Hydration in infants and children

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Homeostasis – the key to adequate hydration

In healthy children:

- Large variations in daily intake of water
- Tolerance due to body’s homeostatic mechanisms
- Kidney adjusts absorption & excretion of water → maintain plasma osmolality 275-290mOsm/kg plasma sodium 135-145mmol/l
- No need for exact precision in determining requirements for water
Getting the right balance

**Water in** (+ve balance)
- Drinking
- Produced by body in oxidative metabolism

**Water out** (-ve balance)
- Urine – 60%
- Skin and lungs – 35%
- Stool – 5%

Water balance maintained within ± 0.2% (Grandjean et al, 2003)
**Fluid requirements**

<table>
<thead>
<tr>
<th>Age</th>
<th>Fluid Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young infants</td>
<td>~150ml/kg</td>
</tr>
<tr>
<td>Toddler</td>
<td>~100ml/kg</td>
</tr>
<tr>
<td>Adult</td>
<td>~50ml/kg</td>
</tr>
</tbody>
</table>

*Water depletion more likely in children*
Why do infants and children have higher fluid requirements?

1. **Body composition**
   Larger Total Body Water content

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Foetus</td>
<td>&gt;90% total body mass</td>
</tr>
<tr>
<td>Term infant</td>
<td>~ 75%</td>
</tr>
<tr>
<td>↓ during 1st year of life</td>
<td></td>
</tr>
<tr>
<td>Remains stable until puberty</td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td>60% males</td>
</tr>
<tr>
<td></td>
<td>50% females</td>
</tr>
</tbody>
</table>
Why do infants and children have higher fluid requirements?

2. Higher surface to mass ratio
   - water losses through the skin
   - More susceptible to changes in temperature

3. Higher respiratory & metabolic rate
   - water lost via lungs
   - Dramatic growth in 1\textsuperscript{st} year of life
     - (3 x weight gain; 50\% ↑ in length)
   - Continuing growth to adolescence
Why do infants and children have higher fluid requirements?

4. **Immature renal function**

   **Foetus** produces urine from ~ 10th week of gestation

   **At birth** glomerular & tubular function deficient

   **Glomerular Filtration Rate** is low

   Impacts water & electrolyte homeostasis & excretion of waste products

   Low concentrating capacity

   

   ∴ if water depleted

   ➔ the kidney still produces dilute urine
Immature renal function

<table>
<thead>
<tr>
<th></th>
<th>2 weeks</th>
<th>8 weeks</th>
<th>1 year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum urine osmolality (mOsm/kg H₂O)</strong></td>
<td>700-800</td>
<td>1000-1200</td>
<td>1200-1400</td>
</tr>
<tr>
<td><strong>GFR (ml/min/1.73m²)</strong></td>
<td>35-45</td>
<td>75-80</td>
<td>90-110</td>
</tr>
</tbody>
</table>

(from Guignard & Drukker in *Clinical Paediatric Nephrology*, eds Webb & Postlethwaite, 2003)
Other risks for water depletion

5. **Thirst sensitivity**
   Learned behaviour  \( \text{dryness} \rightarrow \text{drinking} \)

\( \uparrow 1-2\% \text{ in plasma osmolality} \rightarrow \text{thirst reflex} \)

Children don’t display this thirst sensitivity
   \( \rightarrow \) long periods without drinking  (Box & Landman, 1994)
   \( \rightarrow \) may not drink enough after exercise  (Bar-Or et al, 1980)
Other risks for water depletion

6. Body cooling mechanisms & heat tolerance

↓ sweat rates (Meyer et al, 1992)

↓ acclimatisation to heat (Falk & Dotan, 2008; Bytomski & Squire, 2003)

↑ risk when exercising (AAP, 2000)

Lack of recognition of need to replace lost fluids
Infants & children are at greater risk for dehydration because of their age

**Physiological**
- Body composition
- Higher surface to mass ratio
- Higher metabolic rate
- Immature renal function
- Less heat tolerant
- Decreased thirst sensitivity

**Developmental and social**
- Dependency on caregivers
Dependency on care givers

- Infants & toddlers cannot ask for drinks
  Must be given regular fluids
  Rely on caregivers to pick up on cues
  *hunger vs thirst*
  Lack of awareness of insensible water losses

- Inadequate *spontaneous* intake
  Lack of thirst response
## Signs of dehydration

Only ~ $\frac{2}{3}$ parents can identify > 1 sign of dehydration

(Gittelman et al, 2004)

<table>
<thead>
<tr>
<th>Degree of dehydration</th>
<th>Infant</th>
<th>Older child</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mild</strong></td>
<td>&lt;5% infant, &lt;3% child</td>
<td>Thirsty, alert, restless, ↓ urine</td>
</tr>
<tr>
<td><strong>Moderate</strong></td>
<td>5-10% infant, 3-6% child</td>
<td>Lethargic, drowsy, sunken eyed, ↓ urine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alert, postural dizziness, sunken eyed, ↓ urine</td>
</tr>
<tr>
<td><strong>Severe</strong></td>
<td>&gt;10% infant, &gt;6% child</td>
<td>Limp, cold, ° urine, ↓ consciousness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apprehensive, cold, ° urine, cramps</td>
</tr>
</tbody>
</table>
Water requirements for infants and children

Need for water highly individual & multifactorial:
- age, gender, body mass, environment, activity

Difficult to define *universal recommendation* for populations

- **European Food Safety Authority 2008***
- **Institute of Medicine 2005**
- **World Health Organization 2003, 2005***

*includes water from beverages and food
**includes water from beverages, food and water absorbed during cooking

Based on water intakes & urine osmolality, not hydration status
## Comparison of recommendations – infants

<table>
<thead>
<tr>
<th>Age months</th>
<th>EFSA 2008 Draft Dietary Reference Values</th>
<th>Institute of Medicine 2005 Adequate Intakes</th>
<th>WHO 2003, 2005 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td></td>
<td></td>
<td>750 ml/d</td>
</tr>
<tr>
<td>0-6</td>
<td>100-190 ml/kg/d</td>
<td>700 ml/d</td>
<td></td>
</tr>
<tr>
<td>6-12</td>
<td>800-1000 ml/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-12</td>
<td></td>
<td>800 ml/d</td>
<td></td>
</tr>
<tr>
<td>8-12</td>
<td></td>
<td></td>
<td>1000 ml/d</td>
</tr>
</tbody>
</table>
Fluid requirements for infants

**Young infant (0-6m)**

Fluid = nutrition

- **Breast fed**
  - Demand breast feeding provides fluid & nutritional requirements
    - 150ml/kg
    - 100kcal/kg
    - 130ml water/kg

No extra fluid needed
Fluid requirements for infants

**Young infant (0-6m)**
Fluid = nutrition

- **Formula fed**
  - 150ml/kg
  - 100kcal/kg
  - 130ml water/kg

May require extra cooled boiled water
Fluid requirements for infants

Older infant (6-12m)
- Fluid derived from weaning foods
- High water content: fruits & veg 90-95%

6 month old
wt 7kg
120ml/kg formula = 840ml = 80kcal/kg
2 x 120g fruit/veg = 220ml = 20kcal/kg
Total fluid = 150ml/kg
Once weaning is established

- **Foods have lower water content**
  - Rice & pasta 65-80%
  - Fish 70-80%
  - Meat 45-65%
  - Bread 30-45% (Grandjean & Campbell, 2004)

- **Water with meals** (from a clean cup or beaker)
  - Tap water or bottled water (NB Na < 200mg/l)
  - Does not need to be boiled
  - Do not need fruit juices or baby juices
## Comparison of recommendations – children

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>EFSA 2008 Draft DRV</th>
<th>IoM 2005 Adequate Intakes</th>
<th>WHO 2003, 2005 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-24 m</td>
<td>1.1-1.2 l/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-3</td>
<td></td>
<td>1.3 l/d</td>
<td>1.0 l/d</td>
</tr>
<tr>
<td>2-3</td>
<td></td>
<td>1.3 l/d</td>
<td></td>
</tr>
<tr>
<td>4-8</td>
<td>1.6 l/d</td>
<td>1.7 l/d</td>
<td></td>
</tr>
<tr>
<td>9-13 (boys)</td>
<td>2.1 l/d</td>
<td>2.4 l/d</td>
<td></td>
</tr>
<tr>
<td>9-13 (girls)</td>
<td>1.9 l/d</td>
<td>2.1 l/d</td>
<td></td>
</tr>
<tr>
<td>14-18 (boys)</td>
<td></td>
<td>3.3 l/d</td>
<td></td>
</tr>
<tr>
<td>14-18 (girls)</td>
<td></td>
<td>2.3 l/d</td>
<td></td>
</tr>
</tbody>
</table>
How much do children actually drink?

National Diet and Nutrition Survey 2008/09

Doesn’t include fluid from food

<table>
<thead>
<tr>
<th>Fluid</th>
<th>1½ - 3 y</th>
<th>4 - 10 y</th>
<th>11 - 18 y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>whole, skimmed</td>
<td>278</td>
<td>187</td>
<td>141</td>
</tr>
<tr>
<td>semi-skimmed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beverages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fruit juice, soft drinks,</td>
<td>527</td>
<td>668</td>
<td>1025</td>
</tr>
<tr>
<td>tea, coffee, water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>805</td>
<td>855</td>
<td>1166</td>
</tr>
</tbody>
</table>
Are our children chronically dehydrated?

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>NDNS 2008/09 Recorded</th>
<th>Total</th>
<th>EFSA 2008</th>
<th>IoM 2005</th>
<th>WHO 2003, 05</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 3</td>
<td>805ml (+ 400ml)</td>
<td>1205ml</td>
<td></td>
<td>1300ml</td>
<td>1000ml</td>
</tr>
<tr>
<td>4 - 8</td>
<td>855ml (+ 500ml)</td>
<td>1355ml</td>
<td>1600ml</td>
<td>1700ml</td>
<td></td>
</tr>
<tr>
<td>14 – 18</td>
<td>1264ml (+ 600ml)</td>
<td>1864ml</td>
<td></td>
<td>3300ml</td>
<td></td>
</tr>
<tr>
<td>14 – 18</td>
<td>1060ml (+ 500ml)</td>
<td>1560ml</td>
<td></td>
<td></td>
<td>2300ml</td>
</tr>
</tbody>
</table>

EFSA = European Food Safety Authority
IoM = Institute of Medicine
WHO = World Health Organization
Risks of having too much water

**Neonate** cannot efficiently excrete water load

**Infants and toddlers**
- Small stomach volume
- Decreased appetite
- Inadequate energy and nutrients
- Faltering growth
Case study

1 year old girl
At birth weight, length on 25\(^{th}\) centile
HC on 9\(^{th}\) centile
At 1 year dramatic faltering growth

Diet history: fluid intake 190ml/kg
1000ml water daily
300ml formula = 30kcal/kg
3 small meals = 35kcal/kg

Energy intake = 65kcal/kg
normal req = 95kcal/kg
Risks of having too little water

Excessive milk drinking in toddlers

- Decreased appetite for foods
- Iron deficiency anaemia associated with milk intake > 500ml/d (Cowin et al, 2001; Gunnarsson et al, 2004)
- Increased saturated fat intake
Case study

2½ year old girl
Drinking 1000ml full fat cows milk daily

Energy req 1230kcal
Iron req 6.9mg

DRV saturated fat = 11% total dietary energy

1000ml milk
= 650kcal
= 24g SFA (18% energy)
= 0.6mg iron
Risks of having too little water

Excessive intake of high sugar drinks
- **Obesity**
  - school children given water ↑ consumption by 1.1 glasses/day with ↓ risk of overweight of 31% (Muckelbauer et al, 2009)

- **Poor appetite, poor weight gain, loose stools**
  - ‘squash drinking syndrome’ - on reducing sugary drinks toddlers showed improvement in all symptoms (Hourihane & Rolles, 1995)

- **Dental caries**
  - in young children consuming regular soda pop, regular powdered beverages (& 100% fruit juice) had ↑ risk of caries (Marshall et al, 2003)
A practical recommendation for fluid intake in healthy children

6 – 8 drinks a day
- 100-120ml toddlers
- 160-180ml 5 yr old
- 200-220ml 10 yr old
- 280-300ml 15 yr old

Subject to:
age, gender, environment, activity, water from food

Suitable drinks
- Water preferred
- Some milk (350-500ml)
- Fruit juice, smoothies
- ? Fizzy pop, squashes
- ? Artificial sweeteners
- ? Tea, coffee

72.5% preschool children 50% infant school children never drank water
(Petter et al, 1995)
Clinical scenarios – fluid balance critical to maintain hydration

Too much fluid going out

- **Gut**
  - acute gastroenteritis, enteropathy, stomas

- **Lungs**
  - cardiorespiratory diseases, congenital heart disease, cystic fibrosis, tracheostomy

- **Skin**
  - pyrexia, eczema, burns, CF, phototherapy

- **Kidney**
  - renal dyplasia, nephrogenic diabetes insipidus, renal tubular diseases
Clinical scenarios – fluid balance critical to maintain hydration

Not enough fluid coming in

- Dysphagia – cerebral palsy, neurodisability
- Vomiting – chemotherapy, GORD
- Behavioural – fussy feeders and eaters
- Carer – child neglect or abuse
Alternative methods of feeding
Are there added benefits of adequate hydration in the well child?

Cognitive function in young adults

- mild dehydration (2% loss of body weight) ➔ significant impairment of cognitive function
  
  (Gopinathan et al, 1988; Cian et al, 2000)

- Water restriction/consumption following 12 hr water restriction ➔ did not affect cognitive performance; however self-reported arousal as a result of water ingestion

  (Neave et al, 2001)
Cognitive function in children

- **infants**
  dehydration ➔ confusion, irritability and lethargy

- **young children**
  dehydration ➔ decrements cognitive performance?

- **10 – 12 year olds**
  dehydrated group ➔ significantly worse auditory digit span, poorer performance in semantic flexibility & pattern identification

(Bar-David et al, 2005)
Cognitive function in children

Children given drink or no drink 20-45 minutes before cognitive tests. Voluntary water intake 57-250ml

- Improvement in visual attention
  no effect on visual memory in 6 – 7 year olds
  (Edmonds & Jeffes, 2009)

- Improvement in visual attention
  & visual memory in 7 – 9 year olds
  (Edmonds & Burford, 2009)

Children (8y 7m) given 300ml or no water before cognitive tests

- Memory performance improved
  sustained attention not altered
  (Benton & Burgess, 2009)
Summary

- Fluid balance is critical in the child with extra losses or insufficient intake due to disease.
- It is not fully understood how hydration affects health & well-being in children.
- Water is beneficial if in deficit, but does additional water confer any benefit in children who are seemingly well hydrated?
- More knowledge is needed to assess the impact of water and hydration in promoting health in children.