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Mild hypohydration increases the frequency of driver errors during a prolonged, monotonous driving task

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HIGHLIGHTS

- Mild hypohydration has been shown to cause impaired cognitive function and altered mood.
- This study reports an increase in driver errors with mild dehydration.
- Error incidence increased over time, but occurred at a greater rate following fluid restriction
- Higher subjective feelings of thirst, as well as impaired concentration and alertness were also apparent
- Driver education programmes should also encourage appropriate hydration practices.

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ABSTRACT

The aim of the present study was to examine the effect of mild hypohydration on performance during a prolonged, monotonous driving task.

Methods: Eleven healthy males (age 22 ± 4 y) were instructed to consume a volume of fluid in line with published guidelines (HYD trial) or 25% of this intake (FR trial) in a crossover manner. Participants came to the laboratory the following morning after an overnight fast. One hour following a standard breakfast, a 120 min driving simulation task began. Driver errors, including instances of lane drifting or late breaking, EEG and heart rate were recorded throughout the driving task.

Results: Pre-trial body mass ($P = 0.692$), urine osmolality ($P = 0.838$) and serum osmolality ($P = 0.574$) were the same on both trials. FR resulted in a 1.1 ± 0.7% reduction in body mass, compared to −0.1 ± 0.6% in the HYD trial ($P = 0.002$). Urine and serum osmolality were both increased following FR ($P < 0.05$). There was a progressive increase in the total number of driver errors observed during both the HYD and FR trials, but significantly more incidents were recorded throughout the FR trial (HYD 47 ± 44, FR 101 ± 84; ES = 0.81; $P = 0.006$).

Conclusions: The results of the present study suggest that mild hypohydration, produced a significant increase in minor driving errors during a prolonged, monotonous drive, compared to that observed while performing the same task in a hydrated condition. The magnitude of decrement reported, was similar to that observed following the ingestion of an alcoholic beverage resulting in a blood alcohol content of approximately 0.08% (the current UK legal driving limit), or while sleep deprived.

1. Introduction

Under ‘normal’ conditions, an individual's total body water (TBW) fluctuates throughout the day, but overall daily water balance is generally maintained through a series of interrelated factors which control intake and output of water. The homeostatic regulation of salt and water balance normally acts to limit excursions in TBW to no more than about 1% per day [24]. Nevertheless, there are several routinely encountered situations that act to either increase fluid losses (e.g. illness, exposure to heat/humidity, diuretics), or serve to restrict fluid intake (e.g. access to beverages and/or latrines). Over time, one, or a combination, of these factors results in the progressive reduction in TBW. The ensuing hypohydration causes a reduction in the circulating blood volume and an increase in plasma osmolality, which are typically proportional to the magnitude of decrease in TBW [32]. Populations at particular risk of hypohydration are the very young, those engaged in professions where fluid homeostasis is regularly

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challenged and the elderly. Limited data are available on the prevalence of hypohydration, but there is evidence to suggest that this may be relatively common among sections of the elderly population [24].

Mild hypohydration can cause symptoms such as headache, weakness, dizziness and fatigue, and generally makes people feel tired and lethargic, with lower self-reported ratings of alertness and ability to concentrate [36]. Body water losses have been shown to impair performance in a variety of tests of both physical and mental performance. Evidence suggests that either starting exercise in a hypohydrated state, or allowing hypohydration to accrue during exercise, will result in an increase in subjective feelings of exertion, or this likely contributed to the reduction in exercise performance [24]. As little as a 2% reduction in body mass due to insufficient hydration can also result in impaired cognitive function, with changes in mood state and modest reductions in concentration, alertness and short-term memory reported [1,24]. In addition to the established physiological consequences of hypohydration, the generally unpleasant symptoms of hypohydration (e.g. dry mouth, thirst, headache) may directly produce a negative effect on mood state [2,12]. In fact, some authors maintain that dehydration-associated impairment of tasks with a large cognitive component is driven primarily by the discomfort and distraction associated with these symptoms [6].

Data quantifying the hydration practices of regular drivers is scarce, but assessments of hydration status and reported beverage intakes among employees in a variety of workplace settings highlighted that a significant proportion of employees report to work exhibiting signs of dehydration [25]. A large proportion of those individuals also remained in a state of hypohydration at the end of their shift, citing restrictions on when and where they could consume fluid and access to toilet facilities as the primary barriers to increasing water intake. It is likely that driving in a hot car will lead to significant losses of water over the course of a long journey, but these data are not readily available in the scientific literature. Even in an air-conditioned car, evaporative water losses from the skin and lungs are likely to accumulate during a long drive due to exposure to dry air because of the increased vapour pressure gradient. Taking these points into consideration, the European Hydration Institute recommends the regular ingestion of non-alcoholic beverages during long automobile journeys to help to reduce road fatigue [10]. These guidelines are likely to be sound, but anecdotal reports suggest that many drivers avoid drinking adequately, with a view to limiting the need for bathroom stops during long journeys.

While it is widely acknowledged that the use of alcohol or drugs among drivers increases the risk [29] and the severity [3] of road traffic accidents, there are currently no scientific evidence linking dehydration to an increased incidence of traffic accidents. At present only one recent study has investigated the possible effects of dehydration on simulated driving performance [20]. Again the primary focus was to examine the effects of moderate quantities of alcohol on aspects of driving performance, but this group also suggested a possible interaction between alcohol consumption and dehydration. The authors suggested that alcohol-induced impairments in cognition, and consequently on simulated driving performance, would be greater when individuals were also in a state of dehydration. Although the results of this study failed to identify any significant impact of hydration status on driving performance, it is worth noting that the simulated driving task employed was short (15 min) and was set in a suburban environment.

An estimated 1.2 million people worldwide are killed as a result of road traffic accidents each year, with around 50 million people also injured annually [40]. Driver error is by far the largest cause of these accidents, accounting for approximately 68% of all vehicle crashes in the UK [7,8]. Factors including failing to look properly, misjudging another driver's path or speed and driver distraction are cited in the top ten most common causes of traffic accidents [7,8]. During long and monotonous driving, most drivers progressively show signs of visual fatigue and loss of vigilance [4]. Hypohydration has been shown to result in altered mood and deficits in aspects of cognition, it is reasonable to assume that dehydrated drivers may be more susceptible to errors in judgement and/or the successful execution of motor skill. With this in mind, the aim of the present study was an initial exploration of the effects of mild hypohydration, on performance during a prolonged, monotonous driving task where aspects of cognition relevant to driving (e.g. response times and loss of vigilance) are likely to be challenged.

2. Methods

2.1. Participants

Twelve healthy males were recruited to participate in this randomised crossover design study. All participants were experienced drivers; having driven for over 2 years on a full licence and for more than 2 h/week. Prior to volunteering, participants received written information regarding the nature and purpose of the study and a written statement of consent was signed. One participant completed all trials but was excluded from the final results after displaying a high propensity to fall asleep during the driving task (perhaps caused by sleep deprivation). Physical characteristics (Mean $\pm$ SD) of the remaining 11 participants were: age 22 $\pm$ 4 y; height 1.75 $\pm$ 0.06 m; and body mass 77.4 $\pm$ 10.0 kg. This study was approved by the local Ethical Advisory Committee (REF: R14-P12).

2.2. Experimental design

Each volunteer visited our laboratories on three separate occasions. The first visit was a familiarisation trial that involved the completion of the same driving task undertaken in the experimental trials. This was intended to enable the participants to become accustomed with the study protocol and limit any possible learning effect apparent with the use of the driving simulator. This was followed by two experimental trials. All trials were separated by at least 7 days and experimental trials were completed in a randomised order. Participants were provided with a customised diary to record dietary intake and physical activity during the 24 h before the first experimental trial and were asked to replicate this on the day prior to the subsequent experimental trials. During each trial period (as illustrated in Fig. 1), participants were asked to record dietary intake in a food and beverage record diary, using the portion size method. No restrictions on routine or food/beverage intake, other than those mentioned below, were enforced during this period, as the aim was to mimic free-living conditions. To help ensure the volunteers were adequately hydrated, they were instructed to consume at least 2.5 L of fluid, spread evenly across the day [9]. No strenuous exercise or alcohol consumption was permitted in the 24 h before, as well as during, each trial.

2.3. Experimental protocol

Each experimental trial took place over two days, as illustrated in Fig. 1. On day 1, volunteers visited the laboratory in the morning after an overnight fast (10 h, with no food or fluid permitted). A urine sample was obtained and body mass measured to the nearest 10 g in minimal clothing (underwear). Volunteers then sat for 15 min, before a 5 mL blood sample was collected from a superficial antecubital vein. During the 15 min of seated rest, subjective feelings related to thirst, hunger, concentration and alertness were assessed using a series of 100 mm visual analogue scales [36]. Volunteers were then free to leave the laboratory with the instruction to replicate their food intake of the pre-trial standardisation day. During the hydrated (HYD) trial volunteers continued to consume at least 2.5 L of fluid, spread evenly across the day. During the fluid restriction (FR) trial, only 25% of the HYD fluid intake was permitted; this was expected to result in a ~1% reduction in body mass over a 24 h period [36].

Participants then returned to the laboratory the following morning after an overnight fast (10 h, with no food or fluid permitted). A urine sample was obtained and body mass measured in minimal clothing.