Hydration Status, Body Composition and Anxiety Status in Aeronautical Military Personnel from Spain: a cross-sectional study

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Abstract

Background: An adequate hydration status is critical to ensure efficiency during mental and physical activities. Our goal was to assess the hydration status of a group of aeronautical military men and to determine the association of hydration status with body composition and anxiety.

Methods: 188 men were evaluated through a validated hydration questionnaire, anthropometric and biochemical parameters, and an anxiety questionnaire. According to that, criteria of hydration was established.

Results: 81% of the total sample met hydration criteria (urine color = Well hydrated, Water Balance ≥ 0 mL, and total water intake/weight ≥ 35 mL/kg) and 19% did not meet hydration criteria (urine color = Not enough hydrated or Dehydrated, Water Balance < 0 mL, and total water intake/weight < 35 mL/kg). Subjects not meeting the hydration criteria had lower urine pH, negative water balance, and lower water intake. The latter also had higher anxiety status (score = 4 vs 3, $p = 0.026$), weight (84.7 ± 10.5 vs 80.5 ± 10.2 Kg), Body Mass Index (26.3 ± 3.1 vs 25.2 ± 2.8 kg/m²), body fat (22.3 ± 5.6 vs $18.3 \pm 6.5\%$), urine specific gravity and urine color. Furthermore, total water intake/weight was positively correlated with percentage of body water ($\rho = 0.357$, $p = 0.000$) and negatively with body fat (kg) ($\rho = -0.427$, $p = 0.000$), percentage of body fat ($\rho = -0.405$, $p = 0.000$) and waist/hip ratio ($\rho = -0.223$, $p = 0.002$).

Conclusions: All these findings suggest a relationship between hydration status and body composition. These results can be used to improve the hydration status and body composition of military personnel. Trial registration: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Clinical Research Ethics Committee of the CEU San Pablo University (Madrid). The corresponding ethical code was 119/16/08.

Introduction

The optimal functioning of our body requires an adequate hydration level (1), given by a state of water and electrolyte balance (2, 3). The human body has involved to include mechanisms to ensure constant water content by adjusting intakes and wastes. Water balance (WB) is determined by intake (water, beverages, water contained in foods, and metabolic water) and waste (urine, stools, skin, and expired air from the lungs). Failure of these mechanisms and subsequent impairments in WB may produce severe disarrangements (1, 4). Mild, acute, and chronic dehydration can have important implications for human behavior and health. Such implications include short-term memory deficits, impaired problem-solving ability, degraded ability to concentrate, cognitive performance, diminished visual-motor tracking; cardiovascular, and kidney diseases (5-8). Therefore, maintaining an adequate state of hydration is critical to ensure efficiency during mental and physical activities, as well as playing a key role in mishap prevention through minimizing human error (9). Human errors are considered the main cause of flight accidents and crashes (10). In fact, human factors are cited in approximately 70-80% of all accidents in aviation (11). The complexity of the missions of the air force requires the exercise of a diversity of

functions and tasks. The aeronautical military population is vulnerable because of its frequent exposure to a state of hypohydration due to constant physical training, and without having the option of choosing their own desired food (provided in military rationing options during base transfers and/or military exercises). In addition, there are large changes in climatic zones with no acclimatization time (12). There are several guidelines in scientific literature for establishing recommendations of water requirements, and how to keep an adequate WB (13-16). However, fluid-balance needs must be individualized for best results (17), because water intake (WI) and water elimination (WE) depends on unique personal characteristics (eg. age, sex, disease states), environmental conditions and physical activity levels that vary in different countries or population groups (18, 19). It has been noted that the percentage of the general population with inadequate WI varies from 5% to 35% among European countries (20). In Spain, the ANIBES Study (2013) (21) clearly showed that individuals are not consuming the adequate Total Water Intake (TWI) when compared with EFSA reference values (2.0 L/day for females, and 2,5 L/day for males) (13).

Paradoxically, up to the date no study has assessed the Hydration Status (HS) in military personnel in Spain. For these reasons, the purpose of the present study was to evaluate, for the first time, the hydration status of an aeronautical military personnel group in Spain, through a complete and validated questionnaire of hydration (22), as well as anthropometric and biochemical parameters. As a secondary goal, we aimed to investigate a possible relationship between the HS, body composition and anxiety status which could affect the work performance and some abilities in this special population.

Materials And Methods

The present study was a cross-sectional observational study of a sample of Spanish aeronautical military personnel who attend the annual medical check-ups at the official *Centro de Instrucción de Medicina Aeroespacial* (CIMA), Madrid. Subjects from all over Spain, have been informed of the study and invited to participate. The inclusion criteria were individuals who were mentally and physically healthy (which is determined through the various medical consultations, included in the regular medical check-up). Exclusion criteria were people suffering from disease or any special health conditions that limited their flight license. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Clinical Research Ethics Committee of the CEU San Pablo University (Madrid). The corresponding ethical code was 119/16/08. All the aeronautical personnel who participate in the study were voluntary and their written informed consents were obtained prior to study.

2.1 Recruitment

The military aeronautical personnel attended to the CIMA for a 2- to 3-day medical check-up period. Recruitment started the first day of medical check-up of each group, and included a volunteer recruitment briefing, with infographics of the procedure of the study. Volunteers that expressed interest in

participating in the study received the study protocol in writing, as well as verbal responses to any questions.

2.2 Study Protocol

During the first day, the participants completed the self-reported questionnaires under the supervision of trained dietitian personnel:

1. "The hydration status questionnaire" (HSQ), validated by the Nutrition and Food Science research group of CEU San Pablo University (22).
2. A specific designed questionnaire, evaluating physical activity through a brief register of a working day and non-working day activities was used. In this questionnaire, a total of 24 hours were divided into sleeping, eating, work activity, sitting or lying (reading, watching TV...), walking, mode of transport, other activities (specifying domestic tasks, playing with kids...) and sports (specifying which): the total daily energy expenditure (TDEE) was calculated according to their respective metabolic equivalent (MET) intensity levels (23). This TDEE enabled the estimation of the sweat produced by the physical activity, in order to estimate WE.
3. Anxiety questionnaire (State Trait Anxiety Inventory (STAI)) (24): a) STAI-State: assessing a transitory emotional state, b) STAI-Trait: that indicates an anxious propensity. The score for each scale can range from 0 to 10, upper scores indicating higher levels of anxiety.

Furthermore, volunteers provided an afternoon (14.00-16.00 PM) spot urine sample, which has an equivalence with the 24-h value of urine (the mean differences (95% confidence interval) between 24-h and spot urine were 0.0014 (-0.0028 to -0.0001)) (25), in which urine pH and urine specific gravity (USG) were determined through the use of urine stick test Spinreact™, as well as urine color, via the Urine Color Chart (26). Results of USG were compared with reference values of hydration biomarkers in urine afternoon spot (4) (Euhydration values: specific gravity=1080-1020 g/L), and urine color were compared with reference values of Urine Color Chart (26). As indicated by the urine color chart, values 1,2,3 correspond to well hydrated (WH), 4,5,6 correspond to not enough hydrated (NEH), and 7,8 correspond to dehydrated (DH).

Amstrong et al. (27) indicates that to estimate the hydration status information two or more hydration assessment techniques are needed. Therefore, urine color, WB and total water intake/weight were used to classify study participants with respect to hydration adequacy. Participants that met: urine color = WH (26), $WB \geq 0$ mL, and total water intake/weight was ≥ 35 mL/kg weight or more (28), were identified as meeting hydration criteria. Participants that met urine color = NEH or DH, $WB < 0$ mL, and total water intake/weight < 35 mL/kg weight, were classified as not meeting hydration criteria. Note that the hydration criteria in this study represent benchmarks for grouping individuals and are not treated as criteria for as dehydration or any clinical diagnosis.

During the second day of the study, the subjects completed the remaining tests under fasting conditions of water and food. First, blood samples were taken for hemoglobin, hematocrit, and erythrocyte analysis.

All the determinations were performed in a Cobas Core 501 autoanalyzer (Roche- Hitachi, Switzerland). Then, anthropometric parameters were determined, according to the protocol of the International Society for Advanced Kinanthropometry (ISAK) (29). Specifically, measurements of weight, height, waist and hip circumferences were taken. Waist/hip ratio was calculated from the equation: waist (cm)/ hip (cm), following the WHO criteria (30). Body mass index (BMI) was calculated from the equation weight (kg)/height² (m²), and compared to WHO reference values (31). Body fat percentage and Body Water percentage were determined by Bioelectrical Impedance (BIA) (InBody 770®, Spain). Excessive body fat was defined according to body fat ranges for standard adults reported by Gallager et al. (32), whereas body water percentage was compared with standard ranges between 55-65% (33).

2.3 Statistics

The fact that the size of target population (personnel from Spanish Air Forces) is confidential and not public available, makes it impossible to calculate the exact sample size that allows representativeness. Normality of variables was tested using Kolmogorov-Smirnov test. In light of the results obtained, descriptive values are presented as mean \pm standard deviation (SD) or median (interquartile range (IQR)). Differences between normally distributed variables were derived through the Student's t-test. For non-parametric measurements the Mann-Whitney U tests were applied. Urine color was test using Chi². Differences were considered significant at $p < 0.05$.

Correlation analysis was performed using Spearman's coefficient, or Pearson's coefficient according to variables normality. All the statistical analyses were performed using SPSS 24.0 Software (IBM Corp., Armonk, NY, USA)

Results

3.1. Anthropometric measurements, Blood and Urine markers

A total of 188 healthy males aged 23 to 56 years participated in the study. A more detailed description of TDEE, and anthropometric characteristics data of the study population is shown in Table 1. Mean BMI (25.4 ± 2.9 kg/m²) was considered in the lower range of overweight, according to reference values. However, we observed a percentage of body fat ($19.1 \pm 6.5\%$) established as normal in adult men. Furthermore waist/hip ratio (0.87 ± 0.05) in the total sample showed no risk factor for cardiovascular disease. Percentage of body water ($60.4 \pm 7.5\%$) in the total sample was in the range of normal values (55-65%) (33).

Table 1. Anthropometric Characteristics and Total Daily Energy Expenditure of the participants

	Total	
	n=188	
	mean	SD
TDEE (kcal/day)	3158.7	(333.9)
Height (cm)	178.7	(6.2)
Weight (kg)	81.6	(10.3)
BMI (kg/m ²)	25.4	(2.9)
Body water (%)	60.4	(7.5)
Body fat (%)	19.1	(6.5)
Waist/hip ratio	0.87	(0.05)

TDEE: Total daily energy expenditure. BMI: Body mass index

Moreover, blood indices (Erythrocyte (5.2±0.4 million/ µl), Hemoglobin (15.2±1.1 g/dl) and Hematocrit (44.7±2.5%)) were within the physiological range (34) (table 1), as well as the urine markers (35) (table 2).

Table 2. Urine Markers of the participants

	Total	
	n=188	
	median	IQR
pH	6.0	(5-7)
Specific gravity (g/L)	1020	(1015-1020)

3.2. Water Intake, Water Elimination and Water Balance

Water from beverages (2709.5±943.6 mL/day), water from foods (795.5±413.7 mL/day), total water intake (3508.9±1112.1 mL/day), water elimination (3402.4 ±1086.5 mL/day), water balance (88.5±1294.3 mL/day) and total water intake/weight (43.7±14.9 mL/kg), were estimated by the HSQ. Total water intake/weight was correlated positively with percentage of body water (rho=0.357, p=0.000) and negatively with body fat (kg) (rho= -0.427, p=0.000), percentage of body fat (rho= -0.405, p=0.000), waist (rho=0.390, p=0.000), hip (rho= -0.401, p=0.000) and waist/hip ratio (rho= -0.223, p=0.002).

3.3 Hydration Status

It was found that 81 % of the total population met the hydration criteria whereas 19 % did not. Table 3 shows TDEE and anthropometric characteristics, according to the hydration status. Even though there were no statistical differences in anthropometric data according to HS, subjects that did not meet hydration criteria had higher weight (84.7 ± 10.5 vs 80.8 ± 10.2 Kg), BMI (26.3 ± 3.1 vs 25.2 ± 2.8 kg/m²) and body fat (22.3 ± 5.6 vs 18.3 ± 6.5%), higher waist/ hip ratio (0.9 ± 0.1 vs 0.87 ± 0.1), and lower body water (58.1 ± 7.2 vs 60.9 ± 7.5%), than subjects that met hydration criteria.

Table 3. Total Daily Energy Expenditure and Anthropometric Characteristics categorized by Hydration Status.

	Not Meet Hydration Criteria		Meet Hydration Criteria		P values
	n=36		n=152		
	mean	SD	mean	SD	
TDEE (kcal/day)	3196.9	(352.4)	3149.6	(329.9)	0.938
Height (cm)	178.7	(5.8)	178.7	(6.3)	0.746
Weight (Kg)	84.7	(10.5)	80.8	(10.2)	0.543
BMI (kg/m ²)	26.3	(3.1)	25.2	(2.8)	0.244
Body water (%)	58.1	(7.2)	60.9	(7.5)	0.868
Body fat (%)	22.3	(5.6)	18.3	(6.5)	0.551
Waist/hip ratio	0.9	(0.1)	0.87	(0.1)	0.171

P-values derived through Student's T-test. TDEE: Total daily energy expenditure. BMI: Body mass index

Results of WI, WE and WB are presented in Table 4, and urine markers in Table 5. Subjects that did not meet the hydration criteria had significantly lower water intake from beverages (p=0.002), water from food (p=0.005), total water intake (p=0.000), water balance (p=0.034), total water intake/weight (p=0.000), pH (p=0.023), higher specific gravity (p=0.043) and urine color (Chi2 p=0.000) than subjects that met the hydration criteria. However, differences in blood indices were not observed in both groups (erythrocyte: 5.2±0.3 vs 5.2±0.4 million/ µl (p=0.953), hemoglobin: 15.3±0.8 vs 15.2±1.1 g/dl (p=0.840) and hematocrit: 44.8±2.3 vs 44.7±2.2 % (p=0.710)). Urine and blood indices were within the physiological ranges in both groups (34, 35).

Table 4. Total Water Intake, Water Elimination, Water Balance, and Total Water Intake/Weight by Hydration Status

	Not Meet Hydration Criteria		Meet Hydration Criteria		P values
	n=36		n=152		
	mean	SD	mean	SD	
Water from beverages(mL/day)	1704.4	(489.9)	2947.6	(865.5)	0.002*
Water from food (mL/day)	574.1	(250.4)	847.9	(427.7)	0.005*
Total water intake (mL/day)	2278.4	(473.6)	3800.4	(1016.4)	0.000*
Water loss (mL/day)	3383.3	(1130.9)	3406.9	(1079.5)	0.975
Water balance (mL/day)	-1104.8	(996.6)	371.1	(1193.5)	0.034*
Total water intake/Weight (mL/kg)	27.1	(5.4)	47.6	(13.8)	0.000*

P-values derived through Student's T-test. * Significant differences between groups (Student's T-test, $p \leq 0,05$)

Table 5. Urine Markers by Hydration Status

	Not Meet Hydration Criteria		Meet Hydration Criteria		P values
	n=36		n=152		
	median	IQR	median	IQR	
pH	5	(5-6.5)	6	(5-7)	0.023*
Specific gravity (g/L)	1020	(1015-1020)	1020	(1015-1020)	0.043*

P-values derived through Mann-Whitney U test. * Significant differences between groups (Mann-Whitney U test, $p \leq 0.05$)

3.4 Anxiety Status

Anxiety results showed a low level of anxiety in the total sample: score 3 (interquartile range: 2-5) for STAI-State and score 2 (interquartile range: 2-3) for STAI-Trait score. No correlation with any variable of HS was observed.

By HS category, significant differences were noted in the anxiety test STAI-State ($p=0.026$), where subjects that did not meet hydration criteria had higher scores value (4 vs 3) than the group that met the hydration criteria (Table 6).

Table 6. Anxiety Status of the participants sorted by the Hydration Status

	Not Meet Hydration Criteria		Meet Hydration Criteria		P values
	n=35		n=149		
	median	IQR	median	IQR	
State Trait Anxiety Inventory -State	4	(3-5)	3	(2-4)	0.026*
State Trait Anxiety Inventory -Trait	2	(2-3)	2	(2-3)	0.312

P-values derived through Mann-Whitney U test. * Significant differences between groups (Mann-Whitney U test, $p \leq 0,05$)

Discussion

The present study represents the unique exploration of the HS on aeronautical military personnel in Spain, as well as the association of this variable with body composition and anxiety status.

The main findings of our study indicate that TWI was adequate for the majority of the population, in accordance with recommendations established by WHO (3.7 L/day) (16), the National Health and Medical Research Council (3.4 L/day from males) (14) and the Institute of Medicine of the United States of America (IOM) suggest 3.7 L/day for males (36). Nevertheless, they consumed approximately 40% more of TWI than the EFSA WI reference values for men (2,5 L/day) (13) and the Spanish Society of Community Nutrition (SENC) recommendations (37). Many studies take into account only the water from beverages but no water intake from all sources (beverages plus food water intake) (38, 39). Previous studies in general European population found that TWI ranges 2310 mL/day in Ireland to 3254 mL/day in Greece (40-44); and findings in the Spanish population (ANIBES Study) showed intakes of 1625 mL/day (21), much lower than our results. Worldwide, TWI ranges from 2230 mL/day in Japan to 3563 mL/day in the USA (45, 46). Deviation in water intake may reflect country differences in dietary habits, lifestyle choices, and environmental conditions; but also differences in the selection of method used to evaluate total water intake (41).

On the other hand, mean daily WE was 3402.4 mL/day for the whole sample. WE data were in accordance to current literature, which is 1500-3100 mL/day for adults (13, 15). In addition, the WB was positive for the total sample. WI is usually expressed in absolute units (L/day) even though a given L/day intake of water can be expected to have different effects on the hydration status of small versus large individuals (47). Nevertheless, recent NHANES studies suggest that not accounting for body weight to express WI (mL/kg of weight), may introduce confounding and/or effect modification into hydration studies (47-49). In addition, the Spanish Guidelines of Hydration suggest that the standard requirements of WI are 30-35 mL/kg of weight (28), data that our sample accomplished.

Laboratory data for urine (USG, urine color, osmolality) are considered good markers to evaluate HS (50). In the present study urine was measured via color chart in an afternoon urine spot, since USG findings of

Bottin et al. (25) suggest that an afternoon sample may be an accurate and practical tool for hydration monitoring.

Blood parameters (hematocrit and hemoglobin) were analyzed due to their potential as HS markers (50); however, no correlation was observed with any other HS variables in the present study. Francesconi et al. (51) investigated military personnel over field training and reported that even when the subjects had lost more than 3% of their body mass and had a high urine specific gravity, there was no change in hematocrit or serum osmolality measurements. They concluded that plasma volume is defended by the body in an attempt to maintain cardiovascular stability, and therefore plasma variables are not affected by mild hypohydration until a certain degree of body water loss (at least 3% of body mass loss). Similar findings were reported by Armstrong et al. (52).

In our population, 81% of the participants met the established hydration criteria and 19% did not meet the hydration criteria. A US military study showed that 31% of the total sample met the criteria for hypohydration (using USG of first urine of the morning) (12). Malisova et al. (40) concluded that 60% were euhydrated, 20% hyperhydrated and another 20% dehydrated on average over a seven-day period (using cutoffs of 24 h urine osmolality) in an adult free-living population. Furthermore, they observed that euhydrated subjects had a higher total water intake and water intake from beverages, but lower specific gravity and lighter color. These results are mostly in agreement with our study.

Regarding to anthropometric parameters, BMI suggests overweight values in the total sample. Conversely, the % body fat was considered in the range of healthy values. Several studies observed similar results, and the inability to distinguish the different contributions to body weight, fat and non-fat tissue, which explains why the BMI might overestimate adiposity in muscular and lean body in active people (53, 54). Body water content is an accepted indicator of HS (50). In this study, this parameter was assessed through BIA, and showed normal values (33). Although no significance differences were observed according to HS, subjects that did not meet the hydration criteria had higher weight, BMI, body fat (%) and waist/hip ratio than subjects that met the hydration criteria. In addition, total water intake per kg of weight is positively correlated with percentage of body water and negatively with body fat (kg), percentage of body fat and waist/hip ratio for the total sample, demonstrating a relation between hydration status and body composition; following data were noticed in recent studies (55).

In our study, subjects that did not meet the hydration criteria had significantly higher scores, in STAI-State, than subjects that met the hydration criteria, indicating a possible relationship between these two variables that should be carefully further evaluated. However, in other studies the relationship between hypohydration status and degraded mood was consistent (8, 56).

The strengths of this study include the novelty in a vulnerable and high-risk group such as the aeronautical military personnel as well as the careful protocol and methodology used.

Even if the present study's protocol was well controlled, some limitations should be acknowledged. Regarding the HS, the selection of hydration markers may have limitations. The most important limitation

refers to the impossibility of directly assessing water consumption, since it has been estimated through a validated questionnaire. Other limitation refers to the measurement of USG through reagent strips instead of refractometry and the non-availability of 24 hours urine samples.

Conclusion

Our results indicate that there is a clear association between hydration status, body composition and anxiety status in the military personnel evaluated. These results can be used to highlight the importance of an adequate hydration status and body composition for military personnel, to maintain a physical and mental performance for their professional career and development.

Declarations

Ethics approval and consent to participate: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Clinical Research Ethics Committee of the CEU San Pablo University (Madrid). The corresponding ethical code was 119/16/08.

Consent for publication: The authors affirm that human research participants provided informed consent for publication of their data

Availability of data and materials: Not applicable.

Competing interests: The authors declare that they have no conflict of interest.

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Abbreviations

Water balance (WB)

Water intake (WI)

Water elimination (WE)
Total Water Intake (TWI)
Hydration Status (HS)
Centro de Instrucción de Medicina Aeroespacial (CIMA)
The hydration status questionnaire (HSQ)
Total daily energy expenditure (TDEE)
Metabolic equivalent (MET)
State Trait Anxiety Inventory (STAI)
Urine specific gravity (USG)
Well hydrated (WH)
Not enough hydrated (NEH)
Dehydrated (DH)
International Society for Advanced Kinanthropometry (ISAK)
Body mass index (BMI)
Bioelectrical Impedance (BIA)
Standard deviation (SD)
Interquartile range (IQR)
Institute of Medicine of the United States of America (IOM)
Spanish Society of Community Nutrition (SENC)

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