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Hydration status, total water intake and subjective feelings of adolescents living in a hot environment, during a typical school day

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Abstract:

Aim: Individuals living in a hot environment appear to face increased risk of dehydration. Currently there is not extensive literature on the adolescent population in relation to hydration. The aim of the present study was to assess hydration status and total water intake (TWI) at school, of adolescents living in a hot environment, and to investigate the association of hydration and TWI with various subjective feelings.

Methods: The hydration status of 141 adolescents (boys $n = 102$), age 15–17 years, was assessed via urine specific gravity (USG), at the beginning (07:30 am) and at the end (1:30 pm) of one school day. TWI from fluids and solid food was assessed via detailed food and fluid records. Subjective feelings (i.e. thirst, alertness, ability to concentrate) were recorded by specific scales.

Results: Ninety percent of the students arrived dehydrated at school (USG >1.020). Thirteen students were hydrated (USG <1.020), 67 students were slightly dehydrated (USG $1.021–1.029$), and 50 students were seriously dehydrated (USG >1.030). There was no difference in TWI between the three groups (765 ± 451 mL). TWI correlated with alertness ($p = 0.005$) and the ability to concentrate ($p = 0.015$), and inversely correlated with fatigue ($p = 0.015$). Seriously dehydrated students felt less alert in the morning ($p < 0.035$) whereas the feeling of thirst was similar between all groups.

Conclusions: The prevalence of the dehydration of the adolescents during school time appeared to be extremely high, and thirst was not driving those adolescents to drink enough. Apart from health concerns, school performance could be affected by dehydration and inadequate water intake.

Keywords: adolescents, hydration, subjective feelings, urine specific gravity, water intake

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Introduction

Water makes up for 60–70% of total body mass and proper water intake can be crucial for one's health and well-being, as well as for mental and physical performance [1]. Water is a nutrient essential for life and health. Even minor losses of 2% body weight can have adverse effects on body thermoregulation and physical activity capacity [2], feelings of fatigue, concentration and alertness [3] and cognitive function [4], [5].

Studies examining hydration status, fluid and TWI of the general population in Europe have shown that daily TWIT may be lower [6], [7], [8] than the recommended water intake guidelines (2.0 L per day for females and 2.5 L per day for males over 14 years) of the European Food Safety Authority (EFSA) [9] and around 19% of the adult population across Spain, Germany and Greece appear to be dehydrated [10]. Even if some guidelines on daily water requirements may be based on weak population-level measures of water intake and urine osmolality [11], children and adolescents have been shown to drink less than the adult population [12], making them more susceptible to dehydration. As a result, perceived effort of activity can be increased when exercising or playing games in a hypohydrated state [13] and exercise cessation due to fatigue is accelerated [14]. This could result in decreased capacity for those youngsters engaging in physical activity, recreational or competitive sport, but on the other hand, dehydration could also result in decreased cognitive function and performance at school [5], [15].

Water consumption, water requirements and energy intake are linked in complex ways, partially because physical activity and energy expenditures affect the need for water [16]. The available literature on hydration

of students living in a hot environment have shown that many elementary school children in Israel [17] and adolescents from Spain are dehydrated in the morning hours at school [18] and Italian school children do not drink enough to meet their daily needs [19]. However, most information on hydration during school time derives from studies which were either carried out on elementary school children, in countries with a temperate climate, or outside the summer months [7], [12], [20].

Water losses can be greater in the summer, especially for individuals living in a hot environment. Additionally, data on adolescents during school time are lacking. Therefore, the primary aim of this study was to investigate the hydration status upon arrival at school and during a school day of adolescents living in a hot environment such as in Cyprus. The secondary aims were to investigate total water intake (TWI – from fluids and solid food), and self-rating of subjective feelings affected by hydration, during a typical school day, in the month of May, when temperatures reach and exceed 30 °C during school time.

Materials and methods

Participants

One hundred and forty-one adolescent students (15–17 years; boys $n = 102$, height 168 ± 10 cm, body mass 61.5 ± 12.5 kg; girls $n = 39$, height 158 ± 7 cm, body mass 58.7 ± 21.2 kg) volunteered for this study. The participants were recruited from three different cities of Cyprus. Initially, various schools were conducted, and following clearance and approval from the schools' administration board, the researchers were allowed to contact the students and their parents or legal guardians to provide verbal and written explanation of the study, methodology and its purpose. The potential participants had to be 15–17 years of age, attending the last three grades of schooling in Cyprus, they had to report that they were healthy and not on any medication during the study, nor on any specific diet to lose weight. All participants and their parents or legal guardians provided a written consent for participation, prior to the commencement of the study, which conformed to the principles enumerated in the Helsinki Declaration. This study was approved by the Cyprus National Bioethics Committee.

Data were collected during the last 2 weeks of May. Temperatures in the morning ranged between 20 and 21 °C (at the first urine collection), and between 28 and 30 °C at the end of the school day (1:30 pm).

Instruments

Body mass (kg) was measured with a portable scale (Seca model 755, Hamburg, Germany) and height was measured with a standing stadiometer (Seca model 720, Hamburg Germany). The ambient temperature was measured to the nearest 0.1 °C using a portable hygro thermometer (Radiance Instruments Ltd, Hong Kong, China).

Urine specific gravity (USG) was estimated using a urine refractometer (DIGIT 0–12, Medline Scientific Limited, Chalgrove, UK) shortly after the investigators received the samples. All remaining urine was immediately disposed of. No biological samples were stored after determination of USG. Hydration status was classified according to specific gravity: euhydration was set at $USG \leq 1.020$ [21], slight dehydration was set at $USG 1.021–1.029$ and serious dehydration was at $USG \geq 1.030$ [22].

Questionnaires were used to describe subjective feelings on thirst, fatigue, head numbness, alertness and ability to concentrate [3]. The participants were asked to self-rate their feelings on a 0–100 mm visual analog scale, where “0” was “not-at-all” and “100” was “very much”.

A food record was given to the participants upon arrival at school. All participants reported what they had already had for breakfast, and they kept this record with them during school time, in order to write down in detail all their food and fluid intake until the end of the school day. This record was later analyzed using DietPlan6 software which can estimate the water content of various foods and fluids. This allowed estimation of water intake during a typical school day, to make correlations and establish potential associations between hydration status, water intake and subjective feelings.

Procedure

Data (urine samples and questionnaire) were collected twice on the school premises during a typical school day; at 7:30 am upon arrival of the students at school premises (beginning of school day), and at 1:30 pm (end of the school day) just before the students left the school. The main investigators were on site during the entire

school day. Urine collection bottles (60 mL) were given to the participating students at the appropriate time points. Within 15 min of urine collection USG was measured on site and the remaining urine was disposed immediately in the toilet. The subjective feelings questionnaire on thirst, fatigue, head numbness, concentration and alertness was answered in the presence of the main investigators. A detailed food record was also completed by the participants, to allow estimation of water intake (from solid food and fluids) during the school day.

Statistical analyses

All data analysis was carried out using SPSS 21 (IBM Deutschland, Ehningen, Germany) statistical software. Comparisons between the three hydration groups were made using one-way analysis of variance (ANOVA) and the Bonferroni post hoc test was used to distinguish differences between groups. F values and eta squared (η^2) are also reported. Due to the difference in group size between the three hydration groups, the average data between groups were analyzed after being adjusted to the size of each hydration group. Comparisons between the beginning and the end of the school day were made with paired t-tests. Pearson's correlation test was used to assess the relationship between the examined variables. All data are reported as mean $\pm$ standard deviation and the level for statistical significance was set at $p < 0.050$.

Results

Upon arrival at school, 13 students were hydrated (group 1), 67 students were slightly dehydrated (group 2), and 50 students were seriously dehydrated (group 3), according to USG values. Comparisons within hydration-level groups on USG, between morning and end-of-school-day (Table 1), showed that there was no change for group 1 ($p = 0.072$) nor for group 2 ($p = 0.303$). There was a statistical decrease of USG for group 3 ($p = 0.001$), but the average value for USG remained at 1.030 ± 0.006 , and the hydration status of this group did not change.

Table 1: USG in the morning and at the end of school day, within-group comparisons.

	USG morning		USG end of school day		p-Value
	Mean	SD	Mean	SD	
Hydrated group (n = 13)	1.016	0.004	1.019	0.006	0.072
Slightly dehydrated group (n = 67)	1.025	0.003	1.024	0.006	0.303
Seriously dehydrated group (n = 50)	1.033	0.002	1.030	0.006	0.001

USG, urine specific gravity.

TWI in the morning was on average 247 ± 135 mL. Water intake in the morning differed significantly between groups ($F_{2, 282} = 8.738$, $p < 0.001$, $\eta^2 = 0.059$). Bonferroni post-hoc analysis showed that group 3 had significantly less water intake (209 ± 108 mL) than the two other groups (group 1: 234 ± 114 mL; group 2: 274 ± 149 mL).

The TWI for the entire school day was on average 805 ± 474 . More specifically, TWI was 730 ± 430 mL for group 1, 875 ± 489 mL for group 2 and 751 ± 451 mL for group 3. There was no difference in the TWI between groups ($F_{2, 282} = 2.083$, $p = 0.126$, $\eta^2 = 0.015$). Contribution of the fluids was 661 ± 435 mL ($85 \pm 19\%$ TWI) and water intake from solid food was on average 91 ± 79 mL ($15 \pm 19\%$ TWI) for all participants combined together. Some participants had zero water from solid food. For the hydrated participants, water from fluids was 661 ± 435 mL ($88 \pm 10\%$ TWI) and water from solid food was 76 ± 48 mL ($12 \pm 10\%$ TWI). For the slightly dehydrated participants water from fluids was 805 ± 478 mL ($85 \pm 19\%$ TWI) and water from solid foods was 90 ± 74 mL ($15 \pm 19\%$ TWI). For the seriously dehydrated participants, water from fluids was 693 ± 454 mL ($84 \pm 22\%$ TWI) and water from solid food was 96 ± 95 mL ($16 \pm 22\%$ TWI).

Comparisons on subjective feelings in the morning showed that seriously dehydrated individuals felt less alert than the rest of the students ($p = 0.001$). There was no other difference on the remaining subjective feelings at the morning data collection point (Table 2).

Table 2: Rating of subjective feelings in the morning (scale 0–100 mm; not-at-all to very-much) – comparisons between groups.

Hydrated group	Slightly dehydrated group	Seriously dehydrated group	p-Value
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	Mean	SD	Mean	SD	Mean	SD	
Thirst, mm	29	21	37	23	40	24	0.236
Dry mouth, mm	33	23	31	25	37	24	0.421
Numb head, mm	09	13	12	18	16	21	0.333
Fatigue, mm	31	24	34	25	35	26	0.926
Concentration, mm	69	19	64	25	60	27	0.420
Alertness, mm	65	20	59	24	48 ^a	28	0.001

^aDenotes difference between group 3 and the other two groups ($F_{2,316} = 7.652$, $p = 0.001$, $\eta^2 = 0.047$; Bonferroni pairwise comparisons $p < 0.035$). SD, standard deviation.

USG at the end of school day correlated with specific gravity in the morning ($p < 0.001$), morning water intake ($p < 0.001$) and TWI ($p < 0.001$) (Table 3).

Table 3: Pearson's correlation coefficients between USG-morning and subjective feelings.

Variables	USG morning	Head numbness	Concentration	Fatigue	Alertness	Thirst
USG morning	1.000					
Head numbness	0.099 $p = 0.250$	1.000				
Concentration	-0.159 $p = 0.063$	-0.437 $p < 0.001$	1.000			
Fatigue	0.035 $p = 0.679$	0.311 $p < 0.001$	-0.366 $p < 0.001$	1.000		
Alertness	-0.257 $p = 0.002$	-0.129 $p = 0.133$	0.331 $p < 0.001$	-0.111 $p = 0.195$	1.000	
Thirst	0.155 $p = 0.069$	0.184 $p = 0.031$	-0.207 $p = 0.015$	0.067 $p = 0.436$	-0.060 $p = 0.488$	1.000

USG, urine specific gravity.

Correlation analysis on TWI and subjective feelings (Table 4), showed that TWI inversely correlated with head numbness ($r = -0.248$, $p < 0.000$), and feeling of fatigue ($r = 0.170$, $p = 0.005$) at the end of the school-day. At the same time point, TWI correlated with concentration ($r = 0.146$, $p = 0.015$) and alertness ($r = 0.170$, $p = 0.005$).

Table 4: Pearson's correlations between total water intake and subjective feelings at the end of school day.

Variables	Total water, mL	Head numbness	Concentration	Fatigue	Alertness
Total water, mL	1.000				
Head numbness	-0.248 $p < 0.001$	1.000			
Concentration	0.146 $p = 0.015$	-0.419 $p < 0.001$	1.000		
Fatigue	-0.170 $p = 0.015$	0.496 $p < 0.001$	-0.313 $p < 0.001$	1.000	
Alertness	0.170 $p = 0.005$	-0.248 $p < 0.001$	0.352 $p < 0.001$	-0.320 $p < 0.001$	1.000

Discussion

According to the findings of the current study, 90% of the participants arrived at school with a USG above 1.020 and nearly half of these students had a USG over 1.030, which indicates serious dehydration. At present, not much data is available in the literature on adolescents during school time, but other similar studies on children showed that 67.2% of Italian children [19] and 63–66% of children in a study in the USA [23] had raised urine osmolality during school time. The prevalence of dehydration in the present study was much higher. One reason for this discrepancy could be that data in the other studies were collected in countries with a more temperate

climate and/or outside the summer months, whereas data in the present study were collected in the latter part of May, where temperatures reached 30 °C and water losses can be higher [2]. However, dehydration prevalence in other warm countries has been reported to be 67.5% in elementary school children in Israel [17] and 74% in young adults living in Saudi Arabia [24]. Therefore, the warm climate cannot fully explain the high rate of dehydration observed in the present study. Apparently drinking behavior, knowledge and/or education on hydration and its importance could well be lacking in Cyprus. This should be an objective for future studies.

Another finding was that hydration status did not change from the first morning urine collection to the second urine sample, taken at the end of the school day. Studies investigating fluid intake to restore hydration following exercise in the heat indicated that adults do not voluntarily drink enough fluids to restore water balance, whereas children can voluntarily replace a larger volume of fluids, replacing most of the water losses due to sweating [25]. However, voluntary fluid intake for dehydrated adolescents, especially those engaging in physical or sporting activities, also appears to be insufficient to maintain euhydration [26], [27].

The European Food Safety Authority (EFSA) suggests 2.0 L and 2.5 L of water intake for adolescent females and males [9]. If it is assumed that on average, adolescents sleep 8 h/day [28], then time on school premises accounts for almost half of their waking time. Water intake during school-time in the present study was on average 765 mL (ranging between 60 and 2500 mL, very large variation between individuals) and one can hypothesize that many students will probably not meet the recommended daily water intake, confirming data from other countries. According to the HELENA study over many European countries, 69.4% of boys and 64.4% of girls older than 14 years have lower than recommended daily water intake [29], and in Spain this percentage reaches 87% of children and adolescents [18].

It is obvious that dehydrated participants in the present study did not consume adequate amounts of fluids to restore euhydration during school time. Although drinking behavior was not investigated in the present study, in general, beverages may be more readily available and consequently consumed at mealtimes, compared with between-meals. For instance, drinking may occur at meal times to facilitate chewing and swallowing and food palatability [30]. Availability and effort needed to obtain a beverage may also partially account for the apparent association between fluid and food intake, as beverages may be more readily available and consequently consumed at mealtimes. Furthermore, there is the assumption that feeding is a determinant of drinking, and fluid intake is regulated secondarily to food intake. This interpretation is based, partially, on the observations that approximately 75% of fluid intake is peri-prandial and there is a direct relationship between eating and drinking [31]. On the other hand, recent studies have suggested that up to 71% of fluid intake can take place outside of meals [32], [33], but also drinking behavior differs vastly from country to country [32], suggesting that the cultural aspects/habits is a stronger driver than the food. At the moment, no data exist on the drinking behavior of Cypriot adolescents. However, during school-time, although the students are allowed to have a water bottle during class, apparently students do not drink during class and they only drink during break time. For the future, steps should be taken to provide education on proper hydration and potentially change regulations or habits regarding fluid and water availability during class.

With regards to subjective feelings, an important finding of the present study was that there was no difference on sensation of thirst between the groups. Even the seriously dehydrated student did not feel any thirstier than the well hydrated ones. In other studies, dehydrated individuals with ad libitum access to fluids, have been shown to fail to ingest adequate amounts to properly rehydrate following acute dehydration [34], as thirst apparently might not be enough of a stimulus to drink more. As the sensation of thirst and the drive for fluid intake is affected by a number of osmotic, ionic and hormonal factors that interact with the central nervous system [35], this finding is far beyond the scope of the present study.

With regard to other subjective feelings, Shirreffs et al. [3] showed that following acute dehydration, individuals feel more tired, experience greater head numbness and feel less alert. The data in the present study showed that seriously dehydrated students felt less alert than the other students in the morning. Furthermore, USG was inversely correlated with alertness, which in turn was associated with a reduced ability to concentrate. At the end of the school day, TWI correlated with alertness and ability to concentrate, and it was inversely correlated with head numbness and fatigue. These findings indicate that seriously dehydrated students or those who do not drink enough may be susceptible to decreased ability to perform during classes. Indeed, other studies have shown that voluntary dehydration adversely affects cognitive function [4], [5] and that provision of water improves cognitive function in children [36] and handwriting skills [15]. However, this evidence derives from studies done mostly on elementary school children, and at the moment there is a lack of data on the adolescent population, who also appears to suffer from voluntary dehydration.

The present study is one of very few studies to provide information on adolescents and hydration, but it also has certain limitations. USG is not the gold standard of body hydration biomarkers. Specific gravity only shows concentrated urine and does not provide information on plasma osmolality, as the body can maintain body water by reducing water losses via urine. However, USG has clearly shown to increase in individuals with low daily fluid intake, compared with individuals who consume large volumes of fluids in daily life [37].

Another limitation of the study is that data were collected during a single school-day, and no drinking habits or day-to-day variation information is provided. But, the rate of high USG appearance is alarming. Adolescents need proper hydration status determination to enhance safety guidelines on fluid intake patterns and behavior.

With regards to subjective feelings, the visual analog scale used in the present study has often been used after acute dehydration following exercise or fluid restriction when the individuals were dehydrated. In the present study, the statistical association of the subjective feelings with USG and water intake provide a good indication the visual analog scale can provide good information on any given day or time.

Despite the limitations of the present study, the prevalence of high USG is alarming, as potentially many adolescents are dehydrated and not aware of the situation. The findings of subjective feelings, the decreased alertness and the association of high USG and increased feeling of fatigue show there might be a real reason for concern here. This is clearly a health concern for the population under study. Although the students are allowed to carry water with them in class, the students fail to restore euhydration during class, as USG remained raised at the end of the school day.

Conclusions

In conclusion, the prevalence of voluntary dehydration was 90% among a sample of Cypriot adolescents upon arrival at school in the morning. Hydration status did not change by the end of the school-day. Seriously dehydrated students were less alert in the morning. High USG was associated with decreased alertness and the ability of the students to concentrate. Thirst was similar among students and did not drive dehydrated students to drink more.

Future studies should investigate potential chronic dehydration, short- and long-term effects on school performance and overall health.

The degree of dehydration reported in the present study could negatively affect adolescents; health, cognitive function and potentially school performance, could be compromised due to dehydration as has been already discussed here. This high prevalence of dehydration could be attributed (although not examined in the present study) to a lack of education of the students, their parents, guardians, as well as the teachers. Proper measures should be taken to educate people on the importance of adequate hydration. It has been shown that cognitive function requires adequate fluid intake across the school day [38], and school policies should include special provisions for free access to water and fluids throughout the day, potentially including lesson time.

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