Hydration, cognition and health throughout the lifespan

Dr Caroline Edmonds

School of Psychology
University of East London
Overview

• Why is good hydration important
  – How much fluid should we consume?
  – Where do we get that fluid from?
  – Do we consume enough?

• How does hydration affect cognition?
  – Effects of dehydration
  – And drinking

• Assessed across the lifespan
Hydration is important for health

- Moistens tissues such as those in the mouth, eyes and nose
- Protects body organs and tissues
- Helps prevent constipation
- Regulates body temperature
- Lubricates joints
- Lessens the burden on the kidneys and liver by flushing out waste products
- Helps dissolve minerals and other nutrients to make them accessible to the body
- Carries nutrients and oxygen to cells

© Mayo Foundation for Medical Education and Research. All rights reserved.
The proportion of body weight containing water decreases with age

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Mean Body Water as % of Body Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborns to 6 months</td>
<td>74%</td>
</tr>
<tr>
<td>6 months to 1 year</td>
<td>60%</td>
</tr>
<tr>
<td>1 - 12 years</td>
<td>60%</td>
</tr>
<tr>
<td>12 - 18 years male</td>
<td>59%</td>
</tr>
<tr>
<td>12 - 18 years female</td>
<td>56%</td>
</tr>
<tr>
<td>19 - 50 years male</td>
<td>59%</td>
</tr>
<tr>
<td>19 - 50 years female</td>
<td>50%</td>
</tr>
<tr>
<td>51+ years male</td>
<td>56%</td>
</tr>
<tr>
<td>51+ years female</td>
<td>47%</td>
</tr>
</tbody>
</table>

Data from Grandjean and Campbell, 2004
How much should fluid should we consume?

Human water requirements in ml per day according to European Food Safety Authority (EFSA), Institute of Medicine (IOM) and World Health Organisation (WHO)\(^1\)

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>EFSA (2008)(^2)</th>
<th>IOM (2005)(^3)</th>
<th>WHO (2005)(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 to 12 months</td>
<td>M &amp; F</td>
<td>800-1000</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>1 to 2 years</td>
<td>M &amp; F</td>
<td>1100 - 1200</td>
<td>1300</td>
<td></td>
</tr>
<tr>
<td>2 to 3 years</td>
<td>M &amp; F</td>
<td>1300</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>4 to 8 years</td>
<td>M &amp; F</td>
<td>1600</td>
<td>1700</td>
<td></td>
</tr>
<tr>
<td>9 to 13 years</td>
<td>F</td>
<td>1900</td>
<td>2100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>2100</td>
<td>2400</td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td>F</td>
<td>2000</td>
<td>2700</td>
<td>2200</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>2500</td>
<td>3700</td>
<td>2900</td>
</tr>
</tbody>
</table>

\(^{1}\) EFSA and IOM data sourced from Jequier & Constant (2010). WHO data sourced from WHO (2005).

\(^{2}\) Dietary reference intake values, indicating adequate intake

\(^{3}\) Adequate intake from drinking water, other beverages and water in food

\(^{4}\) Volume of water recommended for hydration in a sedentary, temperate environment
Some of our fluid intake comes from food

<table>
<thead>
<tr>
<th>Proportion of water</th>
<th>Visual Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 – 100 %</td>
<td>Water, tea, coffee, celery</td>
</tr>
<tr>
<td>85 – 95 %</td>
<td>Beer, wine, milk, juice, oranges</td>
</tr>
<tr>
<td>80 – 85 %</td>
<td>Strawberries, cantaloupe, grapefruit, tomatoes, carrots, celery, onion, cucumber</td>
</tr>
<tr>
<td>65 – 80 %</td>
<td>Spaghetti, rice, eggs</td>
</tr>
<tr>
<td>40 – 50 %</td>
<td>Bread, potatoes, potato chips, crackers</td>
</tr>
<tr>
<td>20 – 45 %</td>
<td>Nuts, dried fruits</td>
</tr>
<tr>
<td>1-10 %</td>
<td>Seeds, dried beans</td>
</tr>
</tbody>
</table>

Data from Grandjean & Campbell (2004)
Water demands depend on location and occupation.
Are adults consuming sufficient water?

- **UK Fluid Intake Survey** Gandy, 2012
  - Average intakes in line with EFSA guidelines
  - But, 30% of adults had inadequate intakes
    - 25% women
    - 35% men
  - Adults drank more hot beverages than any other drink

- 18% of the world population are likely to be drinking less than an adequate intake because they do not have access to a clean water supply within 1 km of their home WHO; cited in Howard & Bartram
Are adults dehydrated?
How do we assess hydration status?

• Physical signs of dehydration
  – Mild
    • Poor mood, Headache, Fatigue
  – More Severe
    • Shrivelled skin, Clumsiness, Delerium

  BUT
• Symptoms can be present under other conditions
• And they do not indicate extent of dehydration
Hydration status assessment

Urine colour

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |

Change in body weight

Electrical impedance

Urinary/Plasma Osmolality

Dehydration - Uosm 800 mOsm/kg or above
Euhydration - Uosm below 800 mOsm/kg.
There is some evidence suggesting some adults may be dehydrated

- A review of studies examining urine osmolality in adults worldwide revealed a large range (mosm/kg) 
  
  Manz & Wenz, 2003

<table>
<thead>
<tr>
<th>Country</th>
<th>Osmolality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Israel</td>
<td>1028</td>
</tr>
<tr>
<td>China</td>
<td>909</td>
</tr>
<tr>
<td>Tunisia</td>
<td>880</td>
</tr>
<tr>
<td>Nigeria</td>
<td>723</td>
</tr>
<tr>
<td>UK</td>
<td>699</td>
</tr>
<tr>
<td>Germany</td>
<td>659</td>
</tr>
<tr>
<td>USA</td>
<td>649</td>
</tr>
</tbody>
</table>

Dehydration – above 800 mosm/kg

- Individual/group differences have been found for males/females, location, occupation, etc.
Hydration and cognition in adults
Ratings of subjective alertness and concentration decrease when dehydrated

- Fluid restriction
- Euhydration

Thirst

Shirrefs et al, 2004
Effects of dehydration on cognitive performance and mood

% loss of body weight

1%  
No effects on cognition  
Negative effects on mood, anger, fatigue, depression, tension, confusion and vigour  
D’Anci et al, 2009; Shirrefs et al, 2004; Szinnai et al, 2005

2 – 3%  
Negative effects on memory/attention, psychomotor stylus  
Sharma et al, 1986  
Word recognition, Serial addition, trail making  
Gopinathan et al, 1988

Letter-symbol coding  
Sharma et al, 1986

Judgement of line length, digit span, joystick tracking  
Cian et al, 2000, 2001

4%  
Negative effects on serial addition, trail making  
Gopinathan et al, 1988
Dehydration selectively affects cognitive performance

• Performance not affected at <2% dehydration
  – Unaffected processes at <2% - digit span, simple RT, map planning, maths, attention D’Anci et al, 2009
  – Unaffected processes at >2% - long term picture memory, choice RT

• Mode of inducing dehydration may have an influence
  – Dehydration induced by fluid restriction does not appear to affect cognition Szinnai et al, 2005
  – But only 1-2% dehydrated
  – Why not? Allows time to adapt?

• Mood may moderate effect of dehydration on cognition
How does drinking water affect cognitive performance in adults?

- Low thirst
- High thirst

Rogers et al., 2001

Subjective alertness

9 point scale

Rapid Visual Information Processing

2 minutes post treatment

Combined data 25 & 50 mins post treatment

Rogers et al., 2001
In adults, drinking additional water improves attention

- Drinking 200 ml water resulted in improved visual attention and reduced thirst Edmonds, Crombie, Ballieux, Gardner & Dawkins, 2013
  - No effect on digit span or reaction time

- But not all studies find that drinking water improves performance Neave et al, 2001
Drinking water improves reaction time, but only if thirsty

- In thirsty individuals, having a drink quickened reaction times to a similar speed of non-thirsty individuals.
- In non-thirsty individuals, having a drink had no effect on speed.

**FIGURE 1** | Mean RT (correct trials) on the SRT task as a function of water condition (water/no water) and thirst (thirsty/not thirsty). Asterisk indicates a statistically significant simple main effect of WATER, restricted to the Thirsty group.

Edmonds, Crombie, Gardner, 2013
More controlled processes are facilitated by thirst

• Why?

• Potentially explained by the physiological processes involved

• e.g. Vasopressin activates the thirst response,
• vasopressin linked to attention and arousal,
• might explain why thirst linked to better performance

Edmonds, Crombie, Gardner, 2013
Hydration and cognition in children
Children are at particular risk of dehydration

- Water accounts for a higher proportion of body weight
- Higher metabolic and respiratory rates
- Immature thirst reflex
- Reliant on caregivers for access to drinks
Are children drinking sufficient fluid?

• In a UK fluid intake survey, less than 50% of children consumed EFSA’s Adequate Intake Gandy, 2012
  – Children consumed more sugar sweetened beverages and functional drinks than any other group, particularly 15-17 year olds

• Recent studies suggest a large proportion of children arrive at school dehydrated

• 2/3 of children dehydrated on school arrival, Friedlander, 2012
  – USA – 65%, France – 62%, UK – 60%, Italy – 67%

• 62% of French 9-11 year olds urine osmolality >800 mosm/kg Bonnet et al, 2012
Classroom policy on drinking water access affects consumption

145 children aged 6-7 years; 153 children aged 9-10 years

**Figure 1.** Percentage of schoolchildren who achieved minimum expected fluid intake under different water access conditions.

Children’s hydration status is linked to cognitive performance

• In children, dehydration is linked to poorer memory in children Bar-David et al, 2005; Fadda et al, 2008

• And not with
  – Hidden figures, Making groups, Verbal analogies, Number addition Bar-David et al, 2005 Selective attention, Number addition Fadda et al, 2012
  – And children were better at Verbal analogies when dehydrated Fadda et al, 2012

• Studies in children assess voluntary hydration
  – Not fluid restricted
  – Not exposed to heat, but living in hot countries
  – Not exercised to dehydration

• Does performance improve after having a drink?
Thirst ratings decreases and happiness ratings increase after drinking water

Edmonds & Jeffes, 2009
Memory and visual attention improve after drinking water

Edmonds & Jeffes, 2009
Memory improves after drinking water

But no effect on sustained attention

Fig. 1. The influence of drinking water on memory. The data are the mean number of objects recalled ± standard error for a sample of 40 children. Memory was significantly better on the occasions when water had been consumed (main effect for consumption of water $F(1,36) = 4.84, p < 0.03$).
Hydration and cognition in older adults
Dehydration an issue for elderly people, says research

Study finds care home residents 'more likely' to be dehydrated

Scandal of dehydrated pensione hospital because their care hom give them a drink

Care home residents five times more likely to be dehydrated. The Independent reports after a analysis of some London hospital admission records found people admitted from care homes were five times more likely to be dehydrated than people coming from their own homes.

Equally serious was the discovery that dehydration at admission was associated with a higher risk of dying while in hospital.

Much of the media seized on anecdotal reports that dehydration was the result of staff restricting access to residents who were less likely to wet themselves during the night to the toilet.

A study of 20,000 hospital admissions found 12 per cent of pensioners arriving from care homes were dehydrated
Older adults are also susceptible to dehydration

• Total body water decreases with age – 65% in adults to 40% in elderly women Davis and Minaker, 1994

• Thirst mechanism becomes less effective with age Mentes, 2006

• Aging kidneys do not work as effectively Sheehy et al, 1999

• Environmental factors can affect drinking – access to drinks

• Reduced mobility, reduced ability to swallow

• Age-related illness may increase the risk of dehydration (e.g. diabetes, flu, pneumonia, respiratory infections, etc) Sheehy et al, 1991
The evidence suggests many older adults do not consume sufficient fluid

- In a German sample, average fluid intake from food and beverages met recommendations Volkert, Kreuel, Stehle, 2005
  - But 28% of young elderly (65-74 years) and 41% of the oldest old (85+ years) were below recommended intakes

- Fluid intake decreases with increasing age, and reduction is due to decrease in drinks Volkert et al, 2005; Bellisle et al, 2010; Haveman-Nies et al, 1997; Raman et al, 2004; Zizza et al, 2009; Kant et al, 2009

- The most frequently reported drink of adults aged 60-75 was hot beverages Gandy, 2012
There is a higher incidence of dehydration in older adults

• Both in care homes
  – Up to 92% of care home results drink insufficient fluid Mentes & Kulp, 2003
  – Plasma osmolality levels suggested 88% of care home residents dehydrated O’Neill et al, 1990

• And in the community
  – Up to 60% of community-living older adults dehydrated – depending on the measure Stookey, 2005
  – But, much less research on older adults in the community Stookey et al, 2005

• Dehydration is 1 of the 10 most frequent diagnoses reported for hospitalisation of older adults in the United States Sheehy et al, 1999 and is associated with increased mortality Mentes, 2006
Does dehydration affect cognitive performance in older adults?

- Limited evidence

- Better hydration status was related to better working memory and improved recall in 50-78 year old women. Suhr et al, 2004

- Better hydration status related to faster reaction times in 51 – 60 year old men. Ainslie et al, 2002

- But, other studies show no relationship between dehydration and cognitive performance. Ackland et al, 2008
Does drinking additional water improve cognitive performance in older adults?

• We do not know...
How might dehydration and water supplementation affect cognition?

- Thirst diverts attention  
  Cohen, 1983

- Via hormones  
  Wilson & Morley, 2003
  \[\uparrow \text{dehydration} \rightarrow \uparrow \text{cortisol}\]

- Reduction in brain volume with chronic dehydration (16 hours)  
  Duning et al, 2005
Summary and Future Directions

• Performance on memory and visual attention tasks seem particularly hydration sensitive

• We need to explore the effects of dehydration and water consumption in older adults
  – Across the span of older adults

• And to investigate the mechanisms