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Abstract

The aim was to examine the hydration status of adults working in different jobs at the beginning and end of a shift and their reported water intake. 156 subjects (89 males, 67 females) were recruited from workplaces within the local area (students, teachers, security, office, firefighters catering). A urine sample was provided at the start and end of the shift and analysed for osmolality (U_{osm}), specific gravity (USG) and sodium and potassium concentrations. Euhydration was considered U_{osm} <700 mOsmol/kg or USG <1.020. At the end of the shift subjects were asked to report all water intake from beverages during the shift. Females had lower U_{osm} than males at the start (656 (range 85-970) v 738 (range 164-1090) mOsmol/kg) and end (461 (range 105-1014) v 642 (range 130-1056) mOsmol/kg; P<0.05) of their working day. 52% of individuals who appeared hypohydrated at the start of the shift were also hypohydrated at the end. Reported water intake from beverages was greater in males compared to females (1.2 (range 0.0-3.3) v 0.7(range 0.0-2.0) litres respectively; P<0.0001). In conclusion, a large proportion of subjects exhibited urine values indicating hypohydration with many remaining in a state of hypohydration at the end of the shift.

Key Words

hydration, workplace, water intake, classroom

Text

Introduction

The importance of monitoring hydration in the workplace is important from a health and a functional point of view as well as providing indication of drinking behaviours. Previous studies examining hydration status in the workplace have focussed on workers in hot and humid conditions performing physical activity[1,2] and those wearing personal protective equipment[3,4]. These studies have tended to focus on extreme situations and environmental conditions which may not be applicable to those who work in temperate conditions performing less strenuous activity without protective equipment. In many work places, environmental conditions are often controlled by air conditioning and heating systems and many workers may remain seated at a desk for a large portion of the shift.

When hydration status has been examined in the workplace, many workers have arrived already dehydrated[2]. In this study by Brake and Bates[2] it was found that around 60% of underground miners reported to work in a dehydrated state and hydration status did not improve over the course of the shift. With the majority of workers arriving already dehydrated they may be required to consume extra water in addition to normal consumption in order to return to a euhydrated state.

The reasons why individuals chose to drink or not to drink in certain scenarios can be assessed by the consideration of drinking influences and access to beverages. Understanding this may help prevent hypohydration and possible subsequent impairment of performance. For example anecdotal evidence from questionnaires has shown that individuals restricted water intake if toilet facilities were not available[5]. Limited access to toilet facilities (e.g.

when driving or when a teacher is looking after a class) may have had an impact on the amount of subsequent water consumed during the shift, and may have contributed to any dehydration that may have occurred.

Typically euhydration has been considered when USG values are below 1.020 and urine osmolality is below 700 mOsmol/kg[6]. These values outlined by Sawka et al.[6] in the American College of Sports Medicine (ACSM) position stand, provided a guideline for self-assessment and were derived from previous studies[7,8]. The guidelines provide an approximate classification of whether an individual is euhydrated but do not provide an indication of hyperhydration or to the severity of dehydration.

From a health standpoint, reduced habitual water intake has been associated with colon cancer[9] and cancer of the bladder[10]. In the workplace, particularly if water intake or access to beverages is restricted due to the line of work or facilities, it is possible workers may become more at risk to these health issues.

In addition to maintenance of health, one of the main reasons for examining hydration status in the workplace is the associated decline in cognitive function with dehydration. The effect of dehydration has been studied in a variety of situations relating to cognitive performance, however the concluding effect is often varied[11,12]. As part of a review, Lieberman[11] assessed the effect of water restriction alone on cognitive performance and decided that there was not enough evidence to provide a definitive conclusion. However, in the review by Grandjean and Grandjean[12], they concluded that a body mass loss of greater than 2% caused by dehydration through water restriction, exercise and/or heat can have a negative impact on cognitive performance. In the workplace, a reduction in cognitive performance may reduce quality of work, productivity and decision making, thereby making workers ineffectual. Dehydration of between 2 and 4% body mass loss has been shown to reduce short-term memory, visual motor tracking, arithmetic efficiency and attention[13] and decrease perspective discrimination and psycho-motor skills[14]. Studies examining the relationship between dehydration and cognitive performance have tended to elicit dehydration through exercise or heat and exercise[13,14], and therefore not directly applicable to situations commonly experienced in many workplaces.

Assessing water intake behaviours during a shift and hydration status of workers at the start and end of their shift may help identify those who are dehydrated and hyperhydrated whilst also identifying ways to prevent it from occurring. Therefore, the primary aim of this study was to examine the hydration status of different work groups at the beginning and end of a shift (approximately 8 hours). A secondary aim was to examine the influences on water intake (e.g. access to water, water cooler towers, breaks, access to toilet facilities etc.) and behaviours between the groups monitored and examine whether this could affect or influence observed hydration status.

Experimental methods

Subjects

156 subjects (32 (range 19-63) years, 1.74 (SD 0.10) m, 77.6 (SD 15.3) kg) comprising of 89 males and 67 females were recruited from the local area. Subjects were research students (*n* 33), classroom taught students (*n* 24), teachers (*n* 31), security staff (*n* 15), firefighters (*n* 22), office workers (*n* 15) and catering staff (chefs and kitchen assistants) (*n* 16). Subjective characteristics for each group are displayed in Table 1. 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 Loughborough University Ethics Committee. Written informed consent was obtained from all subjects.

Groups

Each group is described below with a brief description of a typical working day and any breaks that were allowed for each group of subjects. Any major barriers to water intake are also noted.

Research – University PhD and research students primarily based in an office environment but with visits to laboratory for short periods of experimental work. No restriction on frequency and duration of break times and were able to eat and drink freely as they worked.

Classroom taught students – University MSc students who participated in laboratory classes all day and therefore considered typical of a laboratory worker with restrictions on food and drink access. Food and water intake banned in the laboratory so subjects had to leave the laboratory to eat and drink. One hour break at lunch.

Teachers – Taught classes (secondary school) for at least five hours per day with a small break of approximately 5 minutes after each one hour lesson. One hour for lunch break and a

20 minute break at around 10am. Unable to leave the classroom and use toilet facilities whilst teaching classes. Unable to eat during classes but were able to consume their own drinks.

Security – University security staff working a variety of shift patterns including night shifts. A 15 minute break before and after a 30 minute lunch/dinner break. Staff patrolled the university on foot, bike and in motorised vehicles and were able to drink freely during the shift when time permitted.

Firefighters – Day (*n* 17) and night (*n* 5) shifts observed. Staff performed maintenance and practice drills throughout the day as well as having a physical activity session involving strength and aerobic activity in the onsite gym. Physical activity and therefore sweat losses were not recorded so that additional measures did not impact and influence a typical day. Average number of call outs was three per day. Were able to eat and drink freely when not performing drills or on call outs, when there was limited access to water.

Office – Staff were sat at computers throughout the duration of the day, two small 15 minute breaks in the morning and afternoon and a 30 minute lunch break. Were able to eat and drink freely whilst working.

Catering – Kitchen staff and chefs at university canteen. On feet throughout the majority of the shift, with a large portion of work time (exact time unknown) spent in the kitchen preparing food. Two 15 minute breaks and a 30 minute break for lunch. Were able to drink, outside of scheduled break times, if time permitted.

Procedure

Subjects arrived at their place of work immediately prior to their shift and were asked to sign an informed consent form, complete a 100 mm visual analogue subjective feelings questionnaire comprising of six questions relating to thirst (0= not at all thirsty, 100= very thirsty), mouth dryness (0= not at all dry, 100= very dry), hunger (0= not at all hungry, 100= very hungry), tiredness (0= not at all tired, 100= very tired), concentration (0= not very well, 100= very well) and energy (0= no energy, 100= lots of energy) and a small questionnaire relating to their water intake patterns during a typical shift. The questionnaire asked about access to drinks, any influences on drinking, typical water consumption and whether they experienced thirst and changes in concentration during a shift. They then provided a urine sample, before height and body mass were measured to the nearest 10 g (Adam CFW-150, Milton Keynes, UK) whilst wearing loose fitting clothing (one layer) and without shoes. The urine sample may not have been the first void of the day but the aim of the study was to examine hydration on arrival at the workplace. Subjects were then asked to complete their work shift as normal. On completion of the shift subjects provided a urine sample. Body mass was measured but not reported. Changes in body mass could not be accurately related to change in hydration status due to not measuring accurately food and drink intake, sweat losses, urine output and excretion losses. It was felt that these measures would impact on the "typical day". They were asked to fill in the same subjective feelings questionnaire and a small questionnaire relating to their water intake during the shift. Questions related to access to drinks during the shift, how much they consumed, whether they experience a feeling of thirst and if so did they drink to alleviate this? Reported water intake was then presented as the water component of all drinks reportedly consumed. They were asked to rate their concentration at the start, middle and end of the shift using a 100 mm visual analogue scale and whether they felt they remained hydrated throughout the duration of the shift. Subjects were then free to leave. Ambient temperature and relative humidity was measured at the start and end of each shift both inside and outside the place of work (RH85 Digital Thermo-Hygrometer; Omega, Manchester, UK). The duration of each shift was based on a typical eight hour working day. To participate, all subjects must have completed a shift of at least seven hours. All subjects completed this and none were excluded.

Sample analysis.

Urine samples were analysed for osmolality by freezing point depression (Gonotec Osmomat auto Cryoscopic Osmometer; Gonotec, Berlin, Germany), specific gravity by refractometry (Digit-012, Ceti, Belgium) and colour[7]. Urine sodium and potassium concentrations were measured by flame photometry (Corning Clinical Flame Photometer 410C; Corning Ltd., Halstead, Essex, UK). All samples were analysed in duplicate and a mean of the duplicate was used.

Statistical analysis

All data was checked for normality using the Kolmogorov-Smirnov test if the data set was large (n>30) and the Shapiro-Wilk test if the data was less than n=30. One-way ANOVA and Kruskal-Wallis tests were used for parametric and non-parametric data respectively to identify differences between groups. Independent sample t-tests and Mann-Whitney tests were subsequently performed as post-hoc analysis when significant differences were observed and also to compare between start and end values within each population. Linear regression was used to identify relationships. A significance value of $P<0.05$ was used. Parametric data is expressed as mean (SD) and non parametric data expressed as median (range).

Results

Environmental conditions

Inside the places of work at the start of the shift, environmental conditions were 19.6 (SD 1.6) °C and 41.9% (range 27.8-55.5%) relative humidity. At the end of the shift, temperature was 20.5 (SD 1.0) °C and relative humidity was 41.7% (range 17.0-49.5%). Outside conditions were 8.7 (SD 3.6) °C and 60.1 (SD 14.7) % at the start and 9.5 (SD 4.1) °C and 56.0 (SD 14.3) % at the end of the shift. Environmental conditions for each group presented in Table 2.

Pre-shift questionnaire

98% (*n* 153) of subjects had access to drinks during the course of their shift. When asked about barriers to drinking during their shift, 67% reported perceived influences on drinking behaviour including sensations of thirst and mouth dryness, a lack of toilet facilities, timings of breaks, remembering to drink and access to drinks in particular environments (e.g. on call or in a laboratory). During a normal shift males reported (through cups and volumes) consuming more water than females (1.0 (range 0.2-4.2) litres v 0.9 (range 0.1-2.0) litres) ($P<0.0001$). Typical reported water intake by classroom taught students (0.6 (range 0.1-1.5) litres), teachers (0.6 (range 0.2-3.0) litres), security (1.0 (range 0.4-1.5) litres), catering (1.0 (range 0.5-2.0) litres) and office groups (1.0 (range 0.3-2.5) litres) was similar ($P>0.05$), whilst greater water intake was typically reported to be consumed in the research group (1.0 (range 0.4-3.0) litres) compared to the teachers group ($P<0.0001$). The firefighters (2.5 (range 1.0-4.2) litres) reported normally consuming more water than all other groups during a typical shift ($P<0.0001$). During a typical shift 56% of subjects reported normally experienced a sensation of thirst and 45% felt, during a normal shift, their concentration was affected if they did not drink enough water.

General results

For the population as a whole, lower urine osmolality and specific gravity values were measured at the end of the shift (Table 3), whilst females arrived and left work with lower urine osmolality and specific gravity values ($P<0.05$). Reported sensations of tiredness and hunger were higher at the end of the shift in the whole population, whilst reported sensations of concentration and energy were lower ($P<0.05$) (Table 3). Sensations of thirst were similar for the whole population ($P>0.05$) but greater in females at the end of the shift compared to the start ($P<0.05$) (Table 3). There was large variation in individual start and end values of urine osmolality and USG for males and females with no clear patterns or trends emerging from the data (Fig 1). Subjects were classed as euhydrated if urine osmolality was less than 700 mOsmol/kg or urine specific gravity was less than 1.020[6]. Hypohydration was classed as urine values above these values. Out of 156 subjects, 54% started the shift with a urine osmolality representing hypohydration, with 35% ending the shift with urine osmolality values considered hypohydrated (Table 4). 64% of males started the shift hypohydrated compared to 42% of females. The research and firefighters group had the greatest proportion of subjects starting the shift in a hypohydrated state.

Group comparison

Between groups

USG values at the start of the shift in the research and firefighter group were greater than the office, teachers and catering groups and were greater than end of shift values ($P<0.05$) (Fig. 2). Urine osmolality values showed a similar pattern except start values for the research and firefighters group were also greater than the classroom taught students group and the firefighters group were not greater than the start values in the catering group (Fig. 2). Urine sodium concentrations were greater in the security group at the start of the shift compared to the classroom taught students and teachers group and at the end of the shift compared to the research, classroom taught students, teachers, firefighters and office groups ($P<0.05$) (Fig. 2). Urine potassium concentrations were lower at the end of the shift compared to the start in the research group ($P<0.05$) (Fig. 2).

Urine colour for males at the end of the shift was lower in the research group (2 (range 1-6)) compared to the classroom taught students group (4 (range 3-7)), security group (4 (range 1-6)) and the catering group (5 (range 3-6)) ($P<0.05$). Classroom taught students had greater values of urine colour compared to teachers (2 (range 1-5)) but lower values than catering staff ($P<0.05$).

Urine sodium concentrations at the end of the shift for males were higher in the security group (145 (SD 39) mmol/l) compared to the researchers (105 (SD 43) mmol/l), classroom taught students students (93 (SD 45) mmol/l), teachers (91 (SD 47) mmol/l), firefighters (99 (SD 43) mmol/l) and office staff (83 (SD 41) mmol/l) ($P<0.05$). Catering staff (151 (SD 30) mmol/l) had greater sodium concentrations at the end of the shift compared to classroom taught students, teachers and firefighters ($P<0.05$).

Females in the classroom taught students group had higher end of shift concentrations for urine potassium concentrations (110 (SD 33) mmol/l) compared to researchers (73 (SD 34) mmol/l), teachers (79 (SD 40) mmol/l) and security guards (58 (SD 17) mmol/l) ($P<0.05$).

Catering staff females had higher urine potassium concentrations at the end of the shift (100 (SD 24) mmol/l) compared to the researchers and security guards (*P*<0.05).

Within groups

In the research group a reduction from the start to the end of shift values for USG, osmolality and potassium concentrations occurred for the whole group and within males and females (*P*<0.05). Urine colour was lower at the end of the shift in the whole research group and for male researchers (both 4 (range 1-6) v 2 (range 1-6)) whilst comparing the research group as a whole revealed a reduction in energy levels at the end of the shift (63 (SD 16) v 54 (SD 21)) (*P*<0.05).

Females in the classroom taught students group had an increase in potassium concentrations at the end of the shift (80 (SD 47) v 110 (SD 33) mmol/l) (*P*<0.05). Reported feelings of hunger were greater at the end of the shift for all the classroom taught students (22 (SD 19) v 50 (SD 26)), male classroom taught students (22 (SD 21) v 52 (SD 26)) and female classroom taught students (21 (SD 17) v 48 (SD 27)) (*P*<0.05).

All reported subjective feelings in the teacher group were different between the start and end of the shift. Thirst (37 (SD 24) v 56 (SD 26)), mouth dryness (39 (SD 25) v 56 (SD 27)), tiredness (51 (SD 23) v 69 (SD 22)) and hunger (15 (SD 21) v 32 (SD 23)) were significantly higher at the end of the shift. Concentration (69 (SD 22) v 51 (SD 23)) and energy (63 (SD 20) v 50 (SD 20)) levels declined throughout the shift (*P*<0.05). In male teachers mouth dryness (30 (SD 24) v 47 (SD 28)) and hunger (9 (range 0-49) v 35 (range 5-65)) increased whilst concentration (82 (range 13-98) v 50 (range 10-80)) decreased throughout the shift (*P*<0.05). In female teachers thirst (23 (range 5-100) v 59 (range 13-100)), mouth dryness

(47 (range 1-82) v 74 (range 11-93)) and tiredness (44 (SD 25) v 69 (SD 19)) increased throughout the shift whilst concentration significantly decreased (66 (SD 21) v 51 (SD 22)) ($P<0.05$).

In all security guards, concentration levels decreased throughout the shift (63 (SD 20) v 50 (SD 20)) ($P<0.05$). Urine specific gravity (1.023 (SD 0.006) v 1.016 (SD 0.007)) and urine osmolality (754 (SD 198) v 573 (SD 230) mOsmol/kg) were lower at the end of the shift in the firefighters group ($P<0.05$). Concentration levels in all office workers (70 (SD 18) v 49 (SD 20)) and in only male office workers (73 (SD 18) v 46 (SD 21)) were lower at the end of the shift ($P<0.05$). Catering staff reported greater levels of tiredness at the end of the shift (29 (SD 23) v 45 (SD 25)). Male catering staff experienced greater feelings of thirst (63 (SD 20) v 50 (SD 20)) and mouth dryness (58 (SD 8) v 19 (SD 9)) at the start of the shift ($P<0.05$).

Reported water intake

Males reported more water consumption compared with females during the monitored shifts ($P<0.0001$). Males reported consuming 1.2 litres (range 0.0-3.3 litres) compared with 0.7 litres (range0.0-2.0 litres) for females. This was equivalent to 14 (range 0-47) ml/kg and 10 (range 0-32) ml/kg for males and females respectively ($P=0.004$). Within each group there was no difference between the water reportedly consumed by males and females (research: 1.2 (0.4-3.3) v 0.9 (0.3-1.9) litres, classroom: 0.7 (0.0-1.1) v 0.5 (0.0-1.4) litres, teachers: 0.8 (0.4-2.5) v 0.6 (0.0-1.2) litres, security: 0.9 (0.3-2.0 v 1.4 (0.8-2.0) litres, office: 1.3 (0.5-3.0) v 0.8 (0.5-1.5) litres, catering: 1.8 (0.4-2.0) v 0.8 (0.4-1.4) litres for males and females respectively) ($P>0.05$). Regardless of gender and focussing just on the work groups, the firefighters reported consuming more water than all other groups ($P<0.05$) (Fig. 3). Reported water intake was weakly related to feelings of thirst at the start of the shift (positively) (r=0.161, *P*=0.044) but not at the end of the shift. At the end of the shift USG values were negatively related to reported water intake for the whole population (r=0.226, *P*=0.005), males (r=0.356, *P*=0.001) and females (r=0.253, *P*=0.039). A similar pattern occurred for osmolality values (whole population (r=0.230, *P*=0.004), males (r=0.349, *P*=0.001) and females (r=0.272, *P*=0.026)). USG and osmolality values at the start of the shift as a whole and within groups were not related to reported water intake values (*P*>0.05). The change in USG and osmolality from the start to the end of the shift was negatively correlated with reported water intake (USG: r=-0.325, *P*<0.0001, U_{osm}: r=-0.329, *P*<0.0001) so the larger the decrease in USG and U_{osm}, the greater reported water intake. When U_{osm} and USG decreased from the start to the end of the shift, reported water intake was greater compared to when U_{osm} and USG increased (1.1 (0.0-3.3) v 0.7 (0.0-2.6) litres) (*P*<0.05).

Sensations of thirst and concentration levels

117 workers reported experiencing a sensation of thirst at some point throughout the duration of the shift. 85% (*n* 99) alleviated thirst by consuming a drink. The average amount of water reported that was used to satiate sensations of thirst was 0.2 (range 0.05-1.4) litres. 92% of males who experienced thirst alleviated the sensation by consuming water compared with 75% of females. Concentration levels at the start and end of the shift were not related to the corresponding values for osmolality and specific gravity (*P*>0.05). 65% (*n* 101) of the workers felt that they kept themselves hydrated throughout the duration of the shift. Of those that thought they were hydrated at the end of the shift 70% (*n* 71) and 68% (*n* 69) had urine osmolality and urine specific gravity values respectively that were below 700 mOsmol/kg and 1.020, whilst of those that did not feel like they kept themselves hydrated 41% (*n* 22) and 43% (*n* 23) had osmolality and USG values respectively, not classed as euhydrated.

Discussion

The purpose of the study was to examine hydration status in different working groups at the start and end of a shift and examine water intake during the shift. Overall there was very little difference in the hydration status parameters and reported water intake values between the groups observed. Reported water intakes between groups were very similar with slight differences between males and females, with males consuming more water.

Individuals in the classroom taught students group reported that the observed shift was not typical of a normal day. This was because they were in laboratory classes where drinking was prohibited unless they left the laboratory. Although not typical of a normal day but typical of one out of five working days, the group was chosen based on the laboratory classes to allow for a comparison to similar subjects in the University research/studying environment.

In general, subjects had higher values of urine specific gravity and osmolality at the start of the shift compared to the end. A large proportion of subjects (54% at the start and 35% at the end) exhibited urine values indicating hypohydration with many (52% of the original 54%) remaining in a state of hypohydration at the end of the shift. Data used as markers of hydration status (USG and urine osmolality) were lower at the end the shift; however, from a physiological perspective it was difficult to determine if the difference in hydration values corresponded to a change in hydration status, particularly when using ACSM guidelines[6] where an individual is classed as either euhydrated or not. Despite this, by collecting urines samples at least 8hr apart and with the reporting of water intake during the shift, a valid representation of hydration status during a typical working day was created.

Females have been shown to consume less water[15-17], confirming reported absolute and relative water intake values in this study. This may have been due to males trying to sustain greater body water content. Kant[15] examined 4112 individuals in North America and found no difference in plain water intake between males and females (1044 (SEM 48) v 1079 (SEM 67) g for males and females respectively; P=0.5) but females consumed significantly less water from other beverages (1783 (SEM 55) v 1298 (SEM 35) g for males and females, respectively; P<0.0001). All three studies examined water intake over 24 h so direct comparisons may not be used but the general trends were similar. The lower reported water intake in the present study may be attributed to the lower values of USG and urine osmolality for women at the start of the shift. If males and females had both begun the shift in a similar state of hydration, reported water intake values in females may have been greater.

The firefighting group reported greater water intake during the observed shift compared with all the other groups. The firefighters are generally encouraged to drink during the shift by management and through urine colour charts in the toilets. Compared to other groups they have previously been made aware of the necessity to drink and maintain hydration status to prevent declines in cognitive and physical performance through initiatives and regular health testing. It has been shown that educating workers about dehydration, whilst assessing hydration status and implementing a water replacement program increases the likelihood of arriving at work and remaining in a euhydrated state[2]. For the firefighters the structure of their general day was dependent on emergency calls (average of three per day) and so it appeared that they would drink in anticipation of this and the possibility of wearing personal protective equipment which can often cause heat dress due to the uncompensable environment they create[3]. In contrast, the classroom taught students group reported drinking very little water. During the laboratory classes they were restricted on where they could drink and thus was reflected in the reported volume consumed and the subsequent urine parameters.

Typical water intake values that have been reported in the general population from beverages are approximately 1.3 litres/d from The National Diet and Food Survey[18]. This value was an average per day over a seven day observation period and included alcohol consumption (approximately 0.3 litres/d). In the present study, water intake was only reported during the working day and so it was difficult to make direct comparison. In 2010, the European Food Safety Authority outlined an adequate intake of 2.5 litres/d for males and 2.0 litres/d for females from also sources of water including food[19] whilst the Institute of Medicine had an adequate intake of approximately 3.7 litres/d for males from food and beverages and 2.7 litres/d for females[20]. The Food Standards Agency[21] suggested a value of 1.2 litres from beverages to prevent dehydration occurring. The recommendations vary in suggested water intake, but if the lowest value is taken, only five groups reported intake close to, or above this value in the monitored shift alone whilst the remaining two groups (classroom taught students and teachers) had the greatest barriers to water intake due to availability of water, restrictions on when and where they could drink and access to toilet facilities. Again, it must be stressed that the adequate water intakes for a day cannot be compared to the water intake during the shift as subjects were only at work for a relatively small portion of the day. However, it can provide an indication of water intake behaviours and patterns. Within the time at work it was likely that either 1 or 2 main meals, where large amounts of water, through food and accompanying drinks, would probably not be consumed.

Several subjects reported water intake over 2 litres per day with one subject in the research group and two in the firefighters group reporting a water intake value of 3.3, 3.0 and 3.0 litres respectively throughout the shift (start U_{osm} of 813, 736 and 779 mOsmol/kg respectively; end U_{osm} of 519, 240 and 507 mOsmol/kg respectively; start USG of 1.028, 1.020 and 1.021 repectively; end USG of 1.014, 1.007 and 1.014 respectively). The firefighters group appeared most at risk from overdrinking with 14 out of 22 subjects reporting water intake over 2 litres during the shift. Despite this, urine osmolality values were, on average, above 700 mOsmol/kg at the start of the shift and this decreased slightly at the end of the shift. This, therefore suggested that either their reported water intake was adequate or that the actual volumes reported were inaccurate. When asking individuals to self report food and drink intake, often errors can occur particularly with underreporting[22] indicating that water intake volumes in the present study might have been underreported. Only with accurate measurement of water intake through weighing of drinks and food consumed, could a more precise analysis of water intake be conducted. However, this may have altered behaviour and made participants more aware of water intake.

During day to day occupational activity thirst is an adequate stimulus to promote water replacement and help maintain hydration status[23]. Of the workers monitored, 117 (75%) experienced a sensation of thirst at some point during the duration of the shift with 85% alleviating the sensation through a drink. These results suggest that thirst was an adequate stimulus in the present study to initiate drinking, however examining the role thirst plays maintaining hydration status is difficult because it was not known whether every bout of water intake was initiated by thirst. This becomes particularly apparent when consideration is taken of the number of subjects who were not euhydrated at the end of the shift despite sensations of thirst and alleviation with consumption of beverages. With sensations of thirst similar at the start and end of the trial, it appeared that enough water was consumed throughout the shift to maintain a certain level of thirst.

Assessing a start and end urine sample provided information regarding these time points but little information regarding hydration was gathered throughout the duration of the shifts. Assumptions could have been inferred involving a direct link between start and end values, possibly suggesting that the end value arose directly from the start value. However, euhydration has been shown to follow a sinosuidal wave and fluctuate around an average value over a period of time[(23)]. Therefore, to determine the pattern throughout the shift it would have been advantageous to increase the frequency of sampling to a fixed number or a collection of all samples produced. The major problem with this would have been the interference with the "typical" day of the subject creating a deviation from normality and thus potentially affecting urine output and normal water intake patterns. A solution to improve this would be to test over a number of days with greater frequency of sampling, thereby allowing the subject to adjust to the method of testing.

The desire to assess hydration status and reported water intake during a typical working day resulted in limitations in the study. A compromise was reached to observe a typical day without measuring variables that, whilst potentially enhancing the results, may have impacted on normal day to day routine, thereby reducing the validity of the results. Accurate measurement of food and water intake, urine output and sweat losses plus assessment over several days may have been beneficial, however in order to provide a 'snapshot' of a typical working day without causing changes to daily routines and providing inconvenience, it was felt that the current study design was most appropriate. This does have limitations in terms of the interpretation of the results and conclusions reached particularly due to the accuracy of reported water intake, despite this, due to the amount of subjects recruited from each place of work, confidence can be taken in the general conclusions reached and trends identified.

Conclusion

In conclusion a large proportion of subjects exhibited urine values indicating hypohydration with many remaining in a state of hypohydration at the end of the shift. A large proportion of workers (75%) experienced a sensation of thirst throughout the shift. Access to water and other beverages at work helped alleviate sensations of thirst. Increasing awareness of drinking and hydration status, helped increase water consumption during the observed shift, whilst males reported consuming more water per kg of body mass compared to females. Further investigation is required to gain insight into the causes and significance of these findings through blood indices and hormone analysis.

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Tables

Table 1. Subjective characteristics for each group of subjects

Group	*n*	Age (years)		Body mass (kg)		Height (m)	
		Mean	SD	Mean	SD	Mean	SD
Research	33	26	4	72.0	11.6	1.75	0.11
Classroom taught	24	23	1	71.8	11.2	1.74	0.08
Teachers	31	47	10	72.4	12.0	1.68	0.08
Security	15	44	9	97.1	11.3	1.83	0.09
Firefighters	22	38	8	85.8	7.9	1.80	0.05
Office	15	32	9	74.1	17.8	1.73	0.11
Catering	16	50	13	81.8	21.5	1.64	0.10

Table 2. Environmental conditions inside and outside the place of work. Shifts column denotes number of different shifts required to collect all subject group data.

		Environmental Conditions															
		Inside								Outside							
Group	Shifts	Start Temp (°C)		Start RH (%)		End Temp (°C)		End RH (%)		Start Temp (°C)		Start RH (%)		End Temp (°C)		End RH (%)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Research	5	19.3	1.4	30.9	4.0	20.7	0.9	27.4	9.7	5.4	2.0	74.0	7.9	5.4	3.6	66.5	11.1
Classroom	2	20.7	0.4	35.1	8.8	21.8	2.1	34.0	12.0	5.1	0.1	83.4	8.2	8.1	1.6	79.9	3.3
Teachers	2	18.7	2.2	45.1	2.5	21.4	1.7	39.0	4.2	5.1	0.1	83.4	8.2	8.1	1.6	79.9	3.3
Security	15	20.0	0.3	41.9	0.5	20.0	0.4	41.9	0.4	9.5	3.0	50.9	8.4	9.1	2.4	50.0	8.8
Firefighters	3	19.7	1.1	49.8	5.1	20.4	1.7	47.9	1.7	12.8	5.2	56.5	4.8	13.1	5.2	54.3	0.1
Office	2	20.6	3.0	48.4	6.8	22.0	0.8	41.4	0.7	12.5	1.5	66.3	13.4	17.8	3.4	52.2	9.6
Catering	2	15.5	1.9	41.8	0.9	20.5	0.1	25.9	0.1	7.4	0.1	46.5	5.9	12.5	2.1	34.0	9.5

Table 3. Start and end values of urine parameters and subjective feelings questionnaires for all subjects and male and females separately.

	All				Males				Females			
	Start		End		Start		End		Start		End	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
Urine Specific Gravity	1.021	1.002-1.034	1.016*	1.002-1.033	1.022	1.004-1.034	1.018*	1.004-1.033	1.019[†]	1.002-1.029	1.013[†]	1.002-1.030
Osmolality (mOsmol/kg)	717	85-1090	571*	105-1056	738	164-1090	642*	130-1056	656[†]	85-970	461[†]	105-1014
Colour	4	1-7	3*	1-7	4	1-7	3*	1-7	3[†]	1-7	3	1-6
Sodium conc. (mmol/l)	95	13-203	90	14-205	101	32-203	108	16-205	86[†]	13-182	76*[†]	14-177
Potassium conc. (mmol/l)	95	11-169	86*	16-179	96	21-157	85*	17-179	93	11-169	87	16-159
Thirst	49	0-100	49	2-100	52	0-100	48	2-89	38[†]	0-100	57*	2-100
Mouth Dryness	46	0-100	50	0-93	50	0-100	50	2-86	40	0-84	48	0-93
Tiredness	49	0-100	63*	0-100	50	0-100	63*	7-100	47	0-98	62*	0-100
Hunger	19	0-96	30*	0-94	24	0-85	35*	0-80	13[†]	0-96	20*[†]	0-94
Concentration	70	2-100	62*	5-98	68	7-100	63*	6-95	70	2-95	61	8-98
Energy	63	0-100	53*	0-92	63	0-100	55*	0-91	63	1-100	55*	11-92

* Different to start value (*P*<0.05). [†] Different to males (*P*<0.05).

Table 4. Percentage of subjects in each group who were hypohydrated at the start and end of the shift using urine values of greater than 1.020 (USG) and 700 mosmol/kg (osmolality)[6]

			Subjects hypohydrated (%)					
			Osmolality (mOsmol/kg)			Urine Specific Gravity		
Group		*n*	Start	End	Both	Start	End	Both
All		156	54	35	26	53	33	29
	Males	89	64	40	33	63	37	35
	Females	67	42	28	19	40	27	21
Research		33	73	33	27	70	27	30
	Males	22	77	36	32	73	32	36
	Females	11	64	27	18	64	18	18
Classroom		24	46	54	33	42	50	38
taught students	Males	12	50	58	33	42	50	42
	Females	12	42	50	33	42	50	33
Teachers		31	39	23	16	39	23	13
	Males	11	45	27	18	33	17	18
	Females	20	35	20	10	30	20	10
Security		15	67	53	40	60	53	47
	Males	11	73	55	45	73	55	45
	Females	4	50	50	25	25	50	50
Fire		22	73	36	23	73	36	32
	Males	22	73	36	23	73	36	32
	Females	0	-	-	-	-	-	-
Office		15	40	13	13	47	20	13
	Males	8	38	25	25	38	38	25
	Females	7	43	0	0	57	0	0
Catering		16	38	38	38	38	38	38
	Males	3	67	67	67	67	67	67
	Females	13	31	31	31	31	31	31

Figures

Figure 1

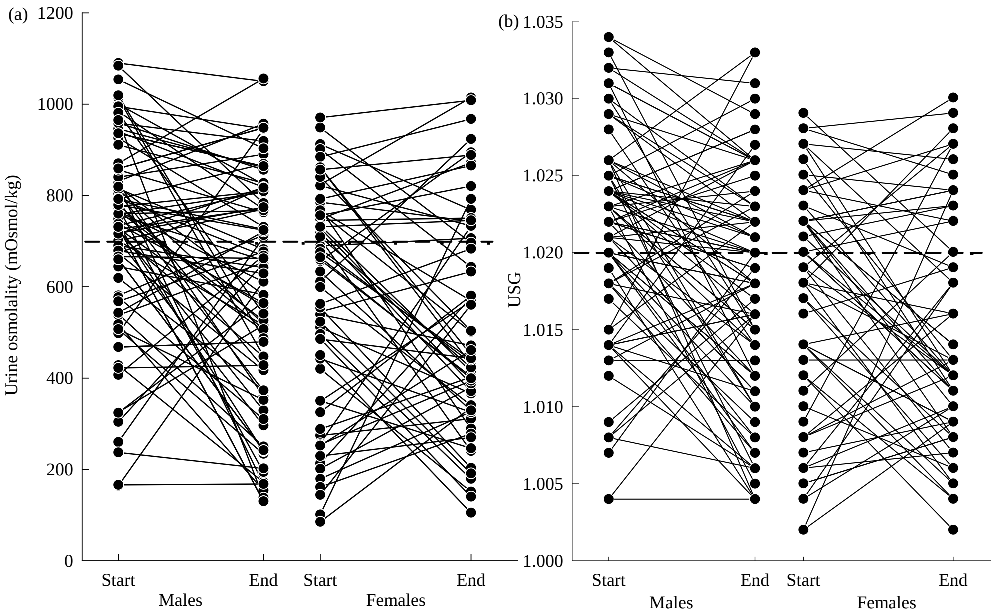


Figure 2

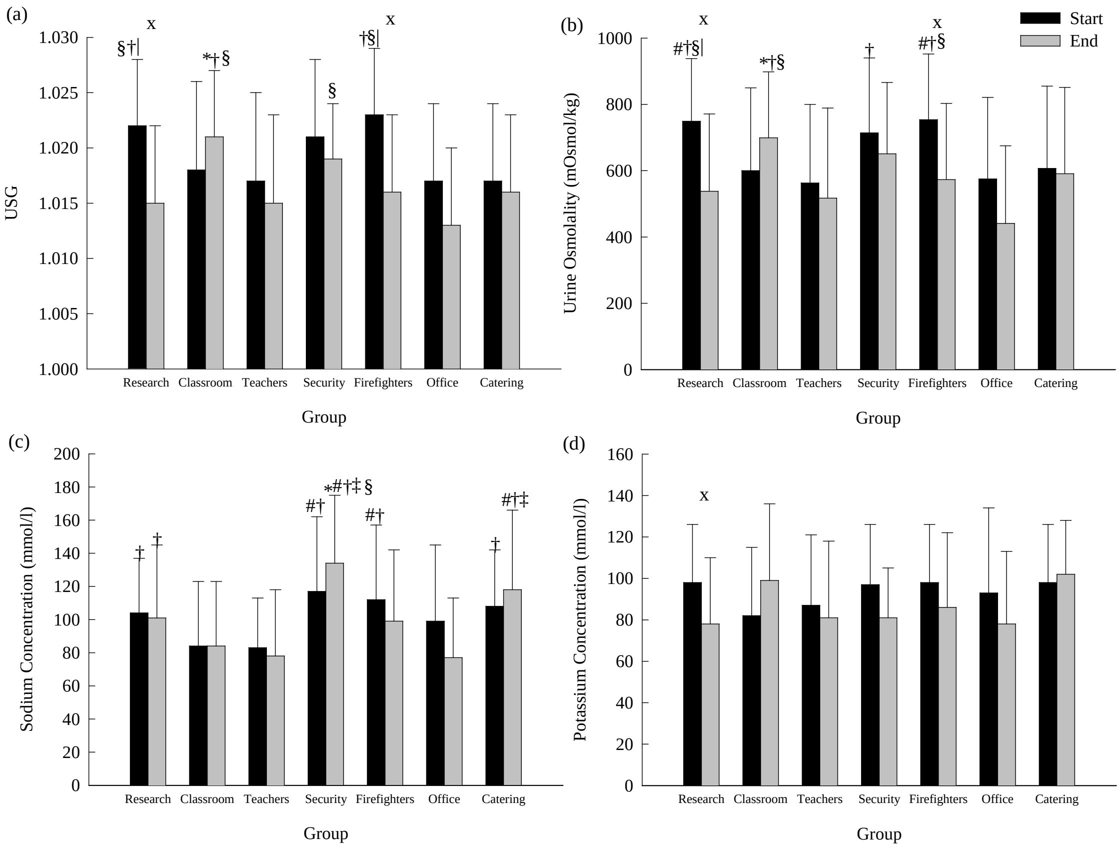
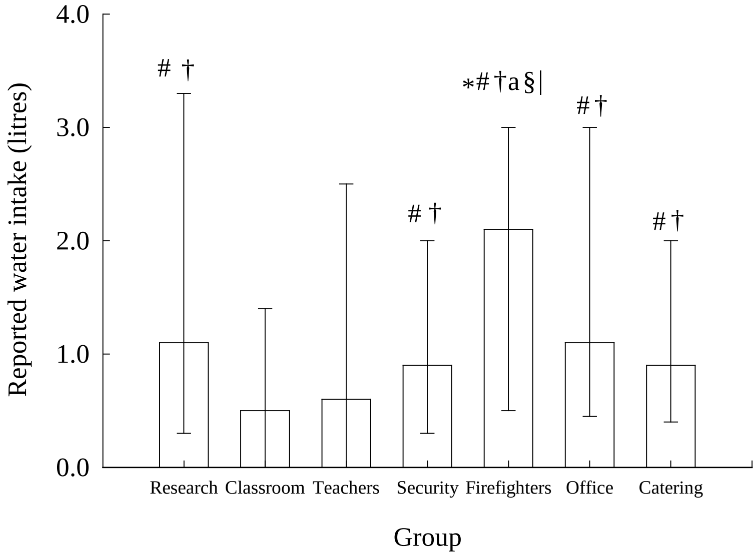

(a)
USG
1.030
1.025
1.020
1.015
1.010
1.005
1.000
Research
Classroom
Teachers
Security
Firefighters
Office
Catering
Group
(b)
Urine Osmolality (mOsmol/kg)
1000
800
600
400
200
0
Start
End
(c)
Sodium Concentration (mmol/l)
200
180
160
140
120
100
80
60
40
20
0
(d)
Potassium Concentration (mmol/l)
160
140
120
100
80
60
40
20
0

Figure 3


4.0
3.0
2.0
1.0
0.0
Reported water intake (litres)
†
*#†a§|
#†
†
#†
Research
Classroom
Teachers
Security
Firefighters
Office
Catering
Group

Legends

List of figures

Figure 1. Start and end (a) osmolality (mOsmol/kg) and (b) urine specific gravity for males and females. - - - represents euhydration values of less than 1.020 and 700 mOsmol/kg[6]

Figure 2. USG (a), osmolality (mOsmol/kg) (b), urine sodium (c) and potassium concentrations (mmol/l) (d) at the start (black) and end (grey) of the shift (mean ± SD). * denotes greater than research group, # denotes greater than classroom taught students, † denotes greater than teachers, ‡ denotes greater than firefighters, § denotes greater than office and | denotes greater than catering (P<0.05). x denotes difference between start and end values (P<0.05)

Figure 3. Reported water intakes for each group during the shift (median (range)). * greater than research group, # greater than classroom taught students, † greater than teachers, [a] greater than security, § greater than office and | greater than catering (P<0.05)