Hydration in pregnancy and breastfeeding

Physiological changes, water balance and water needs

The H4H Hydration for Health Initiative

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For healthcare professionals, scientists and academic researchers

Developed by DANONE NUTRICIA RESEARCH for the Hydration for Health Initiative

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Introduction

For many women, pregnancy and lactation are very special life stages for taking care of their health and diet, in order to ensure the best start in life for their baby. However, even though changes in hydration physiology and balance are numerous during pregnancy and lactation, this topic is often overlooked.

This document aims at providing an overview of the existing science on changes in hydration physiology, water balance and needs during pregnancy and lactation.

Indeed, during pregnancy, changes arise in water dynamics. These changes result in increased body water content and subsequent adaptations in its regulation. Preliminary evidence suggests health benefits result from an appropriate hydration during pregnancy. After birth, breastfeeding should be preferred whenever possible, as the ideal way to ensure the required nourishment for the newborn. However, lactation induces extra water loss for the mother. Considering the increased water needs during pregnancy and lactation, specific recommendations on fluid intake have been issued for these physiological stages.

I. Hydration and the role of water during pregnancy

Pregnancy involves many changes in a woman's body to support the growth of the fetus. Among these changes, modifications occur in the water dynamics, with an increase in total body water and changes in the regulation of body water balance

I.1. Changes in body water during pregnancy

I.1.1. Total body water increase

Pregnancy leads to a significant weight gain, which averages 12 kg at term in women with a normal BMI *(IoM, 2009)* (Figure 1). A major contributor to this weight gain is body water; it increases by 6 to 8 L in healthy pregnant women *(Chesley, 1978; Hytten, 1980)*. This additional body water is located in the amniotic fluid and the placenta, but also in the expansion of maternal intra- and extracellular fluid volumes, such as blood volume *(Beall et al., 2007; Larcipetre et al., 2003)*. Moreover the fetus itself is mostly composed of water (75-90%) *(Givens and Macy, 1933; Ziegler et al. 1976)*.

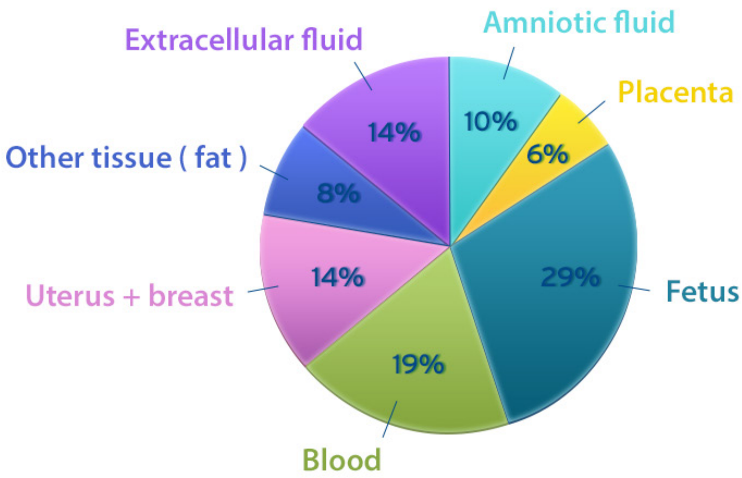

Figure 1. Components of gestational weight gain at term.
Adapted from Pitkin, 1976.

This increase in the mother's total body water is needed for plasma volume expansion, for the constitution of the amniotic fluid and for the placenta, which are essential for the development of the fetus.

I.1.2. Plasma volume expansion

Plasma, being the liquid phase of blood, represents about 3 liters in adults *(Guyton and Hall, 2006)*. In pregnant women, plasma volume increases up to 40-50% above pre-pregnancy value *(Clapp et al., 1988; Metcalfeand Ueland, 1974; Ueland, 1979)*.
This increase is concurrent with progressive sodium retention, but to a lesser extent. This leads to a lower blood osmolality than in non-pregnant women, mostly due to a lower sodium concentration: plasma osmolality is decreased by 10 mOsm/kg, from 290 to 280 mosm/kg compared to non-pregnant women *(Davison et al., 1981)*.
This increase in blood volume is needed for placenta vascularization without jeopardizing maternal organ perfusion. It enables fetal-maternal exchanges of nutrients and other compounds through the placenta. Plasma volume expansion also plays the role of physiological reservoir in case of hemorrhage *(Koller, 1982)*.

I.1.3. Amniotic fluid: ensuring fetal development

The amniotic fluid is a clear, yellowish liquid that surrounds the fetus inside the amnion. Its volume varies widely during gestation, from 500 to 1200 mL *(Goodwin et al., 1976)*.

The amniotic fluid functions as storage of water for the fetus along with an environment for its development. It insures protection against mechanical trauma, temperature variations, and bacterial infections; it enables normal anatomic development, allows movement and supports the development of fetal lungs *(Beall et al., 2007)*. Amniotic fluid volume has been recognized as a predictor of fetal well-being *(Hinh and Ladinsky, 2005)*.

The amniotic fluid production and reabsorption is a dynamic process: large water volumes circulate from the mother via the placenta into the fetal circulation to eventually become part of the amniotic fluid; the amniotic fluid is then reabsorbed via fetal swallowing into the fetal circulation and finally into the maternal circulation. *(Beall et al., 2007)* (Figure 2).

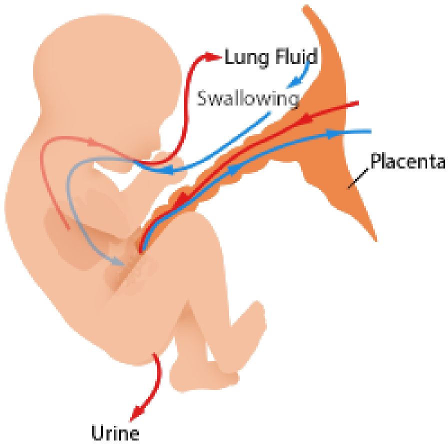

Figure 2. Water circulation between the fetus and amniotic fluid
during the second and third trimesters.
Adapted from Beall et al., 2007.

Some exchanges also exist directly between amniotic fluid and the maternal circulation, via amnion membranes, but this pathway represents only a small proportion of all water exchanges between the mother and the fetus. Most of these exchanges occur via the placenta *(Hutchinson et al., 1959)*.

I.1.4. The placenta: the organ for fluid supply to the fetus

The placenta's primary role is to ensure the physiological exchanges between the fetal and maternal systems: it is the major site for exchange of oxygen, nutrients including water and waste between the mother and the fetus *(Meschia, 1983; Reynolds and Redmer, 1995)*. It consists of 85% water (*i.e., about 500 mL; Barker et al., 1994)*. However, placental water volume increases over the gestation period since it is proportional to the weight of the fetus *(Beall et al., 2007)*.

The exchange of water from mother to the fetus progressively increases with gestational age, in proportion to the weight of the fetus *(Faber and Thornburg, 1983; Meschia, 1983; Reynolds and Redmer, 1995)*. The amount of water exchanged per hour has been estimated to range from 100 mL per hour at 12 weeks, to as high as 3600 mL per hour at term *(Hutchinson et al., 1959)*.

The increase in the mother's total body water content during pregnancy is necessary for the development of the fetus and allows for the exchange of large volumes of water between the mother and the growing fetus.

I.2. Regulation of body water in pregnant woment

The changes observed during pregnancy in water dynamics and the increased total body water imply changes in the overall water balance, as well as adaptations in body water regulation.

I.2.1. Water balance in pregnant women

Body water balance is defined as the equilibrium between body water gains and body water losses. Water gains come from water contained in fluid and food, as well as metabolic water (water produced by the organism during nutrient oxidation) *(Shirreffs, 2003; Benelam and Wyness, 2010)*. In non-pregnant women, body water losses average 1.5 to 3.0 L/d. The losses occur mainly through urine and skin and to a lesser extent, through breathing and fecal losses *(Grandjean et al., 2003)*.
Water needs in pregnant women are significantly increased to allow for the increase in body water and to meet the increased metabolic needs of the fetus **(Figure 3)**.

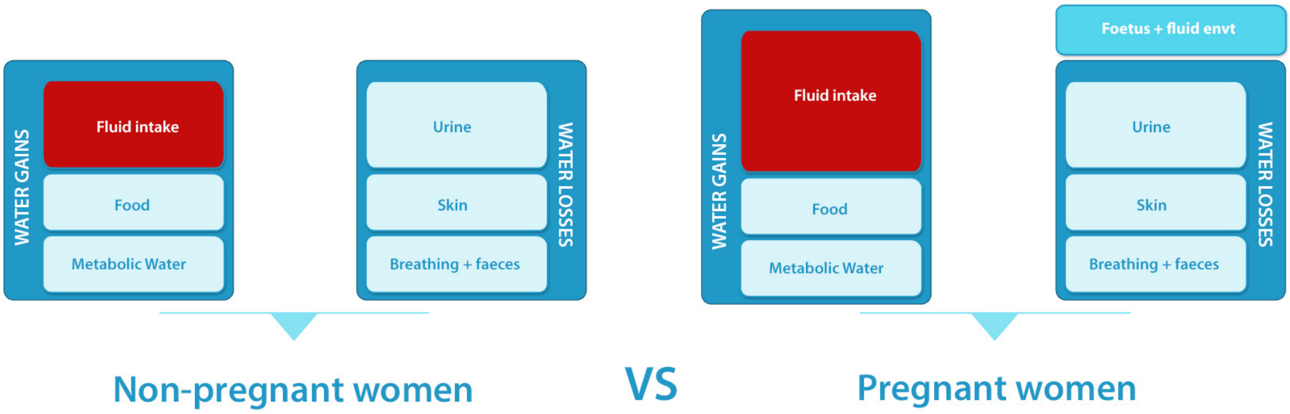

Figure 3. Water balance in non-pregnant vs pregnant women (sedentary women in temperate climate).

In addition, 80 to 90% of women experience nausea and vomiting during pregnancy, which adds extra stress on their water balance *(Einarson et al., 2007)*. Fluid intake should therefore be adapted to meet the increased needs. In parallel, adaptations occur in the regulation of body water balance.

I.2.2. Adaptations to ensure body water balance

Slight changes are observed during pregnancy in the regulation of the body water balance. Indeed, the decrease in plasma osmolality observed during pregnancy would lead, in non-pregnant state, to a decreased secretion of the anti-diuretic hormone (ADH), and thus to a lower water reabsorption and an increased urine output. However, this new state is considered as normal thanks to a "reset" of osmoreceptors. Indeed, both plasma osmolality thresholds triggering thirst and ADH secretion are reduced during pregnancy, enabling a mother-to-be to achieve a normal water balance based on these new levels *(Davison, 1983; Brenner, 2008)*. As a result, the water balance is regulated in the same way as in non-pregnant women, but with other thresholds considered as normal during pregnancy **(Figure 4)**.

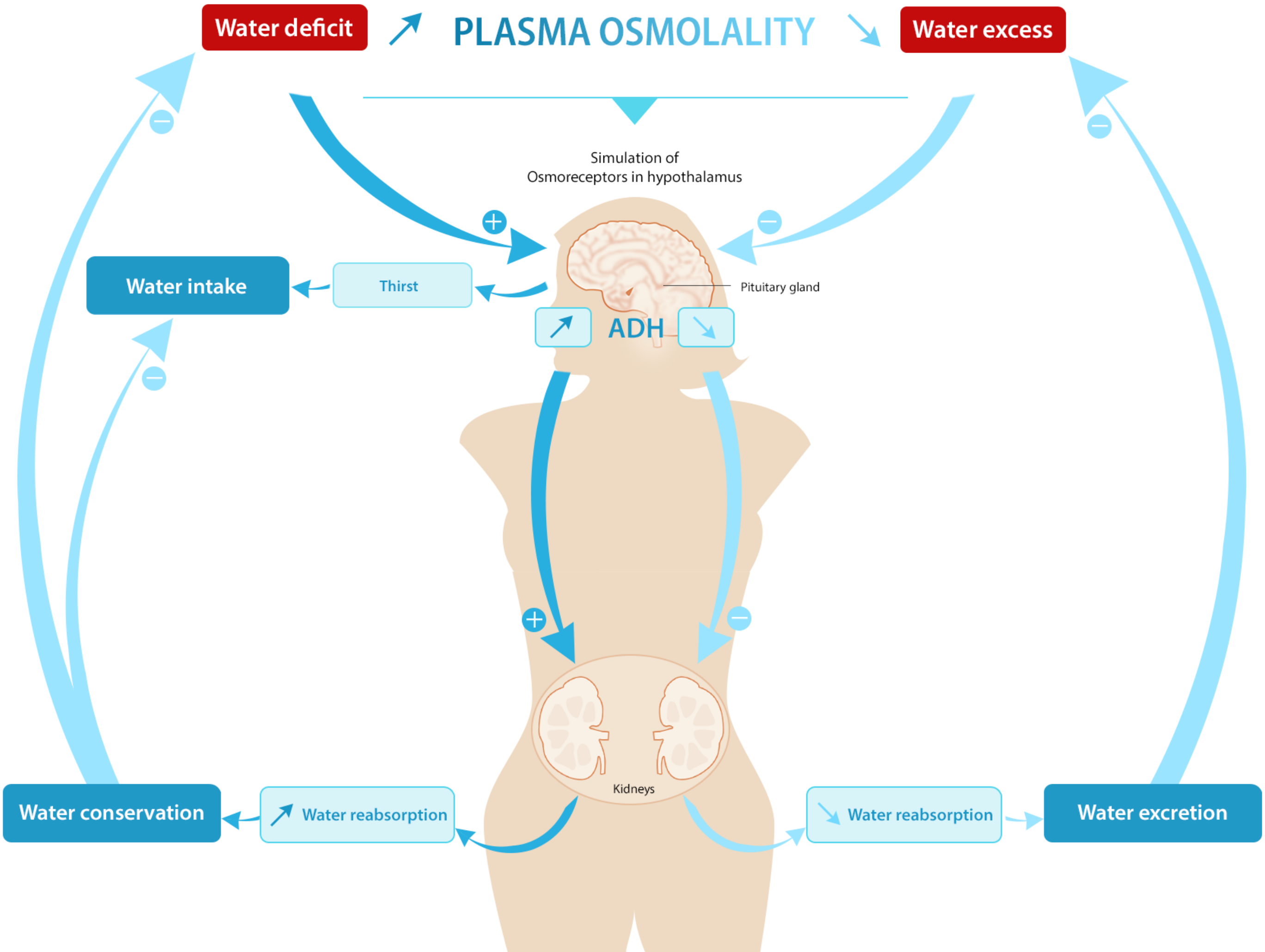

Figure 4. Regulation of body water balance by the anti)diuretic hormon (AH) and the kidneys.

The urinary system also adapts to support these changes **(Figure 5)**. The renal plasma flow is increased by 50 to 85% and GFR *(Glomerular Filtration Rate)* is increased by 40 to 65% *(Jeyabalan and Lain, 2007; Brenner, 2008)* in the first half of pregnancy. Those adaptations are amongst the earliest and most impressive adaptations to pregnancy *(Davison et al., 1981)*, but the mechanisms are not completely understood. To face this increased flow, the length of the kidneys also increases by approximately 1 cm and 30% in volume *(Jeyabalan and Lain, 2007)*. This increased GFR leads to an increased rate of urinary excretion of proteins and glucose, leading to mild glycosuria and proteinuria, considered to be normal during pregnancy *(Williams, 2004)*.

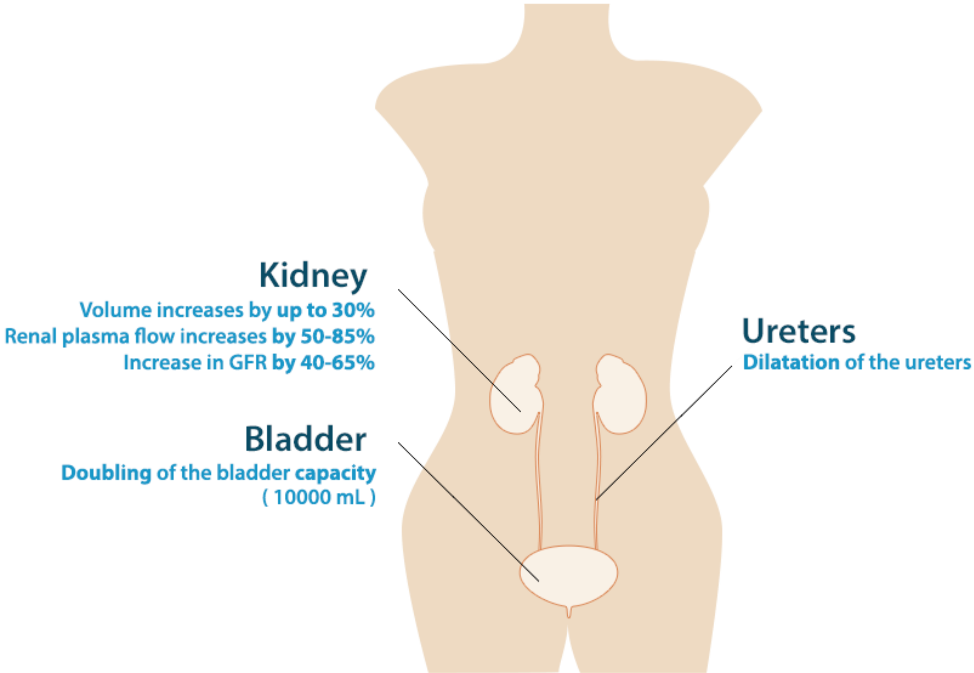

Figure 5. Main adaptations of the urinary tract to pregnancy.

I.3. Emerging science regarding water and health outcomes during pregnancy

Even though the adaptations required during pregnancy to maintain body water balance are important, there is to date little information on the influence of mother's hydration status for her own health and for the fetus. Preliminary evidence seems to indicate that the volume of fluid consumed per day might be important for perinatal outcome, and for the prevention of constipation and urinary tract infections in the mother.

I.3.1. Maternal hydration status: influence on perinatal outcomes

Amniotic fluid volume has been recognized as a predictor of fetal well-being, and subsequently of poor perinatal outcome *(Cunningham et al., 1993; Beall et al., 2007)*. In practice, amniotic fluid volume can be evaluated using the amniotic fluid index *(AFI) (Fok et al., 2006)*.

Several studies have demonstrated that maternal fluid intake and hydration status of the mother may influence the AFI *(Borges et al., 2011; Fait et al., 2003; Kilpatrick et al., 1991; Kilpatrick and Safford, 1993; Malhotra and Deka, 2004; Sciscione et al., 1997)*. A potential, suggested mechanism is presented in Figure 6.

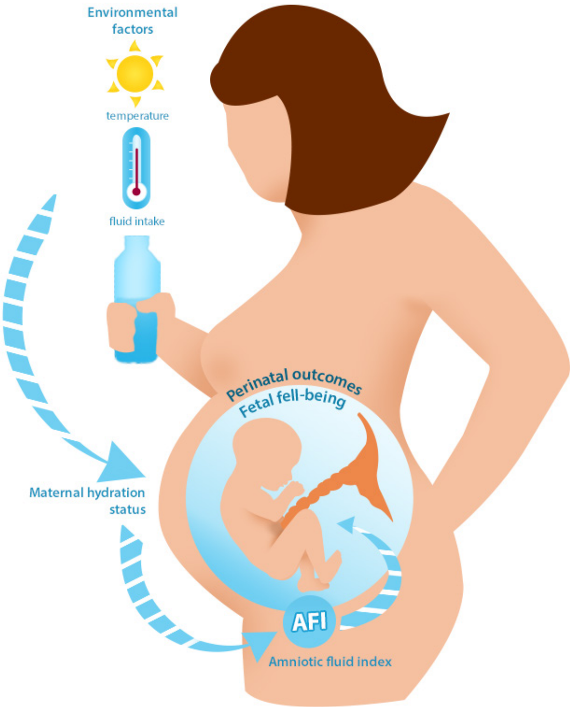

Figure 6. Potential consequences of maternal fluid intake on fetal well-being.

Water intake could therefore be a way to increase amniotic fluid volume *(Hofmeyr et al., 2002)*. However, more research is needed to determine the fluid intake needed to obtain an optimal amniotic fluid volume and pregnancy outcome in general.

I.3.2. Constipation

Constipation is a common disorder in pregnancy, affecting up to 40% of pregnant women *(Anderson, 1984; Cullen and O'Donoghue, 2007)*. Several factors can contribute to gestational constipation, such as hormonal and anatomical changes, or dietary factors.

There is some evidence that changing dietary habits towards a high-fiber diet, combined with drinking more water, prevents or relieves constipation in pregnant women *(Cranston et al., 1988, Trottier et al., 2012)*, by optimizing the normal gastrointestinal transit time *(Cullen and O'Donoghue, 2007; Derbyshire et al., 2006; Vazquez, 2010)*. A hypothesis to explain the effect of water intake on constipation is that low fluid intake decreases the mass and frequency of stools *(Klauser et al., 1990)*, but further research is needed to precisely understand the underlying mechanisms.

Despite this limited evidence, healthcare professionals generally advise pregnant women to consume a high-fiber diet with an adequate fluid intake to limit constipation *(Trottier et al., 2012)*, as it is done in the non-pregnant population *(WGO, 2010; Selby and Corte, 2010)*.

I.3.3. Urinary tract infections

Urinary tract infection (UTI) is the most common bacterial infection during pregnancy *(Schnarr and Smaill, 2008)* and a common medical complication *(Dwyer and O'Reilly, 2002)*. It is characterized by the presence of bacteria in urine, and may be symptomatic or asymptomatic. Asymptomatic bacteriuria occurs in 2 to 10% of pregnancies *(Schnarr and Smaill, 2008; Dwyer and O'Reilly, 2002*). Due to the changes in urinary tract during pregnancy, asymptomatic bacteriuria can more easily progress into kidney infection, or pyelonephritis, than in non-pregnant state *(Brenner 2008, Schnarr and Smaill, 2008)*. Acute pyelonephritis prevalence in pregnant women has been reported to be as high as 0.5 to 2% *(Schnarr and Smaill, 2008)*.
In non-pregnant adults, preliminary evidence suggests that chronic dehydration or fluid restriction might increase the susceptibility to UTI and that an increased water intake might decrease the risk of recurrence *(Beetz, 2003; Eckford et al., 1995; Nygaard and Linder,1997; Pitt, 1989)*. One hypothesis states that increased fluid intake could have a flushing effect on bacteria in the urinary tract and therefore reduce the risk of adherence and colonization *(Beetz, 2003)*. However, no clinical studies have been conducted on this topic in pregnant women.

KEY MESSAGES

Pregnancy induces a significant weight gain of about 12 kg at term. Most of this weight gain is water, and total body water therefore increases by 6-8 L in healthy pregnant women.

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During pregnancy, maternal blood volume increases up to 40-50% above pre-pregnancy level, mainly due to plasma volume expansion.

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The amniotic fluid, surrounding the fetus, is mainly composed of water. Its volume varies from 500 to 1200 mL and it constitutes a protection reservoir of water for the fetus.

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The placenta contains approximately 500 mL of water, which is 85% of placental weight. It is the major organ for supplying water to the fetus.

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Water needs in pregnant women are significantly increased to allow for the increase of body water and meet the increased metabolic needs of the fetus.

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Plasma osmolality thresholds for initiating thirst and ADH secretion are reduced during pregnancy, enabling a mother-to-be to achieve a normal water balance based on these new levels.

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First evidence seems to indicate a potential benefit of hydration for amniotic fluid volume. As in non-pregnant women, hydration might be beneficial against constipation and urinary tract infections recurrence. However, more research is needed to clearly establish these relationships.

II. Hydration and the role of water during lactation

Breastfeeding is recognized as the best nutrition for infants and is recommended whenever possible. Many reports emphasize the short and long-term benefits of breastfeeding, for the mother as well as for the child *(Turck, 2005; Schack-Nielson and Michaelsen, 2006)*. During this period, hydration becomes particularly important, since breast milk production significantly increases a mother's water loss.

II.1. Water in breast milk

Lactation involves specific physiological responses of the mother and requires both an increased supply of nutrients and water *(IoM, 1991)*.
Milk production gradually increases across the lactating period; it averages 750 mL/d at 6 months postpartum in exclusively breastfeeding women *(Neville et al., 1988)* (**Figure 7**). But milk output can be considerably higher: lactating mothers with exclusively breastfed twins can produce up to 2-3 L/d of milk *(IoM, 1991)*. The produced quantity directly depends on the infant's demand.

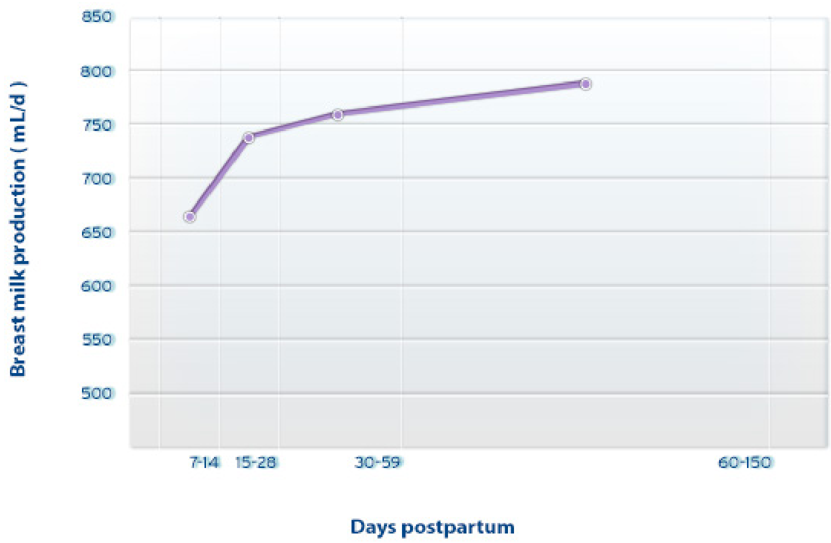

Figure 7. Potential consequences of maternal fluid intake on fetal well-being.
Adapted from Neville et al. 1988.

Breast milk contains, on average, 87% water *(EFSA, 2010)*, water content varies depending on the time of day. During a single breastfeeding episode, foremilk (the milk obtained at the beginning of breastfeeding) has higher water content and keeps the infant hydrated, whereas hindmilk (milk released near the end of breastfeeding) contains two to three times more fat than foremilk *(Riordan and Wambach, 2009)*.
Since breast milk is produced using maternal body water, a milk volume of 750 mL/d at 87% of water equals a significant extra water loss for the mother, compared to the daily normal losses. Maintaining water balance can therefore be challenging for lactating women.

II.2. Consequences of breastfeeding for body water

Maternal water intake during lactation should be sufficient to compensate the water lost through milk. Thus, in theory, the water intake of lactating women should be at least equivalent to non-breastfeeding women, plus the quantity of water transfered into the maternal milk, estimated to be 600 to 700 mL/d *(EFSA, 2010; IoM 2004)* (Figure 8).

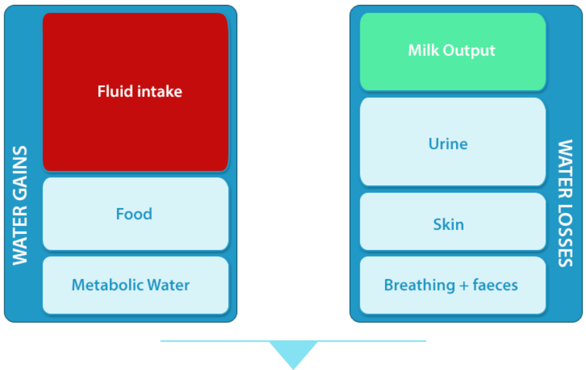

Figure 8. Water balance in breastfeeding women.

Data on actual fluid intake in breastfeeding women are scarce. Two studies, performed with a limited number of subjects, have shown that fluid intake of US lactating women is about 16% (300mL) higher than non-breastfeeding women *(Ershow et al., 1991)*; this is not enough to meet theoretical requirements *(Stumbo et al., 1985)*, but these results need to be confirmed with further research.
From a physiological point of view, a powerful thirst sensation, reported during breastfeeding episode, could help increasing fluid intake *(Bentley, 1998)*. However, the underlying mechanisms are unclear and the effect of this thirst sensation on women's fluid intake is unknown.

II.3. Consequences of breastfeeding for body water

The question has been raised whether fluid intake quantity can influence breast milk production. But scientific data have consistently shown that neither an increased nor a restricted fluid intake quantity affects the volume of milk produced *(Dusdieker et al., 1985; Dusdieker et al., 1990; Horowitz et al., 1980; Prentice, 1984)*.
This is consistent with data demonstrating that overall maternal nutrition status has little influence on milk quantity and quality *(IoM, 1991)*. Infants receive the nutrients and water they need, sometimes to the detriment of the mother, and milk quantity is driven by infant demand.
However, healthy diet and adequate hydration desirable to maintain maternal health *(IoM, 1991)* and are therefore often advised by health care professionals to breastfeeding mothers *(Lawrence and Lawrence, 1999)*.

KEY MESSAGES

Breast milk production progressively increases across the lactating period, reaching 750 mL/d at 6 months postpartum.

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Breast milk is mainly composed of water (on average, 87%).

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The mother needs to compensate the production of milk by drinking sufficient water.

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Water needs in pregnant women are significantly increased to allow for the increase of body water and meet the increased metabolic needs of the fetus.

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The quantity of milk produced meets infant needs, even if this means putting the mother at risk of dehydration.

III. Guidelines for fluid intake during pregnancy and lactation

In contrast to other nutrients, water needs in pregnant and lactating women have attracted little research attention. Theoretically, adequate water intake during pregnancy should match that of a non-pregnant woman, plus the fluid required to support fetal growth, amniotic fluid accretion, and higher blood volume *(Montgomery, 2002)*. During breastfeeding, it should compensate the physiological needs of the mother plus water contained in breast milk.

Several theoretical methods have been used to establish reference values.

- In the USA and Canada, adequate water intakes are based on the median total water intake observed in NHANES III data *(Third National Health and Nutrition Examination Survey)* for pregnant and lactating women, respectively 3000 mL/d and 3800 mL/d *(IoM, 2004).*
- In Australia and New-Zealand, adequate intakes are also based on median water intake. For lactating women, the adequate intake accounts for water lost through breast milk, so that water needs increase by 700 mL/d, compared to non-lactating women.
- In Europe, the European Food Safety Authority (EFSA) has set the total water need in pregnant women based on a theoretical calculation. During pregnancy energy intake is estimated to increase by 300 kcal/day. When adjusted to reach an available water amount of 1 mL/kcal ingested, EFSA recommends adding 300 mL/d of water, compared to non-pregnant women of the same age. In lactating women, total water needs should be equivalent to the sum of adequate intake of the non-lactating women plus the water content of the milk produced daily during the first 6 months of lactation, i.e. an addition of 700 mL/d *(EFSA, 2010)*.

Because of these methodological differences, guidelines for total water intake vary greatly among countries **(Table 1)**.

Country (References)	World (WHO, 2003)	USA & Canada (IoM, 2004)	Australia & New Zealand (NHMRC, 2006)	Europe (EFSA, 2010)
Adults women	2200 mL/d	2700 mL/d	2800 mL/d	2000 mL/d
Pregnant women	4800 mL/d	3000 mL/d	3100 mL/d	2300 mL/d
Lactating women	5500 mL/d	3800 mL/d	3500 mL/d	2700 mL/d

Table 1. Reference values for total water intake in pregnant and lactating women.

Despite large discrepancies in the recommended intake, some conclusions can be drawn by looking at the most recent recommendations. Pregnant women are advised to increase their fluid consumption by at least 300 mL, whereas it seems clear that the needs of lactating women increase by at least 700 mL per day above basic needs *(IoM, 2004; NHMRC, 2006; EFSA, 2010)*. The needs obviously increase far above these figures, in the case of physical activity or living in hot climates *(WHO, 2003)*.

KEY MESSAGES

Limited research has been dedicated to determinate the water needs of pregnant and lactating women.

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Water intake during pregnancy should equal the adequate intake of a non-pregnant woman, plus the fluid required to support fetal growth, amniotic fluid accretion, and higher blood volume.

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In lactating women, total water needs should be equivalent to the sum of the adequate intake of non-lactating women plus the amount of water lost in breast milk, during the first 6 months of lactation.

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Despite different guidelines for total water intake among countries, additional amounts of water recommended during pregnancy and lactation are globally consistent, about +300 mL per day in pregnant women and +700 mL per day in breastfeeding women.

Conclusion

The body of a pregnant or breastfeeding woman undergoes specific physiological adaptations, to address the needs of the growing fetus or infant. These adaptations involve important changes in water physiology.

During pregnancy, body water content increases, in particular due to larger plasma volume and amniotic fluid accretion within the mother's body. Physiological adaptations occur in order to maintain water balance and homeostasis. Fluid intake needs are also increased, and first evidence suggests that maintaining proper hydration might be important for fetal well-being, and, as for non-pregnant women, for preventing constipation and urinary tract infections recurrence.

Breastfeeding women have even higher water requirements, in order to compensate for the water lost through breast milk. This loss can put water balance at risk, as the quantity of milk produced meets infant needs, even in the event of low fluid intake or dehydration of the mother.

However, very little is known about the actual fluid intake of pregnant and breastfeeding women. Recommendations are based on estimations of additional needs.

Further research is needed to confirm changes of hydration status in pregnant women and the risk of dehydration in breastfeeding women.

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