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Dehydration and cognition: an understated relation

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Abstract

Purpose – Water is essential for mental health. In spite of research evidence that dehydration has detrimental effects on cognitive functioning, the element of water has often been understated in the nutrition literature. The purpose of this paper is to highlight the necessity to integrate water as an essential nutrient for healthy cognitive functioning in nutrition research.

Design/methodology/approach – This study is based on a general review. The first section reviews the literature on the relationship between dehydration and cognitive performance in both adult and children populations, using electronic databases for systematic reviews and meta-analyses (excluding vulnerable populations, such as infants, the elderly and people with disabilities). The second section examines the status of water, as a nutrient, in nutrition and water-related documentation by international authorities (FAO, UNICEF, World Food Program, WHO, etc.).

Findings – Dehydration, even at mild levels, is associated with impairments in basic and higher order cognitive functions. Websites from international authoritative nutrition sources understate the role of water in healthy nutrition, and omit the discussion of the impact of dehydration on cognitive functioning.

Originality/value – The relation between dehydration and cognition is under-documented and not enough elaborated in guidelines and texts of authoritative international health policy and dietary sources.

Keywords Health care quality, Qualitative research, Public health regulations, Determinants of health, Dehydration, Cognitive performance, Cognitive processes

Paper type General review

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Introduction

Water is essential for life across all species living on land. It is the most abundant and the major constituent of the body cells, tissues and organs, including the brain and the central nervous system (Kempton *et al.*, 2011; Asogwa and Lai, 2017). Water and the brain are directly linked as the effective functioning of the brain depends on adequate hydration (Jéquier and Constant, 2010).

Dehydration leads to reversible brain changes (such as the reduction of brain volume), which negatively impact the brain functions underlying important cognitive (executive) processes (Kempton *et al.*, 2011). In their research on patients with Alzheimer's disease (AD) and mild cognitive impairment (MCI), Streitbürger *et al.* (2012) note a decrease in the volumes of gray and white matter following dehydration. Normal white matter development predicts normal cognitive development. Nagy *et al.* (2004) found significant correlations between the white matter maturation index and children's and adolescents' performance on working memory and reading speed tasks. According to Streitbürger *et al.* (2012), the decrease in white matter volume in patients with AD is due to long-term dehydration rather than to the degeneration of brain tissue, and long-term dehydration may be one of the contributing causes, not a consequence, of AD or MCI (Streitbürger *et al.*, 2012, p. 7).

Considering that a loss of more than 2 percent of body water causes reduction in brain performance (Asogwa and Lai, 2017), the impact of dehydration on cognitive performance is a topic of multi-disciplinary interest, including nutrition, medicine and nursing, developmental and cognitive psychology, neuroscience, and in the context of school performance, education.

In nutrition research, water is less commonly discussed than proteins, carbohydrates, vitamins and minerals, and is sometimes referred to as the "overlooked" nutrient (Kleiner, 1999; Masento *et al.*, 2014), or is altogether omitted from dietary recommendations

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(Jéquier and Constant, 2010). Interestingly, dehydration is recognized as a component of malnutrition (Douglas *et al.*, 2014).

The aim of this paper is to highlight the relationship between dehydration and cognition as per the research evidence and the necessity to further emphasize the status of water as a nutrient in documentation of authoritative bodies on health, nutrition, and children's health and education (FAO, UNICEF, World Food Program (WFP), WHO, etc.).

Method

For the first part of the study, the initial round of the literature search using electronic databases such as PsycINFO, Academic Search Premier, JSTOR, and PubMed, as well as Google Scholar was made as a function of the following keywords: hydration, dehydration, cognition, cognitive performance. This search yielded 80 resources (meta-analyses, systematic reviews and original articles). Of these, 25 articles were excluded because of their combined emphasis on physical and mental activity; their focus on particular populations such as patients with AD, or pregnant women, or pilots, or Ramadan fasters, or infants; their overly clinical and pathophysiological content, such as relating the causes of dehydration to a combination of physiological and disease processes; the specificity of the discussion (such as the emphasis on delirium as a result of dehydration in older populations); their nature (either protocol study types, or proposals of randomized controlled trials where no findings are reported); and the perceived methodological limitations (such as small sample size or unclear description of the extent to which subjects' compliance to the study's water restriction instructions was assessed).

The remaining 55 resources were included in the present review as long as they provided a relevant discussion of the relation between dehydration and cognition through the examination of the effects of dehydration, exposure to hot climate, and both conditions, on cognitive performance, for both healthy adult and children populations. Articles on dehydration in the elderly population were excluded from the present review because they were irrelevant to our topic or to the purpose of our study, as stated above.

Our search revealed an absence of literature on dehydration in populations of people with disabilities, with the exception of one rather speculative and poorly documented article on the relationship between dehydration and attention-deficit hyperactivity disorder. It was decided to exclude, at least for the purpose of the present paper, any reference to intellectual disability to avoid the overlapping effect of the type of disability itself on the cognitive performance of subjects in a study on dehydration and cognition.

For the second part of the study, a search from gray literature (international, governmental or institutional reports and websites) was conducted, with additional keywords such as nutrition policies, health guidelines, diet requirements, etc. This search focused on reports issued within the decade between 2008 and 2018 in order to match the impact of the growing literature on dehydration and cognition with the recent health and nutrition policies and dietary recommendations. The search yielded 12 relevant resources, of which 3 were excluded due to their emphasis on physical rather than mental activity, their highly technical quality, and their irrelevance (whereby "water" was used in the contexts of sanitation and hygiene, and not in the context of the present paper).

Relationship between dehydration and cognitive performance

Definition, induction and measurement of dehydration

Definition of dehydration. Most of the reviewed studies define dehydration as a 1–2 percent loss of bodyweight caused by fluid losses, exposure to heat, sustained physical activity, or a combination of these (Adan, 2012; Benton and Young, 2015; D'Anci *et al.*, 2009; Kempton *et al.*, 2011; Kleiner, 1999).

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Induction of dehydration. In a typical dehydration research, dehydration is either actively induced in consenting adult subjects through controlled passive exposure to heat, or sustained and controlled physical exercise, or a combination of these, or passively induced through fluid restriction (Adan, 2012; Cian *et al.*, 2001; Masento *et al.*, 2014; Popkin *et al.*, 2010). For ethical considerations, the available literature on dehydration in children populations has focused on children who happen to be dehydrated because of living in hot climates (Assael *et al.*, 2012; Bar-David *et al.*, 2005; Edmonds *et al.*, 2013; Fadda *et al.*, 2012; Gouda *et al.*, 2015; Trinies *et al.*, 2016).

Measurement of dehydration. Studies on dehydration measure hydration levels in subjects by determining percent total body water by weight (WT), and/or analyzing urine samples for urine color (Kavouras *et al.*, 2016, 2017), urine-specific gravity, volume, and osmolality (Bonnet *et al.*, 2012; Fadda *et al.*, 2012), or urinary output and urine osmolality (Bar-Or *et al.*, 1980; Gouda *et al.*, 2015; Kavouras *et al.*, 2017). While other hydration markers (blood parameters, skinfold thickness and bioelectrical impedance analysis) have been used, the most promising marker is urine osmolality (Kavouras, 2002; Shirreffs, 2003). When laboratory analysis is not available, and where clinical exactness is not essentially required (Asogwa and Lai, 2017), the assessment of urine color of first morning samples has been used with reasonable accuracy (Guelinckx *et al.*, 2015; Kavouras, 2002), and is valid for both adult and children populations (Kavouras *et al.*, 2016). However, urine color may be affected by dietary intakes, drugs and supplements which are difficult to control (Asogwa and Lai, 2017).

Definition and measurement of cognitive performance

Definition of cognitive performance. Cognitive performance operationally defines how one uses cognitive functions (such as memory, reasoning, concentration, etc.) to complete one or more tasks (Riebl and Davy, 2013). These functions operate at the external level (attention, perception, storing and processing of incoming messages), and at the internal level (memory processes, concept formation and schematic organization of information). Most of these functions have further sub-functions, such as memory which is divided into sensory, short-term and long-term memory, or perception which operates through different channels (visual, auditory, verbal, and spatial) (Schmitt *et al.*, 2005).

In the present review, cognitive performance encompasses the following functions: working memory (Adan, 2012; Baker *et al.*, 2007; Bar-David *et al.*, 2005; Benton and Burgess, 2009; D'Anci *et al.*, 2009; Edmonds and Burford, 2009; Fadda *et al.*, 2012; Gopinathan *et al.*, 1988; Suhr *et al.*, 2004), sustained attention (Benton and Burgess, 2009), visual attention (Booth *et al.*, 2012; Edmonds and Burford, 2009), vigilance attention (D'Anci *et al.*, 2009), psychomotor speed (Adan, 2012; Baker *et al.*, 2007), speed in reaction time (Booth *et al.*, 2012; D'Anci *et al.*, 2009), concentration (Baker *et al.*, 2007), arithmetic ability (D'Anci *et al.*, 2009; Gopinathan *et al.*, 1988; Popkin *et al.*, 2010), visual-motor tracking (Popkin *et al.*, 2010), perceptual discrimination (Popkin *et al.*, 2010), verbal analogies (Bar-David *et al.*, 2005), and higher order mental processes such as cognitive control (Khan *et al.*, 2015), and planning and problem-solving (Adan, 2012).

Measurement of cognitive performance. Cognitive functions are commonly assessed by paper-and-pencil neuropsychological tests as well as computerized tests. Measures include response speed (in processing, psychomotor function, perceptual discrimination, perceptual reaction time, problem-solving time, fine motor function), and response accuracy (in visual memory performance, short-term memory performance, visuo-motor processing, vigilance tasks, distance and target judgment, spatial working memory) (Masento *et al.*, 2014).

In a meta-analysis of 26 studies, Masento *et al.* (2014) list the tools commonly used to assess cognitive functioning. The list includes, among others, tests of symbol substitution,

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word recognition, mathematical efficiency, picture recall, auditory number span, verbal analogies, as well as the Stroop task, mental rotation tasks, trail-making tasks, and subtests of the Wechsler intelligence scales. Such heterogeneity in the tools has been criticized as a methodological weakness (Lieberman, 2007; Masento *et al.*, 2014), and in the absence of standardised assessment methods, there is an ongoing debate as to which assessment method is the best (Riebl and Davy, 2013).

Impact of dehydration on cognitive performance

In adult populations. It is generally noted that cognitive decrements due to dehydration, in all-age populations, are observed starting a 2 percent body water loss (Grandjean and Grandjean, 2007).

In healthy adults, lower hydration status was related to slowed psychomotor processing speed and poorer attention/memory performance (Suhr *et al.*, 2004), while among healthy young male athletes, vigilance-related attention in a highly dynamic environment (simulated basketball game) was impaired by dehydration, and fluid replacement was essential to maintain optimal concentration and attentional skills (Baker *et al.*, 2007). In healthy adults subjected to dehydration and heat stress, a significant correlation was reported between cognitive dysfunction (deterioration in arithmetic ability, short-term memory, and visual-motor tracking) and a 2 percent degree of dehydration and above (Gopinathan *et al.*, 1988), and even mild dehydration (1–2 percent) was shown to lead to impairment in cognitive function (D'Anci *et al.*, 2006).

Yet, in another study, dehydration up to 3 percent did not seem to have any significant effect on cognitive performance (Sharma *et al.*, 2007), and a progressive water deprivation (at a moderate dehydration level) over 24 h for young healthy men and women did not show any decrease in cognitive-motor performance (Szinnai *et al.*, 2005). Similarly, in Cian *et al.* (2001), a 2.8 percent dehydration (induced by hyperthermia or by exercise) only temporarily impaired visual perception, short-term memory and psychomotor ability, as the subjects' performance normalized after fluid ingestion (rehydration). A more recent review by Shirreffs (2009) also notes the unlikelihood of an association between mild to moderate dehydration (without heat stress) with decrements in cognitive function and mental readiness, while higher levels (more than 3 percent body mass loss), combined with heat stress, may influence cognitive function and mental readiness.

In child populations. Research relating dehydration to cognitive performance reveals that school-age children are at a high risk for dehydration as they often forget to drink water and are usually negligent of their thirst. This is known as voluntary dehydration whereby children progressively dehydrate when not forced to drink (Bar-Or *et al.*, 1980; Masento *et al.*, 2014). Kavouras *et al.* (2012) highlight the need to raise children's awareness of the importance of hydration, especially during physical exercise. Further, because drinking habits are established in childhood, it is important that young children get used to drinking a range of appropriate beverages, including water, in order to maintain hydration (Benelam and Wyness, 2010).

The relationship between dehydration and cognition for young subjects has been consistently reported (Benton, 2011): In school-age children, dehydration can cause impairments in the fundamental cognitive skills that are needed for adequate school performance (D'Anci *et al.*, 2006), and in higher mental processes such as planning and problem solving (Adan, 2012). Voluntary dehydration in children was shown to affect immediate memory (auditory number span) and verbal analogies (Bar-David *et al.*, 2005), perceptual discrimination, arithmetic ability, visual-motor tracking, and psychomotor skills (Popkin *et al.*, 2010) as well as visual attention, perception speed and short-term memory (for number sequences), regardless of environmental temperature (Adan, 2012).

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Impact of supplementary water consumption on the cognitive functioning of children

Offering children additional drinking water has a positive effect on their cognitive performance (Edmonds *et al.*, 2013): supplementary water consumption positively affects performance on working memory tests and visual attention tasks in children aged 7–9 years (Edmonds and Burford, 2009), and in conditions of mild dehydration without exposure to exercise or heat or intentional water deprivation, six- to seven-year-old children's cognitive performance can be improved by water consumption (Edmonds and Jeffes, 2009). When no attempt was made to influence eight-year-old children's normal drinking pattern in schools that had a policy to allow drinking (permission to carry water bottles in class), additional water consumption (300 ml) led to a significant improvement in sustained attention and verbal recall of objects on the days when additional water had been consumed, vs no such improvement on the days when no additional water had been consumed (Benton and Burgess, 2009). Booth *et al.* (2012) demonstrated that when given 250 ml of supplementary water, eight- to nine-year-old girls' performance on tasks requiring speed in reaction time and visual attention was significantly better than without supplementary water. Fadda *et al.* (2012) report a significantly beneficial effect of supplementary drinking in 9 to 11-year-old children on auditory number span tasks (assessing short-term memory). A study by Khan *et al.* (2015) showed that higher amounts of water consumption by pre-pubertal children over three days increased children's ability for cognitive control on cognitively challenging tasks.

On the other hand, Trinies *et al.* (2016) investigated the relationship between supplementary water provision for pupils from grades 3 to 6 in Zambia and their cognitive test scores, vs a control group who only had access to normally delivered water at school. Hydration level of children was assessed (through urine-specific gravity measures) in the morning prior to water provision. Short-term memory, concentration, visual attention, and visual-motor skills were assessed in the afternoon. Provision of supplementary water was not found to impact cognitive test scores, except for the visual attention test.

Limitations of studies

In addition to the conflicting findings in the existing literature in both adult and child populations, several methodological limitations and weaknesses are noted, including the short-term nature of the studies, the small sampling size, the lack of objective hydration measures, the inconsistency in the measurement tools for cognitive assessment (Adan, 2012; Benton, 2011; Grandjean and Grandjean, 2007; Lieberman, 2007; Masento *et al.*, 2014; Riebl and Davy, 2013), and a generally incomplete inquiry of mediating factors. Benton and Young (2015) note that variables other than mere dehydration ought to be considered before drawing any conclusion regarding the effect(s) of dehydration on cognitive functioning. Moreover, research findings are still inconclusive as to how much water is needed to optimize performance, both at the physical and cognitive levels (Hillyer *et al.*, 2015).

The status of water in the documentation of authoritative nutrition sources

Our survey of the literature on nutritional requirements by international authorities, such as the FAO, WHO or UNICEF, among others, shows that the element of water is almost non-existent in the list of such requirements, or if it does exist, it appears either in a generic recommendation form without further explanations, or in the context of hygiene practices and sanitation.

In the WHO Regional Office for Europe (2003) survey on "Food-based dietary guidelines in the WHO European region," water is mentioned only once (p. 22) in the Bulgarian national dietary guidelines, as Bulgaria is the only country which recommends drinking mineral water instead of soft drinks. In the WHO Programme for Nutrition and Food Security (2006) report on "Food and nutrition policy for schools," water is mentioned in the general context

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of hygiene practices. Although the report criticizes today's school vending machines for not offering water as a healthier option than soft drinks, it does exclude water from the list of the "12 steps to healthy eating for children and adolescents" (WHO Programme for Nutrition and Food Security, 2006, p. 24). In the 2016–2017 WHO Global Nutrition Policy Report (WHO, 2018), water is mentioned in a generic recommendation form.

In the Food and Agriculture Organization (FAO) report entitled "Coping with water scarcity: challenge of the twenty-first century", there is no mention of "dehydration" as a possible consequence of water scarcity in the world, although it does discuss water-related illnesses (diarrhea and malaria) (FAO, UN-WATER, 2007, p. 20). In the FAO Background Document for the High-Level Expert Forum on "How to feed the world in 2050" (FAO, 2009), the problem of water scarcity is discussed in the contexts of natural resources making up the ecosystem, water reserves, water technology, and irrigation. Dehydration, as one of the major consequences of water scarcity, is absent from the report.

In the joint report by the FAO, IFAD, UNICEF, WFP and WHO entitled "The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security" (FAO *et al.*, 2017), the element of water is mentioned as a generic recommendation without further details. The word "dehydration" is completely omitted from this report.

In the joint report by the WFP and UNICEF, entitled "The Essential Package: Twelve interventions to improve the health and nutrition of school-age children" (WFP and UNICEF, n.d.), dehydration is not mentioned as a potential threat for the physical and mental development of children.

In the discussion paper by the United Nations System Standing Committee on Nutrition (UNSCN, 2017), entitled "Schools as a system to improve nutrition," the importance of water as an integral part of a healthy nutrition package for school-age children is overlooked, as the element of water appears as a generic recommendation for the "provision of clean drinking water" (UNSCN, 2017, p. 20).

In a 2002 survey of international food guide illustrations from different countries of the world, it is noted that only Puerto Rico includes water in both its illustration and recommendations, most likely due to the country's tropical climate (Painter *et al.*, 2002).

Martinez *et al.* (2015) analyzed the graphical representations used in the dietary guidelines of 35 selected countries in the Americas, Europe and Asia. It is noted that the first US Food Pyramid, published in the early 1990s by the US Department of Agriculture, did not include any mention of water; nor did the 2005 revamped version. It was not until 2011 when researchers from the Harvard School of Public Health developed the Healthy Eating Plate that water was recommended in addition to healthy oils and physical activity. Dietary guidelines from Argentina, Costa Rica, Uruguay and the Dominican Republic also contain recommendations for water intake. With respect to Europe, 6 out of the 12 surveyed countries include the intake of water (or other fluids) in their dietary guidelines. Out of the six Asian countries included in the survey, only China and Japan expressed recommendations for water/fluid intake.

Discussion

This review highlighted, on one hand, the negative effects of dehydration on cognitive functioning in general, and on school-age children's cognitive performance in particular, and on the other hand, the positive impact of supplementary water consumption on cognition. The evidence for an association between hydration and cognition is correlational, and correlation does not mean causality (Benton, 2011); yet, in spite of their limitations, these studies have something substantial to say about the importance of water in children's nutrition.

Although it is a known fact that children are at greater risk of dehydration than adults (D'Anci *et al.*, 2006; Edmonds, 2010), researchers on school-age child nutrition admit that water requirements are an often overlooked aspect of diet (Riebl and Davy, 2013; Weichselbaum and Buttriss, 2011), underemphasized and frequently underestimated (Bergeron, 2003). Proper water hydration for school-aged children must be a priority item on the school nutrition agenda, and healthful water drinking should always be a part of the diet record (Kleiner, 1999).

Patel and Hampton (2011) identify the challenges that limit access to drinking water in schools in the USA; these could be applicable everywhere else in the world, and include, among others, unsafe school drinking water (especially in schools with old infrastructure), insufficient number and inconvenient location of water fountains in schools, poor maintenance of drinking water outlets, and the increasing availability of competitive sugar-sweetened beverages that are sold and marketed in schools.

In several countries, adequate hydration has been recognized as an integral part of school food standards: In England, Scotland, Wales and Northern Ireland, easy and free access to clean drinking water has become a requirement in school-lunch servings (Weichselbaum and Buttriss, 2011). In the USA, the 2010 federal "Healthy, Hunger-Free Kids Act" requires early childhood day-care centers to make water available to children throughout the day, not just at meal times (Centers for Disease Control and Prevention, 2014).

Dehydration among children is much more common than one may think. Studies have shown that around two-thirds of children living in the UK, Germany, and the southeast coasts of the USA come to school in the morning in a dehydrated state (Edmonds *et al.*, 2013). In France, Bonnet *et al.* (2012) reported a morning hydration deficit in almost two-thirds of a sample of 9- and 11-year-old children, despite their breakfast intake, implying that children's water consumption at breakfast is not enough to maintain an adequate hydration status for the whole morning. In hot climates such as in Egypt, a study assessing the morning hydration status in a sample of school-age children shows that the majority of children arrive to school with a hydration deficit (Gouda *et al.*, 2015). Similarly, in Italy, 84 percent of a sample of 168 school-age children in the city of Sardinia begin their school day in a mild, voluntary dehydration state (Fadda *et al.*, 2012), and 67.2 percent of a sample of 515 school-age children in the city of Verona were found to come to school in the morning with a hydration deficit despite breakfast intake (Assael *et al.*, 2012). Bar-David *et al.* (2005) found 32 cases of voluntary dehydration in a sample of 58 elementary school students in a desert town in the Middle East during Summer. A study on the impact of hydration on cognition in Zambia showed a 42.8 percent morning prevalence of dehydration among pupils whose ages ranged between 8 and 17 years (Trinies *et al.*, 2016).

In a survey by Holdsworth (2012), when asked about their opinion about the importance of water for physical and mental performance, less than 50 percent of a total of 1,980 healthcare professionals from several European countries recognized that hydration had any positive effect on mental performance. Holdsworth (2012) noted a response trend toward overestimating the contribution from food, and underestimating that from beverages, and calls for further reinforcing education among health professionals with respect to the effects of hydration on mental well-being and performance.

Conclusion

The limited documentation on the role hydration plays in the cognitive performance of school-age children explains why health experts do not dedicate much discussion to water (Holdsworth, 2012). More studies are needed to highlight the negative effects of dehydration on fundamental cognitive skills that are required for effective school performance in children. Better methodological tools are required to enhance the quality of such studies. The relationship between dehydration and cognition must be tackled in more depth in the documentation of international organizations seeking to improve the status of nutrition in the world. The following lessons have emerged from this review.

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Many children, all over the world, come to school in a dehydrated state (Assael *et al.*, 2012; Bar-David *et al.*, 2005; Bonnet *et al.*, 2012; Edmonds *et al.*, 2013; Fadda *et al.*, 2012; Gouda *et al.*, 2015); it is therefore crucial to provide fresh clean water to children early n the school day. A study in Cambodia found a strong association between the provision of free and safe drinking water to schools and reduced school absenteeism, implying that availability of improved hydration leads to improved school experience for children (Hunter *et al.*, 2015).

Children must be reminded of the necessity to drink water (Bar-Or *et al.*, 1980; Benton, 2011; D'Anci *et al.*, 2006; Edmonds, 2010; Kavouras *et al.*, 2012); schools must emphasize and encourage the consumption of water during a typical school day, instead of soft beverages, as a thirst quencher. Lessons ought to be learned from previously documented good practices, such as the "Water is Cool in School" campaign for providing access to fresh drinking water for children in UK primary and post-primary schools (Brander, 2003; WHO Programme for Nutrition and Food Security, 2006).

The consumption of water should be reinforced among children during the school day through a variety of practices, such as allowing children to drink in class, providing bottled water in school vending machines, and designing and implementing awareness-raising strategies and creative lesson plans that educate children on the benefits of healthy hydration.

More research is needed to further explore the relation between the impact of water and of dehydration and cognitive functioning, both at the adult and children levels. Such research necessitates the establishment of consistent measurement tools of cognitive performance across different cultural settings. Outcomes of such research ought to be disseminated in a more effective manner so as to reach public audiences, instead of being restricted to the scientific community.

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References

Adan, A. (2012), "Cognitive performance and dehydration", *Journal of the American College of Nutrition*, Vol. 31 No. 2, pp. 71-78.

Asogwa, C.O. and Lai, D.T.H. (2017), "A review on opportunities to assess hydration in wireless body area networks", *Electronics*, Vol. 6 No. 4, pp. 1-16, doi: 10.3390/electronics6040082, available at: www.mdpi.com/2079-9292/6/4/82 (accessed September 5, 2018).

Assael, B.M., Cipolli, M., Meneghelli, I., Passiu, M., Cordioli, S., Tridello, G., Lepicard, E.M., Constant, F., Hawili, N. and Friedlanderet, G. (2012), "Italian children go to school with a hydration deficit", *Journal of Nutrition Disorders and Therapy*, Vol. 2 No. 3, pp. 1-6, doi: 10.4172/2161-0509.1000114.

Baker, L., Conroy, D.E. and Kenne, W.L. (2007), "Dehydration impairs vigilance-related attention in male basketball players", *Medicine and Science in Sports and Exercise*, Vol. 39 No. 6, pp. 976-983.

Bar-David, Y., Urkin, J. and Kozminsky, E. (2005), "The effect of voluntary dehydration on cognitive functions of elementary school children", *Acta Paediatrica*, Vol. 94, pp. 1667-1673.

Bar-Or, O., Dotan, R., Inbar, O., Rotshtein, A. and Zonder, H. (1980), "Voluntary dehydration in 10-to 12-year-old boys (abstract)", *Journal of Applied Physiology*, Vol. 48 No. 1, pp. 104-108.

Benelam, B. and Wyness, L. (2010), "Hydration and health: a review", *Nutrition Bulletin*, Vol. 35 No. 1, pp. 3-25.

Benton, D. (2011), "Dehydration influences mood and cognition: a plausible hypothesis?", *Nutrients*, Vol. 3 No. 5, pp. 555-573.

Benton, D. and Burgess, N. (2009), "The effect of the consumption of water on the memory and attention of children", *Appetite*, Vol. 53 No. 1, pp. 143-146.

Benton, D. and Young, H.A. (2015), "Do small differences in hydration status affect mood and mental performance?", *Nutrition Reviews*, Vol. 73 No. S2, pp. 83-96.

Bergeron, M.F. (2003), "Nutrition and performance: do we still need to stress hydration?", *Current Sports Medicine Reports*, Vol. 2 No. 4, pp. 181-182.

Bonnet, F., Lepicard, E.M., Cathrin, L., Letellier, C., Constant, F., Hawili, N. and Friedlander, G. (2012), "French children start their school day with a hydration deficit", *Annals of Nutrition and Metabolism*, Vol. 60 No. 4, pp. 257-263.

Booth, P., Taylor, B. and Edmonds, C. (2012), "Water supplementation improves visual attention and fine motor skills in schoolchildren", *Education for Health*, Vol. 30 No. 3, pp. 75-79.

Brander, N. (2003), "Drinking water in schools", *Nursing Times*, Vol. 99 No. 1, pp. 50-51, available at: www.nursingtimes.net/roles/childrens-nurses/drinking-water-in-schools/205794.article

Centers for Disease Control and Prevention (2014), *Increasing Access to Drinking Water and Other Healthier Beverages in Early Care and Education Settings*. US Department of Health and Human Services, Atlanta, GA, available at: www.cdc.gov/healthyschools/npao/pdf/water_access_in_schools_508.pdf (accessed June 18, 2018).

Cian, C., Barraud, P.A., Melin, B. and Raphel, C. (2001), "Effects of fluid ingestion on cognitive function after heat stress or exercise-induced dehydration", *International Journal of Psychophysiology*, Vol. 42 No. 3, pp. 243-251.

D'Anci, K.E., Constant, F. and Rosenberg, I.H. (2006), "Hydration and cognitive function in children", *Nutrition Reviews*, Vol. 64 No. 10, pp. 457-464.

D'Anci, K.E., Vibhakar, A., Kanter, J.H., Mahoney, C.R. and Taylor, H.A. (2009), "Voluntary dehydration and cognitive performance in trained college athletes", *Perceptual and Motor Skills*, Vol. 109 No. 1, pp. 251-269.

Douglas, P., Ball, L., McGuffin, L., Laur, C., Crowley, J., Rajput-Ray, M., Gandy, J. and Ray, S. (2014), "Hydration: knowledge, attitudes, and practices of UK dietitians", *Journal of Biomedical Education*, Vol. 2015, pp. 1-6, available at: http://dx.doi.org/10.1155/2015/172020 (accessed September 14, 2018).

Edmonds, C.J. (2010), "Does having a drink of water help children think? A summary of some recent findings", *School Health*, Vol. 6 No. 5, pp. 58-60.

Edmonds, C.J. and Burford, D. (2009), "Should children drink more water? The effects of drinking water on cognition in children", *Appetite*, Vol. 52 No. 3, pp. 776-779.

Edmonds, C.J. and Jeffes, B. (2009), "Does having a drink help you think? 6–7–year-old children show improvements in cognitive performance from baseline to test after having a drink of water", *Appetite*, Vol. 53 No. 3, pp. 469-472.

Edmonds, C.J., Crombie, R. and Gardner, M.R. (2013), "Subjective thirst moderates changes in speed of responding associated with water consumption", *Frontiers in Human Neuroscience*, Vol. 7, pp. 1-8, doi: 10.3389/fnhum.2013.00363.

Fadda, R., Rapinett, G., Grathwohl, D., Parisi, M., Fanari, R., Calò, C.M. and Schmitt, J. (2012), "Effects of drinking supplementary water at school on cognitive performance in children", *Appetite*, Vol. 59 No. 3, pp. 730-737.

FAO – UN-Water (2007), *Coping with Water Scarcity: Challenge of the Twenty-First Century*, Food and Agriculture Organization, Rome, available at: www.fao.org/3/a-aq444e.pdf (accessed June 18, 2018).

FAO – High-Level Expert Forum (2009), *How to Feed The World in 2050*, Food and Agriculture Organization, Rome, October 12–13, available at: www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf (accessed June 19, 2018).

FAO, IIFAD, UNICEF, WFP and WHO (2017), *The State of Food Security and Nutrition in the World: Building Resilience for Peace and Food Security*, Food and Agriculture Organization, International Fund for Agricultural Development, United Nations Children's Fund, World Food Programme and World Health Organization, Rome, available at: www.fao.org/3/a-I7695e.pdf (accessed June 19, 2018).

Downloaded by 185.40.210.2 At 07:47 05 December 2018 (PT)

Gopinathan, P.M., Pichan, G. and Sharma, V.M. (1988), "Role of dehydration in heat stress-induced variations in mental performance", *Archives of Environmental Health*, Vol. 43 No. 1, pp. 15-17.

Gouda, Z., Zarea, M., El-Hennawy, U., Viltard, M., Lepicard, E., Hawili, N. and Constant, F. (2015), "Hydration deficit in 9- to 11-year-old Egyptian children", *Global Pediatric Health*, Vol. 2, pp. 1-9.

Grandjean, A.C. and Grandjean, N.R. (2007), "Dehydration and cognitive performance", *Journal of the American College of Nutrition*, Vol. 26, Suppl. 5, pp. 549S-554S.

Guelinckx, I., Frémont-Marquis, A.S., Eon, E., Kavouras, S.A. and Armstrong, L.E. (2015), "Assessing hydration in children: from science to practice", *Annals of Nutrition and Metabolism*, Vol. 66 No. S3, pp. 5-9.

Hillyer, M., Menon, K. and Singh, R. (2015), "The effects of dehydration on skill-based performance", *International Journal of Sports Science*, Vol. 5 No. 3, pp. 99-107.

Holdsworth, J.E. (2012), "The importance of human hydration: perceptions among healthcare professionals across Europe", *Nutrition Bulletin*, Vol. 37 No. 1, pp. 16-24.

Hunter, P.R., Risebro, H., Yen, M., Lefebvre, H., Lo, C., Hartemann, P., Longuet, C. and Jaquenoud, F. (2015), "Impact of the provision of safe drinking water on school absence rates in Cambodia: a quasi-experimental study", *Annals of Nutrition and Metabolism*, Vol. 66 No. S3, pp. 31-37.

Jéquier, E. and Constant, F. (2010), "Water as an essential nutrient: the physiological basis of hydration", *European Journal of Clinical Nutrition*, Vol. 64 No. 2, pp. 115-123.

Kavouras, S.A. (2002), "Assessing hydration status (abstract)", *Current Opinion in Clinical Nutrition and Metabolic Care*, Vol. 5 No. 5, pp. 519-524, available at: www.ncbi.nlm.nih.gov/pubmed/12172475

Kavouras, S.A., Bougatsas, D., Johnson, E.C., Arnaoutis, G., Tsipouridi, S. and Panagiotakos, D.B. (2017), "Water intake and urinary hydration biomarkers in children (abstract)", *European Journal of Clinical Nutrition*, Vol. 71 No. 4, pp. 530-535, doi: 10.1038/ejcn.2016.218.

Kavouras, S.A., Johnson, E.C., Bougatsas, D., Arnaoutis, G., Panagiotakos, D.B., Perrier, E. and Klein, A. (2016), "Validation of a urine color scale for assessment of urine osmolality in healthy children", *European Journal of Nutrition*, Vol. 55 No. 3, pp. 907-915.

Kavouras, S.A., Arnaoutis, G., Makrillos, M., Garagouni, C., Nikolaou, E., Chira, O., Ellinikaki, E. and Sidossis, L.S. (2012), "Educational intervention on water intake improves hydration status and enhances exercise performance in athletic youth", *Scandinavian Journal of Medicine & Science in Sports*, Vol. 22 No. 5, pp. 684-689.

Kempton, M.J., Ettinger, U., Foster, R., Williams, S.C.R, Calvert, G.A., Hampshire, A., Zelaya, F.O., O'Gorman, R.L., McMorris, T., Owen, A.M. and Smith, M.S. (2011), "Dehydration affects brain structure and function in healthy adolescents", *Human Brain Mapping*, Vol. 32, pp. 71-79.

Khan, N.A., Raine, L.B., Drollette, E.S., Scudder, M.R., Cohen, N.J., Kramer, A.F. and Hillman, C.H. (2015), "The relationship between total water intake and cognitive control among prepubertal children", *Annals of Nutrition and Metabolism*, Vol. 66, Suppl. 3, pp. 38-41.

Kleiner, S.M. (1999), "Water: an essential but overlooked nutrient", *Journal of the American Dietetic Association*, Vol. 99 No. 2, pp. 200-206.

Lieberman, H.R. (2007), "Hydration and cognition: a critical review and recommendations for future research", *Journal of the American College Nutrition*, Vol. 26 No. 5, pp. 555-561.

Martinez, M.B.A., Munoz, A.Y.C., Ojeda, G.M., Sandovall, Y.F.M. and Vizmanos, B. (2015), "A review of graphical representations used in the dietary guidelines of selected countries in the Americas, Europe and Asia", *Nutricion Hospitalaria*, Vol. 32 No. 3, pp. 986-996.

Masento, N.A., Golightly, M., Field, D.T., Butler, L.T. and Van Reekum, C.M. (2014), "Effects of hydration status on cognitive performance and mood", *British Journal of Nutrition*, Vol. 111 No. 10, pp. 1841-1852.

Downloaded by 185.40.210.2 At 07:47 05 December 2018 (PT)

Downloaded by 185.40.210.2 At 07:47 05 December 2018 (PT)

Nagy, Z., Westerberg, H. and Klingberg, T. (2004), "Maturation of white matter is associated with the development of cognitive functions during childhood", *Journal of Cognitive Neuroscience*, Vol. 16 No. 7, pp. 1227-1233.

Painter, J., Rah, J.-H. and Lee, Y.-K. (2002), "Comparison of international food guide pictorial representations", *Journal of the American Dietetic Association*, Vol. 102 No. 4, pp. 483-489.

Patel, A.I. and Hampton, K.E. (2011), "Encouraging consumption of water in school and child care settings: access, challenges, and strategies for improvement", *American Journal of Public Health*, Vol. 101 No. 8, pp. 1370-1379.

Popkin, B.M., D'Anci, K.E. and Rosenberg, I.H. (2010), "Water, hydration and health", *Nutrition Review*, Vol. 68 No. 8, pp. 439-458.

Riebl, S.K. and Davy, B.M. (2013), "The hydration equation: update on water balance and cognitive performance", *ACSMs Health and Fitness Journal*, Vol. 17 No. 6, pp. 21-28.

Schmitt, J.A.J., Benton, D. and Kallus, K.W. (2005), "General methodological considerations for the assessment of nutritional influences on human cognitive functions", *European Journal of Nutrition*, Vol. 44 No. 8, pp. 459-464.

Sharma, V.M., Sridharan, K., Pichan, G. and Panwar, M.R. (2007), "Influence of heat-stress induced dehydration on mental functions", *Ergonomics*, Vol. 29 No. 6, pp. 791-799.

Shirreffs, S.M. (2003), "Markers of hydration status", *European Journal of Clinical Nutrition*, Vol. 57, Suppl. 2, pp. 6-9.

Shirreffs, S.M. (2009), "Symposium on 'performance, exercise and health': hydration, fluids and performance", *Conference on 'Multidisciplinary Approaches to Nutritional Problems'. Proceedings of the Nutrition Society*, Vol. 68, pp. 17-22.

Streitbürger, D.-P., Möller, H.E., Tittgemeyer, M., Hund-Georgiadis, M., Schroeter, M.L. and Mueller, K. (2012), "Investigating structural brain changes of dehydration using voxel-based morphometry", *PLoS One*, Vol. 7 No. 8, available at: https://doi.org/10.1371/journal.pone.0044195 (accessed September 20, 2018).

Suhr, J.A., Hall, J., Patterson, S.M. and Niinistö, R.T. (2004), "The relation of hydration status to cognitive performance in healthy older adults", *International Journal of Psychophysiology*, Vol. 53 No. 2, pp. 121-125.

Szinnai, G., Schachinger, H., Arnaud, M.J., Lindre, L. and Keller, U. (2005), "Effect of water deprivation on cognitive-motor performance in healthy men and women", *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, Vol. 289, pp. R275-R280.

Trinies, V., Chard, A.N., Mateo, T. and Freeman, M.C. (2016), "Effects of water provision and hydration on cognitive function among primary-school pupils in Zambia: a randomized trial", *PLoS One*, Vol. 11 No. 3, e0150071, doi:10.1371/journal.pone.0150071, available at: https://doi.org/10.1371/journal.pone.0150071 (accessed September 1, 2018).

UNSCN (2017), "Schools as a system to improve nutrition: a new statement for school-based food and nutrition interventions", discussion paper, United Nations System Standing Committee on Nutrition, Rome, available at: www.unscn.org/uploads/web/news/document/School-Paper-EN-WEB-nov2017.pdf (accessed June 19, 2018).

Weichselbaum, E. and Buttriss, J. (2011), "Nutrition, health and schoolchildren", *Nutrition Bulletin*, Vol. 36 No. 3, pp. 295-355.

WFP and UNICEF (n.d.), "The essential package: twelve interventions to improve the health and nutrition of school-age children", available at: www.un.org/esa/socdev/poverty/PovertyForum/Documents/The%20Essential%20Package.pdf (accessed June 19, 2018).

WHO (2018), *Global Nutrition Policy Review 2016–2017: Country Progress in Creating Enabling Policy Environments for Promoting Healthy Diets and Nutrition (DRAFT)*, Department of Nutrition for Health and Development, Nutrition Policy and Scientific Advice Unit, World Health Organization, Geneva, available at: www.who.int/nutrition/topics/global-nutrition-policy-review-2016.pdf (accessed June 19, 2018).

WHO Programme for Nutrition and Food Security (2006), *Food and Nutrition Policy for Schools: A Tool for the Development of School Nutrition Programmes in the European Region*, WHO Regional Office for Europe, Copenhagen, available at: www.euro.who.int/__data/assets/pdf_file/0019/152218/E89501.pdf?ua=1 (accessed June 15, 2018).

WHO Regional Office for Europe (2003), *Food-Based Dietary Guidelines in the WHO European Region*, World Health Organization Regional Office for Europe, Copenhagen, available at: www.euro.who.int/__data/assets/pdf_file/0017/150083/E79832.pdf?ua=1 (accessed September 29, 2018).

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