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Dietary reference values for potassium

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Abstract

Following a request from the European Commission, the EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA) derives dietary reference values (DRVs) for potassium. The Panel decides to set DRVs on the basis of the relationships between potassium intake and blood pressure and stroke. The Panel considers that randomised controlled trials and an observational cohort study carried out in a European adult population provide evidence that a potassium intake of 3,500 mg (90 mmol)/day has beneficial effects on blood pressure in adults. Furthermore, there is consistent evidence from observational cohort studies that potassium intakes below 3,500 mg/day are associated with a higher risk of stroke. Available data cannot be used to determine the average requirement of potassium but can be used as a basis for deriving an adequate intake (AI). A potassium intake of 3,500 mg/day is considered adequate for the adult population and an AI of 3,500 mg/day for adult men and women is proposed. For infants and children, the AIs are extrapolated from the AI for adults by isometric scaling and including a growth factor. An AI of 750 mg (19 mmol)/day is set for infants aged 7–11 months. For children, AIs from 800 mg (20 mmol)/day (1–3 years old) to 3,500 mg/day (15–17 years old) are set. Considering that the daily accretion rate of potassium in fetal and maternal tissues can be met by the adaptive changes which maintain potassium homeostasis during pregnancy, the AI set for adults applies to pregnant women. For lactating women, the amount of potassium needed to compensate for the losses of potassium through breast milk is estimated and an AI of 4,000 mg (102 mmol)/day is proposed.

Keywords: potassium, adequate intake, dietary reference value

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Summary

Following a request from the European Commission, the EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA) was asked to deliver a Scientific Opinion on Dietary Reference Values (DRVs) for the European population, including potassium.

Potassium is an essential mineral in the human diet. It is the predominant osmotically active element inside cells. It plays a major role in the distribution of water inside and outside cells, assists in the regulation of the acid–base balance, and contributes to establishing a membrane potential which supports electrical activity in nerve fibres and muscle cells. Potassium has a role in cell metabolism, participating in energy transduction, hormone secretion, and the regulation of protein and glycogen synthesis.

Potassium is present in all natural foods, in particular starchy roots or tubers, vegetables, fruits, whole grains, dairy products and coffee. Based on the data from 13 dietary surveys in nine countries of the European Union, average potassium intakes ranged between 821 and 1,535 mg (21 and 39 mmol)/day in infants (< 1 year), between 1,516 and 2,005 mg (39 and 51 mmol)/day in children aged 1 to < 3 years, between 1,668 and 2,750 mg (43 and 70 mmol)/day in children aged 3 to < 10 years, between 2,093 and 3,712 mg (54 and 95 mmol)/day in children aged 10 to < 18 years, and between 2,463 and 3,991 mg (63 and 102 mmol)/day in adults (≥ 18 years).

Potassium deficiency, presenting as hypokalaemia, is defined as a serum potassium concentration lower than 3.5 mmol/L and is usually caused by increased potassium losses (e.g. via diarrhoea, vomiting or excessive renal losses) or intracellular shift of potassium (e.g. during alkalosis). Hypokalaemia resulting from insufficient dietary intake is rare and may be associated with severe hypocaloric diets, or with a relative insufficiency caused by an increased requirement of potassium for the synthesis of tissue during recovery from malnutrition.

About 90% of dietary potassium is absorbed, mainly in the small intestine. Body potassium content is regulated by the balance between dietary intake and renal excretion. Urine is the major route of potassium excretion, while the remaining part is eliminated in the faeces and, to a lesser extent, in the sweat. Urinary potassium excretion, based on 24-h urine collection, is regarded as a reliable biomarker of dietary intake in adults on a population basis.

Most of body potassium is located in the muscle, with lower amounts present in the bone, liver, skin and red blood cells. Because of tight homeostatic mechanisms, blood potassium concentrations and total body potassium content are only minimally affected by variations in dietary potassium intake. The Panel therefore considers that there is no suitable biomarker of potassium status which can be used for setting DRVs for potassium in the general population.

Potassium intake has been reported to be associated with several health outcomes, particularly cardiovascular endpoints. Overall, the Panel considers that randomised controlled trials and an observational cohort study carried out in a European adult population provide evidence that a potassium intake of 3,500 mg (90 mmol)/day has beneficial effects on blood pressure in adults. Furthermore, there is consistent evidence from observational cohort studies that potassium intakes below 3,500 mg (90 mmol)/day are associated with a higher risk of stroke. Evidence on the association between potassium intake and coronary heart disease is unclear and inconsistent. Evidence in relation to diabetes mellitus type 2, kidney stones and bone health were also reviewed but the available data could not be used to derive DRVs for potassium.

The Panel decides to set DRVs for potassium based on the relationship between potassium intake and blood pressure and stroke. Currently, available data cannot be used to determine the average requirement of potassium but can be used as a basis for deriving an adequate intake (AI). A potassium intake of 3,500 mg (90 mmol)/day can be considered adequate for the adult population and an AI of 3,500 mg (90 mmol)/day for adult men and women is proposed.

No data are available on which to base an average potassium requirement for infants and children. The Panel derives AIs extrapolated from the AI for adults, taking into account differences in reference body weight (isometric scaling) and including a growth factor to take into account requirements for growth. The AI set for infants aged 7–11 months is 750 mg (19 mmol)/day. For children, AIs range from 800 mg (20 mmol)/day (1–3 years old) to 3,500 mg (90 mmol)/day (15–17 years old).

The Panel considers that the requirement for the daily accretion rate of potassium in fetal and maternal tissues can be met by the adaptive changes which maintain potassium homeostasis during pregnancy. The AI for pregnant women is set at 3,500 mg (90 mmol)/day, the same as for non-pregnant women.

Considering evidence which indicates that total body potassium content decreases in lactating women, a conservative approach is taken and the amount of potassium needed to compensate for the losses of potassium through breast milk is added to the AI for adult. Thus, an AI of 4,000 mg (102 mmol)/day is proposed for lactating women.

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Background as provided by the European Commission

The scientific advice on nutrient intakes is important as the basis of Community action in the field of nutrition, for example such advice has in the past been used as the basis of nutrition labelling. The Scientific Committee for Food (SCF) report on nutrient and energy intakes for the European Community dates from 1993. There is a need to review and, if necessary, to update these earlier recommendations to ensure that the Community action in the area of nutrition is underpinned by the latest scientific advice.

In 1993, the SCF adopted an opinion on the nutrient and energy intakes for the European Community.[1] The report provided Reference Intakes for energy, certain macronutrients and micronutrients, but it did not include certain substances of physiological importance, for example dietary fibre.

Since then new scientific data have become available for some of the nutrients, and scientific advisory bodies in many European Union (EU) Member States and in the United States have reported on recommended dietary intakes. For a number of nutrients, these newly established (national) recommendations differ from the reference intakes in the SCF (1993) report. Although there is considerable consensus between these newly derived (national) recommendations, differing opinions remain on some of the recommendations. Therefore, there is a need to review the existing EU Reference Intakes in the light of new scientific evidence, and taking into account the more recently reported national recommendations. There is also a need to include dietary components that were not covered in the SCF opinion of 1993, such as dietary fibre, and to consider whether it might be appropriate to establish reference intakes for other (essential) substances with a physiological effect.

In this context, the European Food Safety Authority (EFSA) is requested to consider the existing population reference intakes (PRIs) for energy, micro- and macronutrients and certain other dietary components, to review and complete the SCF recommendations, in the light of new evidence, and in addition advise on a PRI for dietary fibre.

For communication of nutrition and healthy eating messages to the public, it is generally more appropriate to express recommendations for the intake of individual nutrients or substances in food-based terms. In this context, EFSA is asked to provide assistance on the translation of nutrient-based recommendations for a healthy diet into food based recommendations intended for the population as a whole.

Terms of reference as provided by the European Commission

In accordance with Article 29 (1)(a) and Article 31 of Regulation No 178/2002[2], the Commission requests EFSA to review the existing advice of the Scientific Committee for Food on PRIs for energy, nutrients and other substances with a nutritional or physiological effect in the context of a balanced diet which, when part of an overall healthy lifestyle, contribute to good health through optimal nutrition.

In the first instance, EFSA is asked to provide advice on energy, macronutrients and dietary fibre. Specifically advice is requested on the following dietary components:

- carbohydrates, including sugars;
- fats, including saturated fatty acids, polyunsaturated fatty acids and monounsaturated fatty acids, *trans* fatty acids;
- protein;
- dietary fibre.

Following on from the first part of the task, EFSA is asked to advise on PRIs of micronutrients in the diet and, if considered appropriate, other essential substances with a nutritional or physiological effect in the context of a balanced diet which, when part of an overall healthy lifestyle, contribute to good health through optimal nutrition.

Finally, EFSA is asked to provide guidance on the translation of nutrient-based dietary advice into guidance, intended for the European population as a whole, on the contribution of different foods or categories of foods to an overall diet that would help to maintain good health through optimal nutrition (food-based dietary guidelines).

[1] Scientific Committee for Food, 1993. Nutrient and energy intakes for the European Community. Reports of the Scientific Committee for Food, 31st series. Food – Science and Technique, European Commission, Luxembourg, 248 pp.

[2] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 31, 1.2.2002, p. 1–24.

Assessment

1. Introduction

In 1993, the Scientific Committee for Food (SCF) adopted an opinion on nutrient and energy intakes for the European Community. For potassium, the SCF proposed a population reference intake (PRI) of 3,100 mg (80 mmol)/day for adults, including pregnancy and lactation, and a Lower Threshold Intake of 1,600 mg (40 mmol)/day, which was accepted as the intake needed to avoid low plasma potassium concentrations (SCF, 1993).

2. Definition/category

2.1. Chemistry

Potassium (K) is an abundant and highly reactive alkali metal which makes up 2.4 mass% of the Earth's crust. It has an atomic mass of 39.1 Da. Potassium is present in only one oxidation state (+ 1). It is a powerful reducing agent that is easily oxidised. Because of its high reactivity, potassium is not found free in nature but only as salts. Potassium compounds have good water solubility.

Naturally occurring potassium is composed of three isotopes, namely the stable isotopes ^{39}K (natural abundance 93.3%) and ^{41}K (6.7%), and the radioactive isotope ^{40}K (0.01%), which has a very long half-life (1.251×10^9 years). The latter is responsible for most of the naturally occurring radioactivity in the body (Kee et al., 2010; Crook, 2012).

2.2. Function of potassium

2.2.1. Biochemical functions

Potassium is an essential mineral in the human diet. Potassium is the predominant osmotically active element inside cells. Together with sodium and chloride, which are characteristic of the extracellular fluid, potassium contributes to osmolarity and plays a major role in the distribution of fluids inside and outside cells. In addition, potassium participates in the regulation of the acid–base balance. Differences in potassium and sodium concentrations across cell membranes are maintained by the specific permeability of membranes to each of these ions and by Na^+/K^+-ATPase activity, which pumps sodium out of and potassium into the cells (Bailey et al., 2014; Gumz et al., 2015). The enzyme Na^+/K^+-ATPase plays an important role in the strict homeostatic control of plasma potassium concentrations. As a result, the intracellular potassium concentration is about 30 times higher than that of plasma and interstitial fluid. This concentration gradient (largely responsible for driving the membrane potential) is important for the transmission of electrical activity in nerve fibres and muscle cells. Small changes in the ratio of extracellular to intracellular potassium concentration have large effects on neural transmission, muscle contraction and vascular tone (Bailey et al., 2014; Gumz et al., 2015). Potassium transport across the membranes of the endothelial and vascular smooth muscle cells has important effects on their contractile state, which can, in turn, influence endothelial function, blood flow and blood pressure (Haddy et al., 2006). The concentration of potassium in cells of the collecting duct system of the kidney is important for the excretion of sodium. Maintenance of the transmembrane gradient is the key element for electrolytes and fluid homeostasis, a critical factor in blood pressure regulation (Bailey et al., 2014; Gumz et al., 2015).

Passive transport of potassium occurs via intracellular and paracellular pathways. The intracellular transport mechanism involves potassium channels. Channels have 'gates' which open or close in response to specific stimuli, such as voltage, ATP, ionic calcium concentration, hormones and neurotransmitters. Various stimuli sometimes act together on a channel. Potassium channels exhibit great diversity and may be divided into four main groups: voltage-gated (Kv) channels; calcium-activated (KCa) channels, covering big conductance (BK), intermediate conductance (IK), and small conductance (SK) channels; inwardly rectifying (Kir) channels, and two-pore domain (K2P) channels (Heitzmann and Warth, 2008; Horn et al., 2014). Different types of potassium channels have been implicated in functions such as salivary secretion, bile and gastric acid secretion, protein digestion and absorption, insulin secretion, carbohydrate digestion and absorption, and taste transduction.

Potassium has a role in cell metabolism, participating in energy transduction, hormone secretion and the regulation of protein and glycogen synthesis. Potassium is a cofactor for a number of enzymes

including glycerol dehydrogenase, mitochondrial pyruvate carboxylase, pyruvate kinase, L-threonine dehydratase, ATPases and aminoacyl transferase (Page and Di Cera, 2006; Toraya et al., 2010).

2.2.2. Health consequences of deficiency and excess

2.2.2.1. Deficiency

Potassium deficiency, presenting as hypokalaemia, is defined as a serum potassium concentration lower than 3.5 mmol/L (Pepin and Shields, 2012). In general, deficiency may be caused by increased potassium losses via diarrhoea, vomiting, burns or excessive renal losses (owing, for example, to renal tubular acidosis, high secretion of mineralocorticoids, some diuretics) leading to low total body potassium (Crop et al., 2007; Rodenburg et al., 2014). Hypokalaemia can also occur when total body potassium is normal in case of an intracellular shift of potassium (Rastegar, 1990). The most important causes of an intracellular shift include alkalosis, insulin excess, catecholamine excess and familial periodic paralysis (i.e. a genetic disease related to malfunction in the ion channels in skeletal muscle cell membranes) (Gumz et al., 2015). Hypokalaemia resulting from insufficient dietary intake is rare and may be associated with severe hypocaloric diets or occur as the result of an increased requirement needed for the synthesis of new tissue (e.g. muscle) during recovery from malnutrition.

Hypokalaemia is generally associated with increased morbidity and mortality, especially from cardiac arrhythmias or sudden cardiac death. When serum potassium concentration is < 3 mmol/L, the prevalence of malignant ventricular arrhythmia has been observed to increase twofold in patients on diuretic treatment (Byatt et al., 1990). The risk of atrial fibrillation is higher in hypokalaemic subjects compared to the general population (Krijthe et al., 2013). Other adverse consequences of hypokalaemia include polyuria, muscle weakness, decreased peristalsis possibly leading to intestinal ileus, mental depression and respiratory paralysis in severe cases (Rodenburg et al., 2014).

2.2.2.2. Excess

Hyperkalaemia is commonly defined as a serum potassium concentration greater than approximately 5.5 mmol/L in adults (Pepin and Shields, 2012; Michel et al., 2015). Hyperkalaemia is often asymptomatic and diagnosed because of conduction abnormalities on the electrocardiogram (Lehnhardt and Kemper, 2011). Clinical manifestations of mild to moderate hyperkalaemia are usually non-specific and may include generalised weakness, paralysis, nausea, vomiting and diarrhoea (Pepin and Shields, 2012). Severe hyperkalaemia may lead to life-threatening cardiac arrhythmias (Paice et al., 1983; Lehnhardt and Kemper, 2011).

Hyperkalaemia is rare in the general population. The majority of cases occur from impaired renal function (Lehnhardt and Kemper, 2011; Crook, 2012). Non-renal causes include inappropriately high intakes of oral potassium supplements or parenteral potassium administration and a potassium shift from cells (for instance in the case of metabolic acidosis, hypoxia, severe tissue damage). Hyperkalaemia following excessive dietary intake of potassium is rare because of the effective homeostasis mediated by increased cellular uptake of potassium from the bloodstream by various organs and increased urinary excretion (Lehnhardt and Kemper, 2011).

No tolerable upper intake level (UL) has been set for potassium by EFSA due to insufficient data (EFSA, 2005). The Panel considered that the risk of adverse effects from potassium intake from food sources (up to 5,000–6,000 mg (129–154 mmol)/day in adults) is low for the general healthy population. It also stated that long-term intakes of about 3,000 mg (77 mmol) potassium/day as potassium chloride supplements, in addition to intake from food, have been shown not to have adverse effects in healthy adults (Cappuccio et al., 2016). A few case studies have reported that supplemental potassium in doses of 5,000–7,000 mg (128–179 mmol)/day can cause adverse effects on heart function in apparently healthy adults. Gastrointestinal symptoms have been observed in healthy subjects taking some forms of potassium supplements (e.g. slow release, wax-matrix formulations) with potassium doses ranging from about 1,000 to 5,000 mg (26–128 mmol)/day, but incidence and severity seem to depend more on the formulation than on the dose (EFSA, 2005).

2.3. Physiology and metabolism

2.3.1. Intestinal absorption

About 90% of dietary potassium is absorbed, mainly in the small intestine, mostly through passive mechanisms in response to electrochemical gradients (Agarwal et al., 1994; Bailey et al., 2014).

In the proximal small intestine, water absorption provides a driving force for the movement (solute drag) of potassium across the intestinal mucosa. In the ileum, the transepithelial electrical potential difference strongly influences its movement. It has been hypothesised that potassium may also be actively absorbed in the small intestine due to the presence of an H^+/K^+-ATPase in the apical membrane (Heitzmann and Warth, 2008). In surface cells of the distal colon, potassium is excreted through apical potassium channels in exchange for sodium which is reabsorbed through epithelial sodium channels. Potassium may also be reabsorbed in the colon through the action of luminal H^+/K^+-ATPases (colonic type), which can be of importance during potassium deprivation (Meneton et al., 1998).

2.3.2. Transport in blood

In healthy individuals, serum potassium concentrations range between 3.5 and 5.5 mmol/L, whereas plasma concentrations are lower by about 0.3–0.4 mmol/L. This difference is due to a release of potassium during clot formation (Nijsten et al., 1991; Sevastos et al., 2008). Homeostatic mechanisms act to maintain blood potassium concentration within a narrow range, even in the presence of wide variations in dietary potassium intake (Giebisch, 1998, 2004; Palmer, 2014; Gumz et al., 2015) (Section 2.3.3).

In plasma, most potassium is present as free ions and 10–20% is bound to proteins (Ifudu et al., 1992).

2.3.3. Distribution to tissues

Around 98% of systemic potassium is within the cells, making potassium the major intracellular cation. Most of body potassium is located in the muscle (70%), with lower amounts present in the bone, liver, skin and red blood cells (Weiner et al., 2010). Most of the body potassium (about 85%) is rapidly exchangeable (half time of less than 7 h), while exchanges with red blood cells and brain pools are slower (Jasani and Edmonds, 1971).

Intra- and extracellular concentrations of potassium are maintained within narrow limits. After a meal, potassium is absorbed and rapidly enters the extracellular fluid. The subsequent rise in plasma potassium concentration is quickly attenuated by cellular uptake (Giebisch, 1998; Palmer, 2014). Na^+/K^+-ATPase is responsible for the active transport of potassium into the cells and for the maintenance of the extra- and intracellular sodium and potassium concentrations against electrochemical gradients. This ATPase is found in the cytoplasmic membrane of virtually all cells (McDonough and Nguyen, 2012). Potassium is also actively transported into some gastrointestinal cells and renal tubules by H^+/K^+-ATPase (Sections 2.3.1 and 2.3.5.1). Various Na^+-K^+-Cl^- cotransporters, which carry Na^+, K^+ and Cl^- into the cell and are driven by the force of ion gradients, have been identified in the salivary glands, gastrointestinal tract and renal tubules (Sections 2.3.1 and 2.3.5.1). The K^+-Cl^- cotransporter plays an important role for erythrocytes to maintain a specific shape and mediates potassium efflux (Lote, 2007).

Potassium transfer between the extra- and intracellular milieus is influenced by a variety of endogenous and exogenous factors (Gumz et al., 2015). Cellular potassium uptake by the muscle, liver, bone and red blood cells is promoted by the increase in plasma potassium concentration, by insulin, epinephrine and aldosterone, by metabolic alkalosis, and by drugs activating β-2 adrenergic receptors. Conversely, a decrease in plasma potassium concentration, metabolic acidosis, hyperosmolarity of the extracellular fluid, and α-antagonist drugs induce potassium transport from cells to the extracellular fluid. Hyperkalaemia stimulates the secretion of insulin, aldosterone and epinephrine, while hypokalaemia has the opposite effect (Giebisch, 2004; Grossman et al., 2013).

The mechanisms of fetoplacental potassium transfer have not been fully elucidated. Animal studies indicate that potassium is actively transported across the placenta and that the developing fetus is efficient in maintaining constant potassium concentration in plasma (Atkinson et al., 2006; Lorenz, 2012). Fetal potassium content was observed to be maintained in case of maternal potassium restriction (Lorenz, 2012). In a cross-sectional study on 344 healthy pregnant women, potassium concentrations in both fetal and maternal plasma did not differ with gestational age (15–38 weeks of gestation), at 3.5–3.6 mmol/L in the fetuses and 3.3–3.6 mmol/L in the mothers (Moniz et al., 1985).

2.3.4. Storage

The total body content of potassium is about 40–55 mmol/kg body weight (bw) (Rastegar, 1990; Agarwal et al., 1994; Crook, 2012; Bailey et al., 2014), which corresponds to 3–4 moles (110–150 g)

for a 70-kg adult. Similar potassium body contents (expressed per kg body weight) have been reported in infants and children (Fomon et al., 1982; Butte et al., 2000).

Based on 462 US children (232 boys and 230 girls) aged 3–18 years, no differences in total body potassium were observed for boys and girls between 12 and 30 kg of weight and 100 and 135 cm of height (about 10 years of age) (Flynn et al., 1972). Above these values, girls had less potassium per centimetre of height and per kilogram of weight than boys. In a sample of 116 US children (66 boys and 50 girls, aged 5–17 years), males had larger skeletal muscle (SM) and total body potassium (TBK) compared to females, while the SM:TBK ratio did not differ between both sexes (Wang et al., 2007). SM:TBK was positively correlated with age, weight and height ($r = 0.62$, $r = 0.63$, $r = 0.86$, respectively; all $p < 0.001$). The Panel notes that total body potassium accumulation during growth appears to reflect patterns of skeletal muscle gain.

2.3.5. Losses

Body potassium content is regulated by the balance between dietary intake and renal excretion. In addition to urinary excretion, small quantities of potassium are excreted in the faeces and through the skin.

2.3.5.1. Urine

The kidney is the main route of potassium excretion. Studies in humans reported average urinary excretion of potassium between 77% and 92% of total dietary intake (Mickelsen et al., 1977; Pietinen, 1982; Holbrook et al., 1984; Tasevska et al., 2006; Yoshida et al., 2012). Urinary excretion of potassium varies with dietary intake. According to results published by the Intersalt Cooperative Research Group in late 1980s (Intersalt Cooperative Research Group, 1988), a typical range observed with a mixed Western diet was 46–77 mmol/day.

Potassium is freely filtered by the glomerulus. In healthy adults, the rate of potassium filtration by the glomerular capillaries is 756 mmol/day, considering a glomerular filtration rate of 180 L/day multiplied by a plasma potassium concentration of 4.2 mmol/L (Guyton and Hall, 2006).

The renal tubules are capable of reabsorbing and secreting potassium in response to various stimuli (Rodenburg et al., 2014). The human kidney efficiently excretes potassium in response to high dietary intakes, but is less capable of sparing potassium when dietary intake is low (Kee et al., 2010).

The majority of filtered potassium is reabsorbed in the proximal tubule and loop of Henle, so that less than 10% of the filtered load reaches the distal nephron. In the proximal tubule, potassium absorption is primarily passive and proportional to sodium and water. Potassium reabsorption in the thick ascending limb of Henle occurs through both transcellular and paracellular pathways. The transcellular component is mediated by the Na^+-K^+-$2Cl^-$ cotransporter located on the apical membrane. Potassium secretion begins in the early distal convoluted tubule and progressively increases along the distal nephron into the cortical collecting duct, where active reabsorption of sodium is accompanied by excretion of potassium into the lumen (Palmer, 2014). Most urinary potassium can be accounted for by electrogenic potassium secretion mediated by principal cells in the initial collecting duct and the cortical collecting duct (Gumz et al., 2015). An electroneutral potassium and chloride cotransport mechanism is also present on the apical surface of the distal nephron epithelium. Potassium can be reabsorbed in the collecting duct, in situations of potassium depletion. This process is mediated by upregulation of the apically located H^+/K^+-ATPase on alpha-intercalated cells (Sansom and Welling, 2007; Palmer, 2014; Gumz et al., 2015).

The major factors regulating potassium excretion include dietary potassium, distal nephron flow rate and sodium delivery, mineralocorticoids (including aldosterone), and acid–base balance (Palmer, 2014; Gumz et al., 2015). Renal potassium excretion has also a circadian rhythm independent of food intake (Gumz et al., 2015). The circadian rhythm, which originates from the brain, is transmitted to circadian clocks in the tubule cells responsible for variations in potassium excretion. As a result, potassium excretion is enhanced during the daylight phase and reduced during the night time phase (Gumz et al., 2015).

During pregnancy, potassium excretion is held constant through adaptive mechanisms of renal tubular potassium reabsorption, which adjust to the increased filtered potassium load and the increased retention of sodium mediated by aldosterone (Ehrlich and Lindheimer, 1972; Brown et al., 1986; Cheung and Lafayette, 2013). Progesterone, through its antikaliuretic effect, has been proposed to contribute to maintain potassium homeostasis in pregnant women (Lindheimer et al., 1987; Elabida et al., 2011).

2.3.5.2. Faeces

Potassium concentration in faeces is highly variable (ranging from 20 to 200 mmol/L). Distal ileum and the colon can actively secrete potassium (Sorensen et al., 2010) (Section 2.3.1). Net absorption only takes place when large gradients of concentration between the colon and the blood are present (Devroede and Phillips, 1969).

Faecal potassium excretion is about 10–25 mmol/day, constituting 10–20% of total potassium elimination from the body (Holbrook et al., 1984; Agarwal et al., 1994; Tasevska et al., 2006). Faecal potassium excretion increases with fibre intake (Cummings et al., 1976; Tasevska et al., 2006). Potassium losses in faeces may considerably increase in pathological situations, especially in cases of diarrhoea (Sandle and Hunter, 2010; West and von Saint Andre-von Arnim, 2014) or renal insufficiency (Sandle et al., 1986).

In a study on four adult men in which dietary potassium intake was severely restricted (less than 39 mg (1 mmol)/day) for 2–7 days, faecal potassium loss decreased and was 2.5–7.6 mmol/day at the end of the depletion period (Squires and Huth, 1959). This is presumed to represent obligatory potassium losses related to digestive secretions (salivary, gastric, biliary and pancreatic), cell desquamation, and mucus secretion (Agarwal et al., 1994; Sorensen et al., 2010).

2.3.5.3. Dermal losses

The concentration of potassium in the sweat is relatively low; typical values range from 3 to 7 mmol/L (Costill, 1977; Montain et al., 2007; Penney, 2008; Baker et al., 2009; Kilding et al., 2009; Maughan et al., 2009). In various studies, the concentration of potassium in the sweat was not or only minimally affected by physical exercise (Montain et al., 2007), heat stress (Malhotra et al., 1976) or dietary sodium intake or ethnicity (Palacios et al., 2010), including conditions of dietary potassium restriction (Malhotra et al., 1981; Costill et al., 1982). Sweat potassium concentration stays relatively constant, regardless of sweat rate, level of acclimatisation or an individual's sodium concentration in the sweat (Weschler, 2008).

When sweat losses are several litres a day, as under heat or physical exercise stress conditions, potassium sweat losses may be up to 10–25 mmol/day (Consolazio et al., 1963; Malhotra et al., 1976, 1981).

The Panel considers that potassium losses through the sweat at moderate physical activity performed around thermoneutrality are likely to be in the range of 2–3.5 mmol/day, assuming a daily sweat volume of around 0.5 L/day (Shirreffs and Maughan, 2005; Subudhi et al., 2005).

2.3.5.4. Breast milk

There is a decline in breast milk potassium concentration over the first weeks of lactation, with a high concentration in colostrum followed by a decrease (Atkinson et al., 1995). In longitudinal studies, potassium concentration in breast milk, once mature, was nearly constant (Nagra, 1989; Allen et al., 1991; Wack et al., 1997). Potassium concentration in breast milk shows diurnal variations, reciprocal to sodium concentration (Keenan et al., 1982, 1983).

Atkinson et al. (1995) collected data on the potassium content in breast milk from nine studies conducted in the USA, Canada and the UK. Mean potassium concentrations across studies were between 682 and 725 mg/L (17.4 and 18.5 mmol/L) at day 3 (colostrum), 569 and 659 mg/L (14.5 and 16.8 mmol/L) at day 14 (transitional milk), 464 and 600 mg/L (11.9 and 15.3 mmol/L), 405 and 542 mg/L (10.3 and 13.9 mmol/L), and 366 and 495 mg/L (9.4 and 12.7 mmol/L) at day 30, 90 and 180 of lactation (mature milk), respectively.

Appendix A reports data on potassium concentration in breast milk from additional studies which involved mothers of term infants in Western populations. Mean/median potassium concentrations are between 461 and 594 mg/L (11.8 and 15.2 mmol/L) from six studies which analysed mature breast milk (Keenan et al., 1982; Parr et al., 1991; Holt, 1993; Wack et al., 1997; Fly et al., 1998; Witczak and Jarnuszewska, 2011) and 450 and 633 mg/L (11.5 and 16.2 mmol/L) in two studies which used mixed samples (collected between 1 and 8 weeks post-partum) (Bauer and Gerss, 2011; Bjorklund et al., 2012).

Based on available data, the Panel considers an approximate midpoint of potassium concentration in mature breast milk of women from Western countries of 500 mg (12.8 mmol)/L. Based on a mean milk transfer of 0.8 L/day (Butte et al., 2002; FAO/WHO/UNU, 2004; EFSA NDA Panel, 2009) during the first 6 months of lactation in exclusively breastfeeding women, the Panel estimates the maternal loss of potassium through breast milk to be 400 mg (10.2 mmol)/day.

2.3.6. Interaction with other nutrients

2.3.6.1. Sodium

The metabolism of potassium and sodium are strongly interrelated, principally due to the Na^+/K^+-ATPase. Sodium/potassium interactions are important at the cellular level (Adrogue and Madias, 2014). The renal regulation of sodium homeostasis is closely related to that of potassium (Section 2.3.5.1). However, sodium intake does not influence potassium excretion except at high sodium intakes (≥ 4,830 mg (210 mmol)/day) (Kirkendall et al., 1976; Luft et al., 1982). In the Dietary Approaches to Stop Hypertension (DASH) study, at sodium intakes of 1,500 mg (65 mmol), 2,400 mg (104 mmol) and 3,200 mg (140 mmol) per day for 4 weeks each, urinary potassium excretion did not exceed intake (1,600 ± 500 mg/day) and was similar at each sodium level (Sacks et al., 2001).

Salt sensitivity, defined as either the reduction in blood pressure in response to a lower sodium chloride intake or the rise in blood pressure in response to sodium loading (IOM, 2005), is a condition frequently observed in African Americans and is also associated with genetic or physiological factors (Weinberger, 1996; Strazzullo et al., 2000). Dietary potassium intake modulates the variation of blood pressure levels due to salt sensitivity in normotensive (Luft et al., 1979; Morris et al., 1999; Wilson et al., 1999), as well as in hypertensive individuals (Krishna et al., 1989; Coruzzi et al., 2001).

There is also evidence that the effect of potassium intake on blood pressure may be higher in individuals with high sodium chloride intake compared to those with low sodium chloride intake and that the sodium-to-potassium intake ratio may also influence this relationship (Section 5.6.1.1).

The Panel notes the interaction of potassium and sodium in relation to their metabolism and health effects, particularly under conditions of sodium load or in salt-sensitive individuals.

2.3.6.2. Interactions with other minerals and vitamins

Calcium

Potassium depletion enhances urinary loss of calcium. In a study of six male and two female adults who underwent 5 days of potassium deprivation, increases in both fasting and 24-h urinary calcium excretion were observed; levels returned to normal within 5 days after termination of potassium deprivation (Lemann et al., 1991).

In contrast, potassium supplementation may decrease urinary calcium excretion. Ten male and female adults aged 21–41 years on a controlled diet containing on average 3,323 ± 235 mg (85 ± 6 mmol) potassium/day, 866 ± 36 mg (21.6 ± 0.9 mmol) calcium/day and 3,795 ± 322 mg (165 ± 14 mmol) sodium/day, were supplemented with 90 mmol/day of potassium bicarbonate or potassium chloride (3,510 mg potassium) for 4 days. Potassium bicarbonate, but not potassium chloride, reduced fasting and 24-h urinary calcium excretion (Lemann et al., 1991). In a meta-analysis, Lambert et al. (2015) found that supplementation with alkaline potassium salts reduced calcium excretion compared to a placebo (14 trials, potassium supplemental daily doses 1,170–7,020 mg (30–180 mmol)). In studies which compared alkaline potassium salts with potassium chloride, a higher effect of the alkaline salt on calcium excretion was observed. The Panel notes that most studies used alkaline potassium salts and the independent effect of potassium as compared to alkali administration on calcium excretion is unclear.

Phosphorus and vitamin D

Administration of potassium salts may alter renal tubular phosphate transport and renal synthesis of $1,25(OH)_2$-vitamin D and may increase serum phosphorus concentration (Lemann et al., 1991). Sebastian et al. (1990) studied the effect of potassium supplementation (6,084 mg (156 mmol)/day as potassium bicarbonate and potassium chloride for 8 days each) in six healthy males (25–40 years) on a fixed diet (3,220 mg (140 mmol) sodium, 2,024 mg (52 mmol) potassium, 361 mg (9 mmol) calcium, 836 mg (27 mmol) phosphorus per 70-kg body weight). Both potassium forms caused an increase in serum phosphorus and a decrease in $1,25(OH)_2$-vitamin D compared to a control period in which no supplement was administrated.

The Panel considers that interactions between potassium and other minerals and vitamins, in the context of a mixed European diet, are not relevant for setting dietary reference values (DRVs) for potassium.

2.4. Biomarkers

2.4.1. Biomarkers of intake

In healthy people, a large proportion (about 90%) of dietary potassium intake is absorbed (Section 2.3.1). Urine is the major route of potassium excretion, while the remaining part is eliminated in the faeces and, to a lesser extent, in sweat (Section 2.3.5). Recovery rates of dietary potassium in the urine between 77% and 92% have been reported (Mickelsen et al., 1977; Pietinen, 1982; Holbrook et al., 1984; Tasevska et al., 2006; Yoshida et al., 2012). In the study by Holbrook et al. (1984), duplicate samples of meals and beverages and all urine from 12 men and 16 women were collected daily for four 1-week periods and the potassium content was analysed to estimate the dietary intake and urinary excretion of potassium. Mean (± SEM) urinary potassium excretion was 77 ± 1.7% of potassium intake. Tasevska et al. (2006) conducted a controlled feeding study in which seven men and six women were hosted in a metabolic suite for 30 days. All urine and dietary duplicates were collected for potassium analysis. On average (± SD), 77 ± 6.7% of analysed potassium intake was excreted in the urine. High correlations between 24-h urinary potassium excretion and potassium dietary intake were found in both studies (r = 0.82 and 0.89, respectively). Some studies have indicated a lower urinary excretion of potassium in black as compared to white individuals, although it is unclear whether it reflects differences in potassium intakes or other factors (Voors et al., 1983; Barlow et al., 1986; Langford et al., 1991; Wong et al., 2003; Aviv et al., 2004; Turban et al., 2013). Conversion factors of 1.25 (Freedman et al., 2004, 2015) or 1.3 (Murakami et al., 2007; WHO, 2012b,d, Aburto et al., 2013) have been proposed to estimate daily dietary potassium intake from 24-h urinary potassium excretion. The Panel notes that the percentage of dietary intake recovered in the urine, although quite consistent in different studies, shows a significant interindividual variability, probably in part due to inaccuracies in dietary assessment, errors in urine collections and/or other environmental or genetic factors.

Several equations have been proposed to estimate 24-h urinary potassium excretion from a single morning fasting urine sample (Kawasaki et al., 1993) or random spot urine sample (Tanaka et al., 2002). Using data from 1,083 individuals (35–70 years) who provided both single fasting morning and 24-h urinary samples, Mente et al. (2014) reported interclass correlation coefficients between formula-based and measured 24-h potassium excretion of 0.55 (95% CI = 0.31–0.69) for the Kawasaki formula and 0.36 (95% CI = 0.07–0.60) for the Tanaka formula. Both methods were found to underestimate actual potassium excretion. In contrast, in another validation study where 24-h and random spot urine samples were collected from 147 women (19–26 years), Hooft van Huysduynen et al. (2014) found that the Tanaka formula overestimated actual 24-h urinary potassium excretion. No validation study used chemical analysis of dietary duplicates. The Panel notes that approaches based on spot urine samples may be of some value in population studies but they require cautious interpretation due to the risk of both over- or underestimation of potassium excretion. The Panel notes that they provide imprecise estimates at individual level.

Measures of 24-h potassium excretion in urine have been used for validating dietary questionnaires. Based on data from five validation studies, Freedman et al. (2015) reported average correlation coefficients of 0.37 with food frequency questionnaires (FFQs) and of 0.47 with a single 24-h recall.

A few studies have examined urinary potassium excretion in children and reported values between 1.3 and 1.8 mmol/kg bw per day (Knuiman et al., 1988; Zwiauer et al., 1991; Kristbjornsdottir et al., 2012). However, in the absence of data for dietary potassium intakes (analysed or calculated) in these studies, the reliability of urinary potassium excretion as a biomarker of dietary intake in children cannot be assessed.

The Panel considers that urinary potassium excretion, based on 24-h collection, is a reliable biomarker of dietary intake in adults on a population basis. However, the Panel notes that a single 24-h urinary collection can not accurately assess an individual's usual intake. For converting 24-h urinary potassium excretion values into potassium daily intakes (Section 5.6.1), the Panel selected a factor of 1.30, based on the ratio of potassium dietary intake to urinary excretion reported in two studies which used chemical analysis of the diet and 24-h urinary collection (Holbrook et al., 1984; Tasevska et al., 2006). This factor has also been applied by other authors (Murakami et al., 2007; WHO, 2012b,d, Aburto et al., 2013).

2.4.2. Biomarkers of status

In healthy individuals, homeostatic mechanisms act to maintain blood potassium concentrations within a narrow range (Section 2.3). Changes in extracellular potassium concentration as the result of changes in external potassium equilibrium (i.e. balance between potassium intake and output) usually occur slowly and are buffered by homeostatic changes in internal potassium equilibrium (i.e. shifts between the extra- and intracellular fluids) (Lorenz, 2012). As a result, plasma potassium concentration is a late indicator of changes in potassium balance. In addition, low plasma potassium concentrations can coexist with both normal and low total body potassium content (Section 2.2.2.1). Thus, in most instances, serum potassium concentration does not accurately reflect total body potassium content.

Whole body counting of ^{40}K has been proposed for the determination of total body potassium content (Tyson et al., 1970) and has been used for the assessment of body composition (Forbes, 1987; Dittmar and Reber, 2004; Murphy et al., 2014). This method permits a reliable estimate of total body potassium (Forbes, 1987; Hansen and Allen, 1996). Like blood potassium concentration, total body potassium content is only minimally affected by variations in dietary potassium intake. Total body potassium depletion is usually caused by excessive potassium losses (through urine, diarrhoea or vomiting) associated with certain health conditions or medicines (Section 2.2.2.1).

The Panel considers that there is no biomarker of potassium status which can be used for setting DRVs for potassium in the general population.

2.5. Effects of genotypes

Genetic mechanisms may contribute to the blood pressure response to dietary potassium intake (Section 5.6.1.1). In particular, different chromosome regions (Kelly et al., 2010) or genetic variants (Zhao et al., 2010; He et al., 2011; Liu et al., 2013) were found to be associated with the individual variability of the blood pressure response to oral potassium intake ('potassium sensitivity').

The Panel considers that, although genetic factors may affect the individual blood pressure response to dietary potassium intake, no genotypes have yet been identified that would require consideration with regard to the derivation of DRVs for potassium in the general population.

3. Dietary sources and intake data

3.1. Dietary sources

Potassium is present in all natural foods, in particular starchy roots or tubers, vegetables, fruits, whole grains, dairy products and coffee. Substantial potassium losses may occur during food processing. Drinking water and many food additives also contain potassium; however, it is unlikely that they represent major sources.

Potassium as potassium-L-ascorbate, magnesium potassium citrate, potassium iodide, potassium iodate, potassium bicarbonate, potassium carbonate, potassium chloride, potassium citrate, potassium gluconate, potassium glycerophosphate, potassium lactate, potassium hydroxide, potassium salts of orthophosphoric acid and potassium fluoride may be added to both foods[3] and food supplements,[4] whereas potassium sulfate, potassium L-pidolate, potassium malate and potassium molybdate may only be used in the manufacture of food supplements.[4] The potassium content of infant and follow-on formulae[5] and processed cereal-based foods and baby foods for infants and young children[6] is regulated.

[3] Regulation No 1925/2006 of the European Parliament and of the Council of 20 December 2006 on the addition of vitamins and minerals and of certain other substances to foods, OJ L 404, 30.12.2006, p. 26.
[4] Directive 2002/46/EC of the European Parliament and of the Council of 10 June 2002 on the approximation of the laws of the Member States relating to food supplements, OJ L 183, 12.7.2002, p. 51.
[5] Commission Directive 2006/141/EC of 22 December 2006 on infant formulae and follow-on formulae and amending Directive 1999/21/EC, OJ L 401, 30.12.2006, p. 1.
[6] Commission Directive 2006/125/EC of 5 December 2006 on processed cereal-based foods and baby foods for infants and young children, OJ L 339, 6.12.2006, p. 16.

3.2. Dietary intake

EFSA estimated dietary intakes of potassium from food consumption data available through the EFSA Comprehensive Food Consumption Database (EFSA, 2011b), classified according to the food classification and description system FoodEx2 (EFSA, 2011a). Data from 13 dietary surveys in nine countries of the European Union (EU) were used. The countries included were Finland, France, Germany, Ireland, Italy, Latvia, the Netherlands, Sweden and the UK. The data covered all age groups from infants to adults (Appendix B).

Nutrient composition data for potassium were derived from the EFSA Nutrient Composition Database (Roe et al., 2013). Food composition information from Finland, France, Germany, Italy, the Netherlands, Sweden and the UK were used to calculate potassium intakes in these countries, assuming that the best intake estimate would be obtained when both the consumption data and the composition data are from the same country. For nutrient intake estimates of Ireland and Latvia, food composition data from the UK and Germany, respectively, were used, because no specific composition data from these countries were available. The amount of borrowed potassium values (i.e. values taken from other tables or databases) varied between 15% (Germany) and 84% (Sweden) in the seven composition databases used; in all the countries except Germany, the percentage of borrowed values was higher than 55% of the total. Estimates were based on the consumption of food, including salt substitutes where available, but not dietary supplements.

Data on infants were available from Finland, Germany, the UK and Italy. The proportions of breast-fed infants were 58% in the Finnish survey, 40% in the German survey, 44% in the Italian survey and 21% in the UK survey. For the Italian and German surveys, breast milk intake estimates were derived from the number of breastfeeding events recorded per day multiplied by standard breast milk amounts consumed on an eating occasion at different ages. For the UK survey, the amount of breast milk consumed was either directly quantified by the mother (expressed breast milk) or extrapolated from the duration of each breastfeeding event. In the Finnish survey, information was limited to whether infants were breastfed or not, and the contribution of breast milk to potassium intakes could not be taken into consideration. The Panel notes the limitations in the methods used for assessing breast milk consumption in infants and related uncertainties in the intake estimates for infants (Appendices C and D).

Average potassium intakes across countries ranged between 821 and 1,535 mg/day (279–546 mg/MJ) in infants (< 1 year, four surveys), between 1,516 and 2,005 mg/day (356–495 mg/MJ) in children aged 1 to < 3 years (five surveys), between 1,668 and 2,750 mg/day (284–473 mg/MJ) in children aged 3 to < 10 years (seven surveys), between 2,093 and 3,712 mg/day (280–464 mg/MJ) in children aged 10 to < 18 years (seven surveys), and between 2,463 and 3,991 mg/day (338–497 mg/MJ) in adults (≥ 18 years, eight surveys). Average daily intakes were in most cases slightly higher in males (Appendix C) compared to females (Appendix D), mainly due to larger quantities of food consumed per day.

The main food groups contributing to potassium intakes were starchy roots or tubers and products thereof, sugar plants, grains and grain-based products, milk and dairy products, and vegetables and vegetable products (Appendices E and F). In the youngest population, food products for young population (infants), and milk and dairy products (toddlers and other children) were the most important contributors. In infants, in some surveys, the average contribution of food products for young population represented more than 50% of the total intake of potassium. The impact of milk and dairy products on the intake of potassium in this age class was also quite important, with average contributions up to 22% of the total.

The EFSA intake estimates were compared with the published intake estimates from the same national surveys and age ranges (Appendix G). The differences between the EFSA estimates and those published were always below 10%, except for male adolescents in the German EsKiMo study where the EFSA estimates were 12% higher than the published ones. Published data on potassium intake were also available from the UK diet and nutrition survey of infants and young children (DNSIYC) 2011 survey but comparisons with the EFSA estimates were difficult as they were reported by ethnic groups and socioeconomic classes. Overall, the EFSA average estimates for infants (1,370–1,535 mg/day) and toddlers (1,688–1,794 mg/day) were slightly higher than those reported in that survey (1,024–1,161 mg/day for infants, 1,433–1,633 mg/day in toddlers). Several sources of uncertainties

may contribute to the differences between the EFSA estimates and those published, including inaccuracies in mapping food consumption data according to FoodEx2 classification, analytical errors or errors in estimating potassium, which may cause both too high and too low estimates of potassium intake. As the intake calculations rely heavily on estimates of both food composition and food consumption, it is not possible to conclude which of these intake estimates would be closer to the actual potassium intake of the respective population groups.

4. Overview of dietary reference values and recommendations

4.1. Adults

The Nordic countries (Nordic Council of Ministers, 2004, 2014) based their recommendations on the favourable effect of potassium on blood pressure (Intersalt Cooperative Research Group, 1988; Jula et al., 1990; Appel et al., 1997; Geleijnse et al., 1997, 2003; Whelton et al., 1997; Sacks et al., 1998, 2001; Gu et al., 2001; Naismith and Braschi, 2003; Dickinson et al., 2006; van Bommel and Cleophas, 2012). The recommended intakes for potassium were set at 3,500 mg (90 mmol)/day for men and 3,100 mg (80 mmol)/day for women. It was noted that potassium intakes 'somewhat over and above these values might have further beneficial effects'. A lower limit of 1,600 mg (40 mmol)/day was proposed.

The WHO conducted a systematic review to explore the relationship between potassium and blood pressure in adults (WHO, 2012b), which served as the basis for setting a strong recommendation[7] for an increase in potassium intake from food for reduction of blood pressure and risk of cardiovascular disease, stroke, and coronary heart disease in adults, and for suggesting a conditional recommendation[8] for an intake of 3,510 mg (90 mmol)/day for adults (WHO, 2012a).

The German-speaking countries (D-A-CH, 2015) considered that observed intakes of adults between 2,000 and 3,000 mg (50–75 mmol)/day from common diets in Central Europe are sufficient under normal conditions. An amount of 2,000 mg (50 mmol)/day was designated an estimated value for a minimal intake.

The US Institute of Medicine (IOM, 2005) set an adequate intake (AI) of 4,700 mg (120 mmol)/day based on data on the amount of potassium found to eliminate severe salt sensitivity in African American men (Morris et al., 1999) and considering the decreased risk of kidney stones observed in a 3-year intervention trial (Barcelo et al., 1993) and three epidemiological studies (Curhan et al., 1993, 1997; Hirvonen et al., 1999). Data from studies in non-hypertensive individuals were considered supportive of this level of intake as a means to lower blood pressure. Epidemiological studies also suggested that higher levels of potassium intake from foods were associated with decreased bone loss, mainly when potassium is associated with bicarbonate precursors (New et al., 1997, 2000, 2004; Tucker et al., 1999; Jones et al., 2001; Macdonald et al., 2004). For older adults, although less energy is consumed, there is an increased risk of elevated blood pressure; therefore, the value was not adjusted.

Afssa (2001) considered that the usual potassium intakes of 2,000–6,000 mg (50–150 mmol)/day by the general population (Burgess et al., 1999) exceeds the estimated minimum requirement of 390–585 mg (10–15 mmol)/day. No DRV was derived.

The SCF (1993) suggested a lowest threshold intake of 1,600 mg (40 mmol)/day, to avoid low plasma concentrations and loss of total body potassium (Sebastian et al., 1971). An average requirement (AR) was not set. Using evidence from studies investigating the relationship between potassium intake and blood pressure (Matlou et al., 1986; Rose, 1986; Intersalt Cooperative Research Group, 1988; Krishna et al., 1989), the PRI was set at 3,100 mg (80 mmol)/day.

The UK DH (1991) estimated the requirements based on a factorial approach considering daily potassium losses. The Reference Nutrient Intake (RNI) for adults was set at 3,500 mg (90 mmol)/day. It set a Lower Reference Nutrient Intake (LRNI) of 2,000 mg (50 mmol)/day. No AR was derived.

An overview of DRVs for potassium for adults is given in Table 1.

[7] A strong recommendation is one for which the guideline development group is confident that the desirable effects outweigh the undesirable effects.

[8] A conditional recommendation is one for which the guideline development group concludes that the desirable effects of adherence probably outweigh the undesirable effects, but the group is not confident about the trade-off.

Table 1: Overview of dietary reference values for potassium for adults

	D-A-CH (2015)[b]	NCM (2014)[a]	WHO (2012a)[c]	IOM (2005)[d]	Afssa (2001)[d]	SCF (1993)[a]	DH (1991)[a]
Age (years)	≥ 19	≥ 18	≥ 16	≥ 19	≥ 20	≥ 18	≥ 19
DRV men (mg/day)	2,000	3,500	≥ 3,510	4,700	–	3,100	3,500
DRV women (mg/day)	2,000	3,100	≥ 3,510	4,700	–	3,100	3,500

Afssa: Agence française de sécurité sanitaire des aliments; D-A-CH: Deutschland-Austria-Confoederatio Helvetica; DH: Department of Health; DRV: dietary reference value; IOM: US Institute of Medicine of the National Academy of Sciences; NCM: Nordic Council of Ministers; SCF: Scientific Committee for Food; WHO: World Health Organization.
(a): Population reference intake.
(b): Adequate minimal intake.
(c): Suggested intake.
(d): Adequate intake.

4.2. Infants and children

For children and adolescents, the Nordic countries (Nordic Council of Ministers, 2014) extrapolated recommendations from adult values based on differences in body weight and needs for growth. PRIs of 1,800 mg (46 mmol)/day and 2,000 mg (51 mmol)/day were set for children aged 2–5 and 6–9 years, respectively. For boys and girls aged 10–13 years, the PRI are 3,300 mg (84 mmol)/day and 2,900 mg (74 mmol)/day, respectively.

The WHO (2012a) suggested an increase in potassium intake from food to control[9] blood pressure in children based on an observational study (Geleijnse et al., 1990) and a systematic review in adults (WHO, 2012b). Based on the energy requirements of children relative to those of adults, a conditional recommendation for potassium intake of at least 3,510 mg (90 mmol/day) was set.

The German-speaking countries (D-A-CH, 2015) estimated potassium needs to maintain electrolyte homeostasis and for growth of cellular mass. It was considered that infants during the first 4 months of life, because of their rapid growth, need 35 mg (0.9 mmol)/day for the development of cellular mass. Boys and girls up to 12 years need 16–20 mg (0.4–0.5 mmol)/day. For the period of accelerated growth in puberty, 35 mg (0.9 mmol)/day is required (Fomon, 1993). The requirement for the maintenance of homeostasis was estimated on the basis of total energy intake which, in turn, should be proportional to cell mass and, thus, the body's total potassium content.

For infants, the IOM (2005) proposed an AI that reflects the calculated mean potassium intake of infants principally fed breast milk, or a combination of breast milk and complementary foods. For age 0–6 months, a mean potassium intake of 390 mg (10 mmol)/day was estimated based on an average breast milk intake of 0.78 L/day (Keenan et al., 1982; Butte et al., 1984; Chandra, 1984; Neville et al., 1988) and an average breast milk potassium concentration of 500 mg/L (Gross et al., 1980; Picciano et al., 1981; Keenan et al., 1982; Lemons et al., 1982; Dewey and Lönnerdal, 1983). For age 6–12 months, the average potassium intakes were estimated at 300 mg (8 mmol)/day from breast milk considering an average intake of milk of 0.6 L/day (Heinig et al., 1993) and 440 mg (11 mmol)/day from complementary foods. After rounding, the AI was set at 700 mg (18 mmol)/day for this age group. Due to a lack of evidence in children, the AI for age 1–18 years was extrapolated from the AI for adults based on energy intake (IOM, 2000). This was a conservative choice because of concern that adjustment based on weight might lead to a relatively low and potentially inadequate value; it was considered that greater intake of potassium could also mitigate the effects of high sodium intake associated to the high energy intake relative to weight observed in children.

As for adults, Afssa (2001) considered that the usual potassium intakes of children cover the minimum requirement and did not set a DRV.

The SCF (1993) and the UK DH (1991) concluded that there is a lack of evidence on basal potassium losses in children. The two committees considered urinary excretion of 27–90 mg/kg bw per day (0.7–2.3 mmol/kg bw per day) and an amount needed for growth and lean tissue synthesis of 2,000 mg/kg bw. With these and other factors to allow for faecal losses and for integumental losses, PRIs for children were estimated factorially.

An overview of DRVs for potassium for infants and children is given in Table 2.

[9] 'Control' for this recommendation refers to the prevention of a deleterious rise in blood pressure with age.

Table 2: Overview of dietary reference values for potassium for infants and children

	D-A-CH (2015)[a]	Nordic Council of Ministers (2014)[b]	IOM (2005)[c]	SCF (1993)[b]	DH (1991)[b]
Age (months)	4–< 12	6–11	7–12	6–11	4–6
DRV (mg/day)	650	1,100	700	800	850
Age (months)	–	12–23	–	–	7–12
DRV (mg/day)	–	1,400	–	–	700
Age (years)	1–< 4	2–5	1–3	1–3	1–3
DRV (mg/day)	1,000	1,800	3,000	800	800
Age (years)	4–< 7	6–9	4–8	4–6	4–6
DRV (mg/day)	1,400	2,000	3,800	1,100	1,100
Age (years)	7–< 10	10–13	9–13	7–10	7–10
DRV boys (mg/day)	1,600	3,300	4,500	2,000	2,000
DRV girls (mg/day)	1,600	2,900	4,500	2,000	2,000
Age (years)	10–< 13	14–17	14–18	11–14	15–18
DRV boys (mg/day)	1,700	3,500	4,700	3,100	3,500
DRV girls (mg/day)	1,700	3,100	4,700	3,100	3,500
Age (years)	13–< 15	–	–	15–17	–
DRV (mg/day)	1,900	–	–	3,100	–
Age (years)	15–< 19	–	–	–	–
DRV (mg/day)	2,000	–	–	–	–

D-A-CH: Deutschland-Austria-Confoederatio Helvetica; DH: Department of Health; DRV: dietary reference value; IOM: US Institute of Medicine of the National Academy of Sciences; NCM: Nordic Council of Ministers; SCF: Scientific Committee for Food.
(a): Adequate minimum intake.
(b): Population reference intake.
(c): Adequate intake.

4.3. Pregnancy and lactation

The Nordic and the German-speaking countries as well as the SCF considered that pregnancy and lactation do not impose an additional potassium requirement (SCF, 1993; Nordic Council of Ministers, 2014; D-A-CH, 2015).

The IOM (2005) concluded that potassium accretion during pregnancy is very small and that data are not sufficient to suggest a different requirement for potassium during pregnancy. Therefore, the AI was the same as for non-pregnant women. An AI of 5,100 mg (130 mmol)/day was set for lactation, considering an additional need of around 400 mg (10 mmol)/day of potassium. This was based on an average potassium concentration of breast milk of 500 mg/L (Gross et al., 1980; Picciano et al., 1981; Keenan et al., 1982; Lemons et al., 1982; Dewey and Lönnerdal, 1983) and an average milk production of approximately 0.78 L/day (Keenan et al., 1982; Butte et al., 1984; Chandra, 1984; Neville et al., 1988), during the first 6 months of lactation. In the absence of information to the contrary, it was assumed that the efficiency of conversion of dietary potassium to milk produced is 100%.

The UK DH (1991) assumed that the RNI value would apply for all women in their reproductive years.

Afssa (2001) and WHO (2012a) gave no specific recommendations for pregnant and lactating women.

An overview of DRVs for potassium for pregnant and lactating women is given in Table 3.

Table 3: Overview of dietary reference values for potassium for pregnant and lactating women

	IOM (2005)
Age (years)	14–50
AI pregnancy (mg/day)	4,700
AI lactation (mg/day)	5,100

AI, Adequate intake; IOM, US Institute of Medicine of the National Academy of Sciences.

5. Criteria (endpoints) on which to base dietary reference values

5.1. Biomarkers as indicators of potassium requirement

Plasma potassium concentration and measures of total body potassium cannot be used for setting DRVs for potassium (Section 2.4.2).

The Panel considers that there are no biomarkers of potassium status that can be used for deriving DRVs for potassium in the general population.

5.2. Balance studies

Balance studies are based on the assumption that a healthy subject on an adequate diet maintains an equilibrium or a null balance between nutrient intakes and nutrient losses; at this null balance, the intake matches the requirement determined by the given physiological state of the individual. When intakes exceed losses (positive balance), there is nutrient accretion that may be attributable to growth or to weight gain, anabolism or repletion of stores; when losses exceed intakes (negative balance), nutrient stores are progressively depleted resulting, in the long term, in clinical symptoms of deficiency. In addition to numerous methodological concerns about accuracy and precision in the determination of intakes and losses (Baer et al., 1999), the validity of balance studies for addressing requirements has been questioned: they might possibly reflect only adaptive changes before a new steady state is reached (Young, 1986), or they might reflect only the conditions for maintenance of nutrient stores and exchangeable body pools in the context of a given diet, and the relevance for health of the size of the pools still needs to be established for each nutrient (Mertz, 1987).

In the study by Holbrook et al. (1984) in the USA, 28 free-living adults, 12 men and 16 women (20–53 years), consumed self-selected diets and maintained a daily dietary record for 1 year. During four 7-day periods, one in each season of the year, duplicate samples of meals and beverages and all urine and faeces for the same period were collected and analysed for potassium content by atomic absorption spectrometry (AAS). Mean (± SEM) analysed intake of potassium was 3,300 ± 100 mg (84 ± 2 mmol)/day for men and 2,400 ± 600 mg (61 ± 15 mmol)/day for women (mean analysed intakes for the study group ranged from 2,600 to 2,900 mg (66–74 mmol)/day among the four balance periods). Mean (± SEM) intake calculated from the dietary records was 2,900 ± 100 mg (74 ± 2 mmol)/day for men and 2,100 ± 100 mg (54 ± 2 mmol)/day for women. The correlation between urinary excretion and dietary intake of potassium was significant (r = 0.92). Mean (± SEM) apparent absorption of potassium was 84.5 ± 0.6% and did not change significantly over the range of intakes. Mean (± SEM) balance calculated from the analysed potassium intake was positive, + 280 ± 50 mg/day. For the four study periods, mean balances were + 250 mg/day in spring, + 400 mg/day in summer, + 210 mg/day in autumn and + 280 mg/day in winter, respectively (significant difference between summer and autumn). The Panel notes that other losses of potassium, including dermal losses (skin and sweat), were not measured, and these might explain the more positive balance observed in the summer compared with the autumn.

Sriboonlue et al. (1999) undertook a 10-day balance study in 15 Thai men aged 25–50 years (mean (± SD) body weight 63 ± 9 kg) in two areas (no adaptation period). Subjects were given a fixed diet. Foods were weighed both before and after meals for each subject. Aliquots of foods consumed were taken for potassium analysis. Potassium in urine and faeces were measured daily in all subjects, however, potassium lost in the sweat was analysed only in one subject. The rural group (n = 10) had a mean (± SD) potassium intake of 1,731 ± 138 mg (44 ± 4 mmol)/day and the urban group (n = 5) had a mean intake of 1,839 ± 145 mg (47 ± 4 mmol)/day (not significantly different). Urinary and faecal excretions of potassium were 721 ± 129 and 148 ± 25 mg/day in the rural group and 919 ± 186 and 164 ± 21 mg/day in the urban group, resulting in potassium balances of + 860 ± 140 in the rural group and + 756 ± 222 mg/day in the urban group, respectively. Regression of potassium balance vs intake indicated that rural and urban subjects needed potassium intakes of 832 and 884 mg (21 and 23 mmol)/day to stay in balance. For the one participant in whom sweat potassium was measured, mean balance over the 10 days was + 847 ± 373 mg/day and + 396 ± 344 mg/day without and with subtraction of sweat potassium excretion. The authors reported high ambient temperatures during the study period (mean (± SD): 30.9 ± 1.7°C at 12.00 a.m. and 35.2 ± 2.0°C at 3.00 p.m.) and substantial sweat losses (mean (± SD): 1,927 ± 420 mL/day for the rural subjects and 1,759 ± 408 mL/day for the urban subjects, roughly estimated by subtracting the 24-h urine volume from the daily water intake). The Panel notes the lack of an adaptation period,

the small number of subjects, the fact that the study was conducted in a Thai population, under particular environmental conditions, and the largely positive balance estimates. These may partly be explained by the lack of consideration of potentially substantial potassium losses in the sweat (Section 2.3.5.3). Consequently, the Panel considers that these data cannot be used to estimate the potassium requirement of European people.

Eleven potassium balance studies were conducted in Japan between 1984 and 2000, which involved 109 volunteers (23 males, 86 females; 18–28 years) (Kodama et al., 2005). The duration of the study periods ranged from 5 to 12 days, with 2–4 days adaptation period. The diet of subjects was controlled and duplicate diet samples were taken. Faeces and urine were collected throughout the experiment. In six studies (n = 49), the arm sweat was collected during exercise on a bicycle ergometer. Total sweat loss of potassium during exercise throughout the balance period was divided by days of the balance period and expressed as sweat loss in mg/kg bw per day. The potassium content of the diet, faeces, urine and sweat were measured by AAS. The mean dietary intakes of potassium ranged between 1,830 and 3,610 mg (47 and 92 mmol)/day across studies. From the regression equation describing the relationship between potassium intake and balance of all individuals, the mean (95% CI) intake of potassium when potassium balance was null was 39 (37–42) mg/kg bw per day. The Panel notes the short adaptation periods of the studies and the fact that they were conducted in Japanese populations, and hence considers that this result cannot be used to estimate the potassium requirement of European people.

Nishimuta et al. (2012) applied a similar approach to data from 13 balance studies conducted on young Japanese women (n = 131, 18–26 years). As the median of the potassium balance distribution was found to be positive, the authors adjusted the individual data to set the median value to zero, under the assumption that the positive balance was due to the fact that some pathways of potassium losses had not been assessed, as regulatory mechanisms would successfully maintain the balance at zero. The Panel notes that this adjustment hampers the interpretation of this study.

Potassium balance studies have been found to underestimate potassium losses as compared with repeated assays of body potassium content by the ^{40}K counting method (Isaksson and Sjogren, 1963; Forbes et al., 1981; Forbes, 1983). Several sources of error in the estimation of potassium balances were proposed, including skin losses, other routes for losses (e.g. shaving, nail clipping), systematic errors (systematic overestimation of intake and underestimation of output),and lack of appropriate adaptation time.

The Panel notes that the relatively few available potassium balance studies are heterogeneous with regard to the populations examined, the presence and duration of equilibration periods and the duration of balance periods. The Panel notes the many limitations of these studies and considers that the data derived from the available balance studies cannot be used for setting DRVs for potassium for adults.

5.3. Indicators of requirement in children

No balance studies on potassium on children have been identified.

During growth, total body potassium accumulation appears to reflect patterns of skeletal muscle gain (Section 2.3.4). Butte et al. (2000) reported mean (± SD) total potassium body content of 6.0 ± 0.9 g and 21.5 ± 2.7 g in girls and of 6.4 ± 0.7 g and 22.9 ± 2.1 g in boys, at age 6 months and 2 years, respectively (n = 76 children, mainly Caucasian). This corresponds to an increase in potassium body content of about 16 g over 18 months. Based on a sample of 292 Caucasian children aged 5–18 years, Ellis et al. (2000) found mean total body potassium content from 36.9 ± 4.8 g to 100.0 ± 41.8 g in girls aged 5–7 years and 17–19 years, respectively. In boys, the mean content was 41.9 ± 6.4 g and 152.4 ± 20.7 g at age 5–7 years and 17–19 years, respectively. This represents a total accretion of potassium of 64 g in girls and 111 g in boys over a period of 12 years. From these data, the net daily accretion of potassium in new tissues is estimated to range between ca. 10 and 50 mg/day depending on children's age and sex. The Panel notes that net daily accretion of potassium in new tissues only partly reflects children's potassium requirement.

The Panel considers that there are no data relating to potassium requirement which can be used for deriving DRVs for potassium for children.

5.4. Indicators of potassium requirement in pregnancy

Plasma potassium concentration has been observed to decrease during pregnancy by 0.2–0.4 mmol/L (Brown et al., 1986; Lindheimer et al., 1987). Despite increased filtered potassium load in the kidney

and mineralocorticoid activity, healthy pregnant women do not typically develop hypokalaemia. Renal reabsorption of potassium accompanies the physiological changes which occur during pregnancy and urinary potassium excretion is held constant (Section 2.3.5.1).

Several studies have measured total body potassium in pregnant women using whole body counting. From a cohort of 40 women in the UK followed as of 12–22 weeks of pregnancy, Godfrey and Wadsworth (1970) estimated an accumulation of 307 mmol (12 g) potassium during pregnancy after correcting for possible analytical underestimation due to the changes in mass and body shape. In a longitudinal study of 22 pregnant Swedish women, total body potassium content was of 2,397 ± 327 mmol (93.5 ± 12.7 g), 2,224 ± 298 mmol (86.7 ± 11.6 g), 2,290 ± 330 mmol (89.3 ± 13.0 g) and 2,507 ± 307 mmol (97.8 ± 12.0 g) before pregnancy and at 16–18, 30 and 36 weeks of pregnancy, respectively (Forsum et al., 1988). A total accretion of 283 mmol (around 11 g) potassium between weeks 16–18 and week 36 can be estimated from this study. In 34 US women with a normal body mass index (BMI), Butte et al. (2003) reported total body potassium of 2,610 ± 328 mmol (101.8 ± 12.8 g), 2,543 ± 343 mmol (99.2 ± 13.4 g), 2,602 ± 338 mmol (101.5 ± 13.2 g) and 2,777 ± 382 mmol (108.3 ± 14.9 g) before pregnancy and at 9, 22 and 36 weeks of gestation, respectively. This would represent a total potassium accretion of 234 mmol (around 9 g) potassium between week 9 and week 36 of pregnancy. Both studies indicate that most potassium accretion occurs during the last trimester of pregnancy. During this period, a daily accretion in the order of 3 mmol (120 mg) potassium can be estimated from these data.

A total content of potassium in mature fetuses and full-term neonates between about 100 mmol (4 g) (Ellis et al., 1993) and 150 mmol (6 g) has been reported (Widdowson and Spray, 1951; Widdowson, 1980). Ziegler et al. (1976) and Widdowson (1980) estimated potassium accretion in the fetus based on data from chemical analyses of human fetuses (n = 22 and 38, respectively) and daily increments of weight gain. Daily potassium accretion rate was found to increase progressively over the course of pregnancy. Ziegler et al. (1976) found accretion rates from 0.5 mmol/day at 24–25 weeks to 1.5 mmol/day at 36–37 weeks. Widdowson (1980) reported values from 0.1 mmol/day at weeks 12–16 to 1.4 mmol/day at weeks 36–40 of pregnancy. Placental potassium content around 240 mmol/kg dry weight has been reported (Challier et al., 1988). Considering a mean placenta dry weight of 92 g at term (Hohler et al., 1972), this would correspond to a net transfer of potassium to placental tissues of 22 mmol (858 mg) over the whole pregnancy.

The Panel considers that the requirement for the daily accretion rate of potassium in fetal and maternal tissues can be met by the adaptive changes which maintain potassium homeostasis during pregnancy.

5.5. Indicators of potassium requirement in lactation

Data on body potassium content changes during lactation are very limited. In a sample of 40 lactating and 36 non-lactating women in the USA, significantly greater losses in total body potassium content, measured by whole body counting, were found in lactating women than non-lactating women between 0.5 and 3 months post-partum (Butte and Hopkinson, 1998). The Panel notes that this indicates that total body potassium content decreases in lactating women; however, no quantitative data on the extent of potassium body losses in lactating vs non-lactating women are available from the paper.

Based on available data, the Panel estimates a loss of potassium of 400 mg (10 mmol)/day through breast milk during lactation (Section 2.3.5.4).

5.6. Potassium intake and health consequences

The level of potassium intake has been reported to be associated with several health outcomes. Most studies focused on its relation with cardiovascular endpoints and, in particular, blood pressure and stroke. Several other outcomes, such as bone health and kidney stones and metabolic disease, have also been investigated.

5.6.1. Cardiovascular disease-related outcomes

A large number of observational and intervention studies have addressed the relationship between the dietary intake of potassium and risk of cardiovascular disease in adults, focusing on blood pressure and hypertension, as well as the risk of stroke, ischaemic heart disease and arrhythmia. This section summarises evidence mainly from meta-analyses of randomised controlled trials (RCTs) and prospective observational studies on the relationship between potassium intake and cardiovascular

disease-related outcomes, particularly blood pressure, stroke and coronary heart disease. Where studies measured 24-h urinary potassium excretion as a marker of potassium intake, the Panel applied a factor of 1.3 to estimate the corresponding daily potassium intake (Section 2.4.1).

5.6.1.1. Blood pressure

There is a direct relationship between blood pressure and risk of cardiovascular disease in the general population. The Panel notes that blood pressure is a continuum and studies conducted in people classified as hypertensive may inform the relationship between potassium intake and blood pressure in the general population. The Panel also notes that raised blood pressure affects a large proportion of the adult European population. According to WHO estimates, prevalence of raised blood pressure (defined as systolic and/or diastolic blood pressure equal to or above 140/90 mmHg) in adults aged ≥ 25 years is 44.5% in males and 37.1% in females in the European region (WHO, 2010). The Panel examined the data relating potassium intake to blood pressure when expressed as a continuous variable from intervention studies conducted in normotensive and/or hypertensive people. The Panel also reviewed the evidence, from observational studies, for an association between potassium intake and the risk of developing hypertension. The Panel notes that different criteria may have been used for defining 'hypertension' across studies; the Panel uses the term as defined by the authors when describing the individual studies.

Data in adults

a) Evidence from randomised controlled trials

Several meta-analyses of RCTs have been conducted on the effect of potassium intake on blood pressure. These include a Cochrane review (Dickinson et al., 2006), a meta-analysis commissioned by the WHO (Aburto et al., 2013) as a basis for its guideline on potassium intake (WHO, 2012a), an update of the latter by the Food Standards Australia New Zealand (FSANZ, 2014), and a more recent meta-analysis by Binia et al. (2015). These meta-analyses differ with respect to their inclusion criteria. The review by Dickinson et al. (2006) was limited to RCTs carried out in hypertensive subjects, with at least 8 weeks of potassium intervention and with no other intervention than manipulation of the potassium intake. Aburto et al. (2013), FSANZ (2014) and Binia et al. (2015) included RCTs in both normotensive and hypertensive subjects, with a minimum period of potassium intervention of 4 weeks, and which reported 24-h urinary potassium at the end of the intervention as a marker of potassium intake. Aburto et al. (2013) and FSANZ (2014) included studies in hypertensive subjects with or without blood pressure-lowering medication, while Binia et al. (2015) restricted the included studies to those performed on hypertensive subjects without medication. For the three latter meta-analyses, studies manipulating other dietary factors in addition to potassium intake (such as changes in sodium intake) were eligible.

In the meta-analysis by Dickinson et al. (2006) in hypertensive subjects, five RCTs (n = 425) met the inclusion criteria. Four studies used potassium supplements (between 1,872 mg (48 mmol) and 4,680 mg (120 mmol) per day; background intake levels were not reported), while in one study participants were advised to increase their dietary intake of potassium (> 100 mmol/day). Potassium supplementation compared to control resulted in an overall reduction in systolic blood pressure (SBP) of −11.2 mmHg (95% CI = −25.2–2.7; I^2 = 98%) and in diastolic blood pressure (DBP) of −5.0 mmHg (95% CI = −12.5–2.4; I^2 = 99%). Sensitivity analysis restricted to the two high quality trials found overall reductions in SBP of −7.1 mmHg (95% CI = −19.9–5.7; I^2 = 87%) and in DBP of −5.5 mmHg (95% CI= −14.5–3.5; I^2 = 87%). The Panel notes that all studies included involved hypertensive subjects without blood pressure-lowering treatment. Despite the high heterogeneity, the Panel notes that the point estimates obtained in both the overall analysis and with the high-quality studies suggest a blood pressure-lowering effect of potassium supplementation. The Panel also notes that no additional studies which meet the inclusion criteria of this meta-analysis have been published to date.

The meta-analysis by Aburto et al. (2013) included 21 RCTs (n = 1,892), of which 16 studies were conducted in treated and untreated hypertensive subjects, three studies in normotensive subjects and two studies in mixed populations. In the overall analysis, increased potassium intake, through supplementation or dietary advice, reduced SBP by −3.49 mmHg (95% CI = −5.15 to −1.82; I^2 = 65%) and DBP by −1.96 mmHg (95% CI = −3.06 to −0.86; I^2 = 55%) compared with the controls. When restricting the assessment to the three studies in normotensive adults, no effect of potassium supplementation on blood pressure was found. When only the studies in treated and untreated hypertensive subjects were considered, an increased potassium intake reduced SBP (−5.32 mmHg;

95% CI = −7.20 to −3.43; I^2 = 21%)) and DBP (−3.10 mmHg; 95% CI = −4.53 to −1.66; I^2 = 24%)). Effects of potassium intake on blood pressure levels were also found in subgroup analyses according to the use of blood pressure-lowering treatment (hypertensive subjects without treatment: SBP change: −3.63 mmHg; 95% CI = −5.69 to −1.57; I^2 = 72%; and DBP change: −1.37 mmHg; 95% CI = −2.50 to −0.23; I^2 = 51%); pharmacologically-treated hypertensive subjects: SBP change: −5.85 mmHg; 95% CI = −10.61 to −1.08; I^2 = 34%) and DBP change: −3.80 mmHg; 95% CI = −8.25–0.66; I^2 = 66%)).

Aburto et al. (2013) conducted subgroup analyses where studies were classified according to the 'achieved' potassium intake in the intervention groups (estimated by multiplying urinary potassium following potassium supplementation by a factor of 1.30), the duration of the intervention, or the population average sodium intake at baseline.

The 'achieved' potassium intake in the intervention group was below 3,500 mg (90 mmol)/day in two studies, between 3,500 and 4,700 mg (90 and 120 mmol)/day in five studies, between 4,700 and 6,000 mg (120 and 155 mmol)/day in 11 studies, and ≥ 6,000 mg (155 mmol)/day in four studies. The largest reduction in SBP and DBP was found in the subgroup characterised by an 'achieved' potassium intake of 3,500–4,700 mg (90–120 mmol)/day. The SBP and DBP changes were −7.16 mmHg (95% CI = −12.41 to −1.91; I^2 = 71%) and −4.01 mmHg (95% CI = −8.44–0.42; I^2 = 75%), respectively. A reduction in blood pressure was already apparent in the subgroup of studies with a potassium intake below 3,500 mg (90 mmol)/day. The Panel notes that all studies were included in this subgroup analysis (i.e. studies in normotensive, hypertensive and mixed populations). No separate subgroup analyses were carried out which included only studies in normotensive or hypertensive people.

No effect of duration of intervention (< 2 months, 2–4 months and > 4 months) was found.

A larger blood pressure-lowering effect of potassium was observed in the subgroup of studies with the highest baseline sodium intakes (> 4 g/day) compared to the subgroups of studies with lower sodium intakes (< 2 g/day and 2–4 g/day).

The FSANZ (2014) revised the meta-analysis of Aburto et al. (2013) and included one newly published study (Matthesen et al., 2012). The latter had found no effect of supplementation with 3,900 mg (100 mmol) potassium/day for 28 days on either 24-h ambulatory blood pressure or central blood pressure in 21 Danish normotensive subjects, whose background potassium intake was around 3,800 mg (99 mmol)/day based on urinary potassium excretion. The revision and the update had a limited impact on the overall effect estimates and the FSANZ concluded that the results of the analysis from Aburto et al. (2013) remained valid.

The meta-analysis by Binia et al. (2015) included 14 RCTs. Most of the studies had a potassium intervention of 2,340–2,535 mg/day (60–65 mmol/day), three had a potassium intervention of 1,560 mg/day (40 mmol/day) or less and one study had a potassium intervention of at least 4,680 mg (120 mmol/day). The 24-h urinary potassium excretion increased to between 55 mmol (2,145 mg) and 200 mmol (7,800 mg) in the intervention groups. Results of overall analysis yielded an effect of potassium intervention on SBP of −4.7 mmHg (95% CI = −7.0 to −2.4; I^2 = 79%) and on DBP of −3.5 mmHg (95% CI = −5.7–1.3; I^2 = 93%). When limiting the analysis to untreated hypertensive subjects (10 trials), larger reductions in SBP and DBP were observed. Total daily urinary potassium excretion between 2,300 and 3,900 mg (60 and 100 mmol)/day, corresponding to potassium intakes from 2,900 to 4,900 mg (75–125 mmol), was associated with the highest blood pressure reduction; no dose–response effect was identified. The Panel notes that subgroup analyses according to normotensive vs hypertensive status were not carried out. The Panel notes that results from two of the trials (Chalmers et al. (1986) and He et al. (2010)) were partially considered in the analysis and that two eligible trials (Grobbee et al., 1987; Matthesen et al., 2012) were not included.

One additional RCT has become available since these meta-analyses were published. This involved 37 untreated (pre)hypertensive men and women (baseline SBP: 130–159 mmHg) given a potassium supplement of 2,800 mg/day together with a controlled background diet (sodium: 2,400 mg/day; potassium: 2,300 mg/day) for 4 weeks (Gijsbers et al., 2015). 24-h ambulatory blood pressure was reduced in the intervention group compared to the control group (mean difference SBP −3.9 mmHg (95% CI = −6.9 to −0.9); DBP −1.6 mmHg (95% CI = −3.2 to −0.1)). Office SBP (−3.0 mmHg, 95% CI = −6.7–0.6) but not DBP (−0.3 mmHg, 95% CI = −2.1–1.6) was reduced in the intervention group compared with the controls.

The Panel considers that there is evidence from RCTs for a beneficial effect of potassium intake on blood pressure in subjects classified as hypertensive (with or without medication), but not in subjects classified as normotensive. The Panel further notes that in the analysis from Aburto et al. (2013),

which combined studies in hypertensive and normotensive subjects, the largest reduction in SBP and DBP was found in the subgroup characterised by an 'achieved' potassium intake of 3,500–4,700 mg (90–120 mmol)/day, compared with lower and higher amounts.

b) Evidence from observational cohort studies

Two longitudinal observational studies assessed the association between urinary potassium excretion and incidence of hypertension.

A study conducted in Taiwan included 1,520 middle-aged and older subjects who were free from hypertension at baseline (Chien et al., 2008). Participants were asked to collect their overnight urine and sleep time was recorded in order to estimate 24-h urinary excretion of potassium. Incident hypertension cases were diagnosed according to office blood pressure measurements and medication history. During a median of 7.93 years of follow-up (interquartile range (IQR) 4.07–9.04 years), 669 cases of incident hypertension were documented. No association was found between potassium excretion and risk of hypertension in a multivariate model. The Panel, however, notes the methodological limitation of using an overnight urine collection to estimate daily potassium excretion.

Risk of hypertension was studied in 5,511 normotensive subjects of Caucasian origin from the Netherlands, aged 28–75 years (Kieneker et al., 2014). This population was part of the Prevention of Renal and Vascular End-Stage Disease (PREVEND) study, which recruited a cohort of 8,592 individuals in 1997–1998, oversampling subjects with albuminuria (Kieneker et al., 2016). Potassium excretion was measured in two 24-h urine specimens at baseline (1997–1998) and midway during follow-up (2001–2003). Baseline median potassium excretion was 70 mmol/24 h (IQR 57–85 mmol/24 h), which corresponds to a dietary potassium intake of approximately 3,500 mg (91 mmol)/day. The within-subject correlations for potassium excretion between the paired 24-h urine collections at the first and second examinations were $r = 0.59$ ($p < 0.0001$; $n = 5,489$) and $r = 0.64$ ($p < 0.0001$; $n = 4,410$), respectively. The within-subject correlation between the averaged potassium excretions of the first and the second examinations (separated by a median of 4.3 years; IQR 4.0–4.8 years) was $r = 0.49$ ($p < 0.0001$; $n = 4,429$). Incident hypertension cases were diagnosed according to office blood pressure measurements and medication history. During a median follow-up of 7.6 years (IQR 5.0–9.3 years), 1,172 subjects developed hypertension. The lowest sex-specific tertile of potassium excretion (men: < 68 mmol/24 h; women: < 58 mmol/24 h) had an increased risk of hypertension after multivariable adjustment (hazard ratio (HR) = 1.20; 95% CI = 1.05–1.37), compared with the upper two tertiles combined ($p_{non\text{-}linearity} = 0.008$). A multivariable-adjusted spline curve indicated a non-linear inverse association of urinary potassium excretion with risk of hypertension. A higher risk of hypertension was found with potassium excretion levels lower than 70 mmol/24 h, corresponding to a potassium intake of 3,500 mg (90 mmol)/day.

Three prospective cohort studies in adults have investigated the association between potassium intake, estimated through dietary assessment and subsequent blood pressure levels and/or hypertension incidence.

Ford and Cooper (1991) analysed data from the US National Health and Nutrition Examination Survey (NHANES) Epidemiologic Follow-up study (1971–1984). Dietary intake of potassium at baseline was estimated through a 24-h recall dietary questionnaire (mean = 2,145 mg/day). The average SBP and DBP data from two readings taken at the follow-up examination (mean follow-up 10 years) were used to determine hypertensive status in a total of 5,411 white and black men and women free from hypertension at baseline, and with complete dietary data available for analysis. Dietary potassium intake at baseline was not associated with the incidence of hypertension (1,438 cases) in multivariate analysis, when adjusting for age and energy intake. The Panel notes the methodological limitation of a single 24-h dietary recall in assessing usual potassium intake of individuals.

A large prospective study involved 30,681 predominantly white US male health professionals, 40–75 years old, without diagnosed hypertension at baseline (Ascherio et al., 1992). Potassium intake at baseline was measured by a semiquantitative FFQ (validated with 2 weeks of dietary records; correlation for potassium = 0.65). The lowest category of potassium intake was < 2,400 mg (61 mmol)/day and the highest category of potassium intake was ≥ 3,600 mg (92 mmol)/day. In this cohort, 1,248 men self-reported a diagnosis of hypertension during the 4 years of follow-up. No associations were observed between potassium intake and blood pressure levels at baseline and at the end of follow-up, or blood pressure changes during the follow-up, when calcium, magnesium and dietary fibre were considered in the model, except for DBP level at baseline. No association was found in multivariate analysis between potassium intake and risk of hypertension, after adjustment for potential dietary confounders (calcium, magnesium and dietary fibre) in addition to age, BMI and alcohol intake.

Another large prospective study involved 41,541 predominantly white US female nurses, aged 38–63 years, without hypertension at baseline (Ascherio et al., 1996) updating a previous report in the same cohort (Witteman et al., 1989). Potassium intake at baseline was measured through a semi-quantitative FFQ (validated from 2 weeks of dietary records; correlation for potassium = 0.61). The lowest of five categories of potassium intake was < 2,000 mg (51 mmol)/day and the highest potassium intake category was ≥ 3,200 mg (82 mmol)/day. A total of 2,526 women reported to have had a diagnosis of hypertension during the 4 years of follow-up. Using a multivariate analysis, no association was found between potassium intake and the risk of hypertension, across the various categories of daily potassium intake (< 2,000, 2,000–2,390, 2,400–2,790, 2,800–3,190, ≥ 3,200 mg), adjusting for calcium, magnesium and dietary fibre intake in addition to age, BMI and alcohol consumption. Among women who did not report being diagnosed with hypertension, no associations were observed between potassium intake and subsequent (after 2- or 4-year follow-up) self-reported blood pressure levels, when calcium, magnesium and dietary fibre were considered in a multivariate regression model.

The Panel is aware of the inherent limitations in observational studies in relation to exposure misclassification (particularly for studies based on dietary questionnaires) or unmeasured confounding. Overall, the Panel notes that the study by Kieneker et al. (2014), which used a multiple assessment of 24-h urinary potassium excretion and which was carried out in a European population, provides evidence for an inverse association between potassium intake and risk of hypertension. In this study, an increased risk of hypertension was observed in the lowest tertile of potassium excretion (men: < 68 mmol/24 h; women: < 58 mmol/24 h). A spline regression analysis indicated a higher risk of hypertension with urinary potassium excretion lower than 70 mmol/24 h, corresponding to a potassium intake of 3,500 mg (90 mmol)/day.

Data in children

The relationship between potassium intake and blood pressure levels has also been studied in children.

The WHO (2012c) carried out a meta-analysis of three intervention studies conducted in children. It included a RCT in African-American boys and girls aged 13–15 years without hypertension (Wilson et al., 1996), a RCT in individuals averaging 13 years of age and whose blood pressure was > 109 mmHg for boys and > 108 mmHg for girls (Sinaiko et al., 1993) and one non-randomised trial in normotensive boys and girls aged 11–14 years (Miller et al., 1987). The interventions consisted of 3 weeks with a high potassium (80 mmol/day; n = 20) vs usual diet (n = 20) (Wilson et al., 1996), 3 years with potassium supplementation (1 mmol/kg body weight per day; n = 71) vs placebo (n = 69) (Sinaiko et al., 1993) and 4 weeks with potassium supplementation (36.2 ± 12.8 mmol/day for girls and 45.0 ± 17.4 mmol/day for boys; n = 38) (Miller et al., 1987), respectively. Children were characterised by background dietary potassium intakes in the order of 2,000 mg (51 mmol)/day (Wilson et al., 1996), 2,800 mg (72 mmol)/day (Sinaiko et al., 1993) and 1,900 mg (49 mmol)/day (Miller et al., 1987), as estimated through urinary potassium excretion. When pooling the estimates, there was no effect of potassium supplementation on blood pressure levels (−0.28 mmHg (95% CI = −1.05–0.49) for resting SBP and −0.92 mmHg (−2.00–0.20) for resting DBP).

In another case crossover RCT in 24 normotensive blacks and whites (aged 14.1 ± 1.6 and 15.4 ± 2.1 years, respectively), who received 40 mmol/day potassium supplement or a placebo for 7 days and then the alternate treatment, no effect of the potassium supplementation was found on blood pressure levels (Pratt et al., 1997).

Three observational cohort studies on potassium intake and subsequent blood pressure levels have been carried out in children.

The first study by Geleijnse et al. (1990) assessed urinary potassium excretion in 233 Dutch children (mean (± SD) age: 13.2 (± 2.7) years; range 5–17 years), who were followed for an average of 7 years. Average potassium excretion during the follow-up was determined on the basis of six or more annual overnight urine samples. During the study period, age showed no independent association with estimated potassium intake. Office blood pressure (average of two readings) was assessed yearly. The subjects in the upper urinary potassium tertile (≥ 47.8 mmol/day), compared with those in the lowest tertile (≤ 37.7 mmol/day), had a lower increase in SBP during an average follow-up of 7 years (1.4 vs 2.4 mmHg, p = 0.007), while no association was found for DBP.

Brion et al. (2008) investigated the association between potassium intake in infancy (1-day diary at 4 months and 3-day diary at 8 months of age, including breastfeeding) and office blood pressure (average of two readings) at 7 years in children of the Avon Longitudinal Study of Parents and

Children. In age- and sex-adjusted models, higher potassium intake at 4 months of age (n = 533) was associated with higher SBP at follow-up (mean difference per 1 SD potassium = 0.89 mmHg; 95% CI = 0.09–1.69, p = 0.03). No association was found with potassium intake at 8 months (n = 710; mean difference = 0.12 mmHg/SD; 95% CI = −0.59–0.83; p = 0.7).

Buendia et al. (2015) assessed the association between potassium intake and blood pressure in a US cohort study including 2,185 black and white girls initially aged 9–10 years and who were followed up for 10 years. Potassium intake was estimated through 3-day diet records in eight of the 10 study years and blood pressure as the average of two readings taken every year. Potassium intake was inversely associated with the magnitude of blood pressure change throughout adolescence ($p < 0.001$ for SBP and DBP) and at the end of follow-up ($p = 0.02$ for SDP and $p = 0.05$ for DBP). In the multivariate analysis adjusting for the largest number of potential confounders and using the potassium residuals method, there was an inverse association of potassium intake with SBP in black and with DBP in white subjects, with lower blood pressure values in the highest daily potassium intake category (≥ 2,400 mg (61 mmol)/day).

The Panel notes that two prospective observational studies suggest that a 'higher' potassium intake is associated with a reduction in the age-related increase in blood pressure. A limited number of intervention studies with total potassium intake between 1,700 and 5,100 mg (43 and 130 mmol)/day, and lasting 1 week to 3 years were carried out in children with baseline potassium intakes between 1,900 and 2,800 mg (49–72 mmol)/day. These studies did not show an effect of potassium supplementation on blood pressure levels. The Panel notes the small sample size of these studies and considers that available evidence is limited and cannot be used for the setting of DRVs for potassium for children.

Factors affecting the relationship between potassium intake and blood pressure

(a) Sodium intake

In their meta-analysis, Aburto et al. (2013) conducted subgroup analyses according to levels of sodium intake, as assessed through baseline urinary sodium excretion (Section 5.6.1.1). The largest blood pressure-lowering effect of potassium was associated with the highest category of sodium intake (greater than 4 g/day) compared to the lower categories (< 2 g/day and 2–4 g/day). The summary estimates for SBP changes in the respective categories were −6.91 mmHg (95% CI = −11.53 to −2.29), −1.97 mmHg (95% CI = −3.41 to −0.52) and −2.00 mmHg (95% CI = −11.70–7.70), while summary estimates for DBP changes were −2.87 mmHg (95% CI = −6.96–1.22), −1.96 mmHg (95% CI = −3.16 to −0.76) and 0.00 mmHg (95% CI = −6.12–6.12). When the meta-analysis was restricted to studies on individuals with hypertension, the systolic blood pressure was further reduced in those studies where the baseline sodium intake was 2–4 g/day (−4.07 mmHg; 95% CI = −5.76 to −2.37).

The Panel notes that these data indicate that the blood pressure-lowering effect of potassium is observed in subjects consuming 2–4 g/day of sodium and is greater in subjects consuming more than 4 g/day of sodium, compared with lower levels of sodium intake.

(b) Sodium-to-potassium intake ratio

Attention has also been paid to the possibility that the sodium-to-potassium intake ratio, rather than potassium and sodium intakes independently, may be related to hypertension or generally blood pressure outcomes (Perez and Chang, 2014), or that such ratio may independently influence blood pressure besides potassium (or sodium) intake itself (Binia et al., 2015).

In a systematic review by Perez and Chang (2014), evidence from RCTs carried out in hypertensive subjects suggests that the sodium-to-potassium ratio is more strongly associated with blood pressure outcomes than either sodium or potassium alone. This was supported by seven out of 10 pertinent studies. There was methodological heterogeneity across the seven studies, in particular with respect to the sodium and potassium intakes. All studies except one included in this meta-analysis estimated the sodium-to-potassium intake ratio based 24-h urinary excretion collections. The methodological quality of studies which provided support for a greater hypotensive effect of low sodium combined with high potassium intakes compared to low sodium or high potassium alone (seven studies including four large RCTs that followed subjects for at least 4 weeks) was generally stronger than that characterising the studies that found no effect (three studies, with small study sizes or which used dietary intervention as ancillary treatment). RCTs in normotensive subjects are scarce. A number of observational studies (one prospective cohort and 23 cross-sectional studies) were also included in the review. The prospective

cohort and the majority of the cross-sectional studies reported that the sodium-to-potassium ratio was more strongly associated with hypertension and/or systolic and diastolic blood pressure levels than either sodium or potassium alone. In two prospective cohort studies not included in this systematic review, no association was found between the sodium-to-potassium excretion ratio and the risk of incident hypertension after multivariate adjustment (Chien et al., 2008; Kieneker et al., 2014).

In their meta-regression analyses of 11 RCTs which assessed the effect of potassium intake on blood pressure levels in normotensive (one study) and hypertensive subjects (10 studies), Binia et al. (2015) found that the addition of the sodium-to-potassium excretion ratio in the model better explained the effect of potassium supplementation in reducing SBP.

(c) Ethnic and genetic factors

Ethnic factors have been associated with differential blood pressure response to potassium in a few observational studies (Liu et al., 2001; Stamler et al., 2013; Bartley et al., 2014), while evidence from intervention studies is limited (Whelton et al., 1995).

A few studies have investigated the potential ability of some single nucleotide polymorphisms (SNPs) to modify the blood pressure response to modifications in potassium intake (generally associated with dietary sodium manipulations). In Chinese populations, some SNPs have been found to modify such relation, including common genetic variants of the adiponectin gene (Chu et al., 2016), of nuclear receptor subfamily 3, group C, member 2, angiotensin II type 1 receptor, hydroxysteroid (11-β) dehydrogenase 1, and hydroxysteroid (11-β) dehydrogenase 2 genes (He et al., 2011) and endothelin 1 (Montasser et al., 2010). A cross-sectional report from the large EPIC-Norfolk study has shown that the association between urinary sodium-to-potassium ratio and blood pressure was modified by the SNP rs17238540 in the 3-hydroxy-3-methylglutaryl-CoA reductase (HMGCR) gene (Freitas et al., 2009). The Panel notes that the clinical significance and the size of the effects of possible interactions between genetic characteristics and blood pressure response to potassium intake are not well defined. Data in European and Western populations are limited.

(d) Conclusion

The Panel notes that most data available to date come from studies conducted in adult populations.

The Panel considers that the influence of sodium intake, sodium-to-potassium intake ratio, salt sensitivity, ethnic and genetic factors on the effect of potassium intake on blood pressure needs to be further investigated. Currently available evidence cannot be used for the setting of DRVs for potassium.

Overall conclusion on potassium and blood pressure

The Panel considers that there is evidence from RCTs lasting from 4 weeks to 3 years for a beneficial effect of potassium intake on blood pressure in subjects classified as hypertensive (with or without medication), but not in subjects classified as normotensive. In the analysis from Aburto et al. (2013), which combined studies in hypertensive and normotensive people, the largest reduction in SBP and DBP was found in the subgroup characterised by an 'achieved' potassium intake of 3,500–4,700 mg (90–120 mmol)/day, compared with lower and higher amounts. The Panel notes that the only observational prospective cohort study which assessed potassium intake through potassium excretion based on multiple 24-h urine collections and was carried out in a European adult population of normotensive people, with a follow-up of 7.6 years, reported an inverse association between potassium intake and hypertension incidence, with an increased risk observed for potassium intake below 3,500 mg (90 mmol)/day (Kieneker et al., 2014).

5.6.1.2. Stroke

Stroke is one of the most common causes of morbidity and mortality in the European population (Townsend et al., 2016).

A number of prospective cohort studies have investigated the association between potassium intake and risk of stroke, which have been considered in several systematic reviews and meta-analyses (Larsson et al., 2011a; WHO, 2012d; Aburto et al., 2013; D'Elia et al., 2014; Adebamowo et al., 2015b; Vinceti et al., 2016) (Appendix H). All these analyses report a lower risk of stroke in the highest category of potassium intake compared to the lowest (pooled relative risks (RRs) for models adjusting for the highest number of variables between 0.76 (95% CI = 0.66–0.88) and 0.91 (95% CI = 0.88–0.94)).

Among these publications, only two report on dose–response analyses (Larsson et al., 2011a; Vinceti et al., 2016).

Larsson et al. (2011a) conducted a dose–response meta-analysis using a restricted cubic spline analysis. Data from eight prospective cohort studies (Appendix H), which reported RRs and 95% CIs for at least three quantitative categories of potassium intake, were used in the model. The lowest category of potassium intake (mean = 1,053 mg/day) was used as reference for the estimation of RRs. The analysis showed a linear decrease in the risk of total stroke with increasing potassium intake up to around 3,500 mg/day. Above this value, the inverse relationship was weaker and more uncertain (wider confidence intervals).

A more recent systematic review and dose–response meta-analysis included all studies considered by Larsson et al. (2011a) plus those which became available thereafter (Vinceti et al., 2016) (Appendix H). A total of 16 prospective cohort studies which investigated stroke incidence or stroke mortality and assessed potassium intake through dietary questionnaires or urinary potassium excretion were included (639,440 individuals, 19,522 stroke events). Eight studies assessed potassium intake through food frequency questionnaires, four used structured dietary recall administered by a dietician, two measured urinary potassium excretion with a single morning fasting urine sample, one measured urinary potassium excretion with multiple 24-h urine collections and one study used both a food frequency questionnaire and an overnight urine collection. The latter were included in the dose–response analysis by applying a conversion factor of 1.3 to calculate dietary potassium intake from 24-h urinary potassium excretion. Six studies were conducted in the USA, five in Europe, three in Asia and two studies recruited subjects from several countries. Median follow-up ranged from 3.7 to 25.8 years and was > 10 years in 12 studies. Ten studies reported a follow-up equal or higher than 95% of the baseline cohort. All studies controlled for age and all but two adjusted for smoking status, while seven and five studies, respectively, also adjusted for history of hypertension or blood pressure in one regression model. BMI, obesity, physical activity, total energy intake, serum cholesterol, and intake of cholesterol, saturated fat and alcohol were other covariates generally considered in the cohort studies. Median study quality was reported to be seven out of nine on the Newcastle-Ottawa scale (range 4–9). There was no evidence of publication bias.

A pooled dose–response curve of RRs of stroke according to potassium intake was computed using a restricted cubic spline analysis. An inverse relationship between potassium intake and risk of stroke was observed up to around 90 mmol/day (3,500 mg/day), where the RR was 0.78 (95% CI = 0.70–0.86). Above this value, the dose–response curve flattened and statistical imprecision of the estimates increased. Several sensitivity analyses were conducted (e.g. after excluding studies using urinary potassium to estimate intakes, removing studies which reported fatal stroke only, or considering models which did not include blood pressure or hypertensive status as covariates), and did not affect the nature of the association.

Conclusion

The Panel is aware of the inherent limitations in observational studies in relation to exposure misclassification (particularly for studies based on dietary questionnaires) or residual confounding. The Panel notes that there is consistent evidence from prospective cohort studies for an inverse relationship between potassium intake and risk of stroke. The Panel considers that there is a linear decrease in the risk of total stroke with increasing potassium intake up to around 3,500 mg (90 mmol)/day. Above this value, the risk of stroke does not appear to decrease further.

5.6.1.3. Coronary heart disease and overall cardiovascular disease

Seven observational prospective studies have investigated the association between potassium intake and the risk of coronary heart disease or myocardial infarction (incidence or mortality). Five studies measured urinary potassium excretion as a surrogate for potassium intake (Tunstall-Pedoe et al., 1997; Geleijnse et al., 2007; O'Donnell et al., 2011, 2014; Kieneker et al., 2016) and two studies estimated potassium intake through dietary questionnaires (Bazzano et al., 2001; Umesawa et al., 2008). When comparing the highest to the lowest categories of potassium intake or excretion, four studies reported inverse associations, two studies found positive associations, and one study found no association between potassium intake and the risk of coronary heart disease or myocardial infarction. There was substantial uncertainty associated with all risk estimates. The Panel considers that, overall, these studies provided unclear and inconsistent evidence for an association between potassium intake and coronary heart disease risk.

A number of cohort studies also investigated the relationship between potassium intake and overall cardiovascular disease (Geleijnse et al., 2007; Umesawa et al., 2008; Cook et al., 2009; O'Donnell et al., 2011, 2014; Kieneker et al., 2016). A meta-analysis of the four studies published until 2013 yielded a summary RR of 0.88 (95% CI = 0.70–1.10; I^2 = 69%) (Aburto et al., 2013). However, the Panel notes that different definitions of 'overall cardiovascular disease' were applied in these studies, covering heterogeneous endpoints (i.e. stroke and coronary disease were included in all cases, plus different additional cardiovascular outcomes), thus hampering comparisons between studies and data interpretation.

The Panel concludes that the results of these studies do not yield additional evidence that could inform the setting of DRVs for potassium.

5.6.1.4. Conclusion on cardiovascular disease-related outcomes

The Panel notes the strengths and limitations of the evidence on the relationship between potassium intake and cardiovascular outcomes and considers that there is evidence that a potassium intake of 3,500 mg (90 mmol)/day has beneficial effects on blood pressure in adults. Furthermore, there is consistent evidence that potassium intake below 3,500 mg (90 mmol)/day is associated with a higher risk of stroke. Results on the association between potassium intake and coronary heart disease are unclear and inconsistent.

Overall, the Panel considers that the evidence on the relationship between potassium intake and blood pressure and stroke can be used for setting DRVs for potassium for adults.

5.6.2. Diabetes mellitus type 2

A few prospective cohort studies have investigated the association between potassium intake and risk of metabolic disease, in particular, diabetes mellitus type 2.

No association was found between baseline 24-h urinary potassium excretion and risk of type 2 diabetes over 18 years follow-up in a cohort of 1,935 Finnish individuals aged 35–64 years (Hu et al., 2005).

Colditz et al. (1992) found an inverse association between dietary potassium intake (assessed with a semiquantitative FFQ) and the risk of type 2 diabetes in a 6-year prospective cohort of non-obese registered nurses in the USA (RR in Q1 vs Q5, 0.62; X trend −2.65 (p = 0.008)). In two prospective studies carried out in the USA, no association was found between dietary potassium intake (assessed by FFQ) and risk of incident diabetes in a cohort of 1,475 adults aged 45–65 years (9 years follow-up) and in a cohort of 4,754 subjects aged ≥ 65 years (median follow-up of 12 years), after adjusting for potential confounders (Chatterjee et al., 2010, 2015).

In another cohort of US adults aged 18–30 years, Chatterjee et al. (2012) considered 24-h urinary potassium excretion as well as dietary potassium intake estimated through a quantitative FFQ. When using urinary potassium (n = 1,066), the risk of incident type 2 diabetes was higher in individuals in the lowest quintile of urinary potassium (< 35.3 mmol/24 h) compared to individuals in the highest quintile (≥ 73.2 mmol/24 h) (HR = 2.45; 95% CI = 1.08–5.59; p for trend = 0.04), after adjustment for potential confounders. No dose–response relationship emerged. When using dietary potassium intake (n = 4,754), African Americans but not whites had a higher risk of developing type 2 diabetes in the lowest quintiles of dietary potassium intake compared with the highest quintile (≥ 1,614 mg/1,000 kcal per day); no dose–response relationship was evident.

The Panel considers that data from prospective studies investigating a relationship between urinary potassium excretion or dietary potassium intake and risk of type 2 diabetes are limited and conflicting. The Panel concludes that these data cannot be used to derive DRVs for potassium.

5.6.3. Bone health

A few intervention studies have assessed the effect of potassium supplementation on bone mineral density (BMD). In a RCT where 276 post-menopausal women received 2,164 mg (55.5 mmol) or 6,493 mg (166.5 mmol) potassium per day as potassium citrate or a placebo for 2 years (mean potassium intake at baseline: 3,200–3,500 mg/day across the groups), mean spine and hip BMD losses in the placebo group did not differ from those in the treatment groups (Macdonald et al., 2008). Frassetto et al. (2012) investigated a possible influence of salt sensitivity on bone response to potassium alkali supplements by retrospectively analysing a subset of data from the trial of (Macdonald et al., 2008) (70 out of 276 subjects) and a data set from a previous trial on 196 post-menopausal women who received daily doses of 1,200, 2,300 or 3,500 mg (30, 60 or 90 mmol) potassium as potassium bicarbonate or a placebo for 2 years (Frassetto et al., 2005). No effect of dietary alkali

treatment on BMD was found for either study subgroup, nor did adjustment for the possible calcium- or potassium-lowering effects on blood pressure alter these results. Jehle et al. (2013) conducted a RCT on 201 older healthy adults who received either 7,020 mg (180 mmol) potassium/day as potassium citrate or placebo, along with calcium (500 mg/day) and vitamin D_3 (10 μg/day), for 2 years. Mean (± SD) urinary potassium excretion at baseline was 74 ± 19 mmol/24 h and 73 ± 22 mmol/day in the placebo and treatment groups, respectively. The net effect of potassium citrate administration was an increase in BMD at the lumbar spine (primary endpoint) by 1.7% (95% CI = 1.0–2.3). Positive effects of potassium citrate were also found for BMD at the femoral neck, total hip and total body. Potassium citrate also had positive effects on volumetric BMD (measured by CT scanning) for both dominant and non-dominant radius and tibia.

A number of studies investigated the effect of alkaline potassium salts on urinary calcium and acid excretion and markers of bone turnover. In a meta-analysis, Lambert et al. (2015) found that supplementation with alkaline potassium salts reduced calcium excretion and net acid excretion compared to a placebo. Alkaline potassium salts lowered the bone resorption marker NTX (urinary collagen type 1 cross-linked *N*-telopeptide), while no effect on markers of bone formation was observed. Most studies used supplemental daily potassium doses ≥ 2,300 mg (60 mmol). Notably, in studies which compared alkaline potassium salts with potassium chloride, a higher effect of the alkaline salt on net acid excretion, as well as calcium excretion, was observed.

In a subset of 4,000 individuals (age at baseline: 59.7 ± 9.6 years for men and 59.8 ± 9.5 years for women) from the EPIC–Norfolk cohort, no association was found between dietary intake of potassium, assessed by a 7-day food diary, and risk of hip, spine, and wrist fractures at follow-up stratified by sex and quintile of potassium dietary intake (1,502 fracture cases, mean follow-up 13.4 years) (Hayhoe et al., 2015).

The Panel notes the lack of evidence about an association between potassium intake and fracture risk and the limited and inconsistent evidence for an effect of potassium supplementation on BMD. The Panel also notes that most studies used alkaline potassium salts and cannot conclude on an independent effect of potassium on bone health.

The Panel concludes that these data cannot be used to derive DRVs for potassium.

5.6.4. Kidney stones

In a prospective cohort study which involved 45,619 US men aged 40–75 years, potassium intake (assessed with FFQ) was inversely related to the risk of kidney stones after 14 years of follow-up (multivariate RR Q1 (< 2,914 mg (75 mmol)/day) vs Q5 (> 3,958 mg (101 mmol)/day) = 0.54; 95% CI = 0.42–0.68; p for trend < 0.001) (Taylor et al., 2004). In another cohort of 91,731 US women aged 34–59 years participating in the NHS I (12 years follow-up), the multivariate RR among women in the highest quintile (> 4,099 mg (105 mmol)/day) of potassium intake compared with those in the lowest quintile (< 2,407 mg (626 mmol)/day) was 0.65 (95% CI = 0.51–0.84; p for trend < 0.001) (Curhan et al., 1997). In a cohort of 27,001 Finnish male smokers aged 50–69 years followed up for 5 years, no association was found between baseline potassium intake and the incidence of kidney stones in the fully adjusted multivariate model (RR = 0.79; 95% CI = 0.52–1.19; p_{trend} = 0.34) (Hirvonen et al., 1999). In that cohort, median potassium daily intakes in each quartile were 3,800 mg (97 mmol), 4,600 mg (118 mmol), 5,100 mg (131 mmol) and 5,800 mg (149 mmol), respectively.

The use of potassium citrate, as well as other citrate salts, has been investigated for the management of stone disease (Phillips et al., 2015). Because available RCTs used potassium in the form of alkaline salts, an independent effect of potassium on stone formation or stone growth cannot be ascertained. Potassium citrate is used in the treatment of hypocitraturia, which is one of the most common metabolic abnormalities associated with calcium kidney stone formation (Türk et al., 2015). Although the potassium moiety has been proposed to have an independent effect on urinary citrate excretion (Jaipakdee et al., 2004), RCTs found no effect of potassium chloride on urinary citrate excretion (Sakhaee et al., 1991; Tosukhowong et al., 2002; Jaipakdee et al., 2004; Maalouf et al., 2011). Similarly, no independent effect of potassium on urinary pH was found (Jaipakdee et al., 2004; Maalouf et al., 2011).

The Panel notes that there is some evidence for an association between low potassium intake and the increased risk of kidney stones from prospective cohort studies. However, an independent effect of potassium on kidney stones cannot be ascertained from available RCTs. Available RCTs using potassium chloride do not support an independent effect of potassium on urinary citrate excretion and pH.

The Panel concludes that these data cannot be used to derive DRVs for potassium.

6. Data on which to base dietary reference values

The Panel decides to set DRVs for potassium on the basis of the relationships between potassium intake and blood pressure and stroke (Section 5.6.1).

6.1. Adults

There is evidence that a potassium intake of 3,500 mg (90 mmol)/day has a beneficial effect on blood pressure in adults. Furthermore, there is consistent evidence that potassium intakes below 3,500 mg (90 mmol)/day are associated with a higher risk of stroke. Currently, available data do not allow the determination of the distribution of individual requirements for potassium in relation to these endpoints. The Panel considers that available data cannot be used to determine the AR for potassium but can be used as a basis for deriving an adequate intake (AI).

The Panel considers that a potassium intake of 3,500 mg (90 mmol)/day can be considered adequate for the adult population. The Panel sets an AI of 3,500 mg (90 mmol)/day for adult men and women.

6.2. Infants and children

No data are available on which to base an average potassium requirement for infants and children. The Panel proposes AIs extrapolated from the AI for adults: considering the distribution of potassium in all the compartments of the body and the size of the rapidly exchangeable pool (Section 2.3.3), isometric scaling was used, taking into account differences in reference body weight (isometric scaling) and including a growth factor to take into account requirements for growth:

$$\mathrm{AI}_{\mathrm{child}} = \mathrm{AI}_{\mathrm{adult}}(\text{body weight of child}/\text{body weight of adult})(1 + \text{growth factor}).$$

The following growth factors have been applied: 0.57 for boys and girls aged 7–11 months, 0.25 for boys and girls aged 1–3 years, 0.06 for boys and girls aged 4–6 years, 0.13 for boys and girls aged 7–10 years, 0.11 for boys and 0.08 for girls aged 11–14 years, and 0.08 for boys and 0.03 for girls aged 15–17 years (EFSA NDA Panel, 2014).

During childhood, there are differences in potassium body accretion rates between boys and girls, which reflect their respective patterns of skeletal muscle gain (Sections 2.3.4 and 5.3). However, the Panel considers that these differences are negligible relative to the overall potassium requirement. The Panel decides to set AIs that apply to both boys and girls. The age categories proposed by the EFSA NDA Panel (2010) are applied (Table 4).

Table 4: Reference body weights and adequate intakes (AIs) of potassium for children

Age	Reference body weight (kg)[(a)]	AI (mg/day)[(b),(c)]
7–11 months	8.6	750
1–3 years	11.9	800
4–6 years	19.0	1,100
7–10 years	28.7	1,800
11–14 years	44.6	2,700
15–17 years	60.3	3,500

(a): Rounded mean of median weight-for-age of boys and girls aged 24 months, according to the WHO Growth Standard (WHO Multicentre Growth Reference Study Group, 2006), and aged 5, 8.5, 12.5 and 16 years, according to van Buuren et al. (2012).

(b): Adequate intakes were derived from the unrounded AI for adults after adjustment on the basis of differences in reference body weight and application of a growth factor, then rounded to the closest 50.

(c): Equivalent to: 19 mmol/day for infants 7–11 months, 20 mmol/day for children aged 1–3 years, 28 mmol/day for children aged 4–6 years, 46 mmol/day for children aged 7–10 years, 69 mmol/day for children aged 11–14 years and 90 mmol/day for children aged 15–17 years.

6.3. Pregnancy

The Panel notes that there is a lack of data on potassium requirement in pregnancy, but considers that the requirement for the daily accretion rate of potassium in fetal and maternal tissues can be met

by the adaptive changes which maintain potassium homeostasis during pregnancy (Section 5.4); thus, the AI for pregnant women is set at 3,500 mg (90 mmol)/day, the same as for non-pregnant women.

6.4. Lactation

An average amount of potassium secreted in breast milk of 400 mg (10 mmol)/day was estimated (Section 2.3.5.4). There are no data on adaptive changes in potassium metabolism during lactation, but some evidence indicates that total body potassium content decreases in lactating women (Section 5.5). Taking a conservative approach, the Panel proposes to increase the AI for lactating women in order to compensate for the losses of potassium through breast milk.

There is no specific information on potassium absorption efficiency in lactating women. Considering an absorption efficiency of 90% from usual diets based on data in non-lactating subjects (Section 2.3.1), an additional potassium intake of 444 mg (11 mmol)/day was considered sufficient to replace these losses. Thus, an AI of 4,000 mg (102 mmol)/day is proposed for lactating women, after rounding up to the closest 100.

Conclusions

The Panel concludes that there is insufficient evidence to derive an AR and a PRI for potassium. Evidence on the relationships between potassium intake and blood pressure and risk of stroke are used to set an AI for adults (Table 5). It is considered unnecessary to give sex-specific values. The Panel proposes that the adult AI also applies to pregnant women. For lactating women, an increase in AI is proposed on the basis of the estimated loss of potassium secreted in breast milk. In infants over 6 months of age and in children, AIs are proposed based on extrapolation from the adult AI using isometric scaling and body weights of the age groups and application of a growth factor.

Table 5: Summary of dietary reference values for potassium

Age	AI[(a)] (mg/day)
7–11 months	750
1–3 years	800
4–6 years	1,100
7–10 years	1,800
11–14 years	2,700
15–17 years	3,500
≥ 18 years	3,500
Pregnancy	3,500
Lactation	4,000

AI: Adequate intake.

(a): Equivalent to: 19 mmol/day for infants 7–11 months, 20 mmol/day for children aged 1–3 years, 28 mmol/day for children aged 4–6 years, 46 mmol/day for children aged 7–10 years, 69 mmol/day for children aged 11–14 years, 90 mmol/day for children aged 15–17 years, 90 mmol for adults, including pregnant women, and 102 mmol for lactating women.

Recommendations for research

The Panel recommends improving the knowledge of potassium metabolism and homeostasis, and of its inter-relationship with the metabolism of sodium and chloride. This would, in turn, allow the identification of potential biomarkers for validation and use in population-based health studies.

The Panel recommends further studies on the relationship between potassium intake and cardiovascular endpoints, in particular in relation to hypertension and stroke risk. Further investigation into the mechanisms involved in the protective role of potassium against these conditions is needed.

The Panel recommends that the potential modification of the effect of potassium intake on blood pressure by sodium intake, sodium-to-potassium intake ratio, salt sensitivity, ethnic and genetic factors be further investigated.

The Panel recommends further research on a potential 'independent' effect of potassium on bone health.

The Panel also recommends generating evidence that can be used to assess the potassium requirements of infants and children.

References

Aburto NJ, Hanson S, Gutierrez H, Hooper L, Elliott P and Cappuccio FP, 2013. Effect of increased potassium intake on cardiovascular risk factors and disease: systematic review and meta-analyses. British Medical Journal (Clinical Research Edition), 346, f1378.

Adebamowo SN, Spiegelman D, Flint AJ, Willett WC and Rexrode KM, 2015a. Intakes of magnesium, potassium, and calcium and the risk of stroke among men. International Journal of Stroke, 10, 1093–1100.

Adebamowo SN, Spiegelman D, Willett WC and Rexrode KM, 2015b. Association between intakes of magnesium, potassium, and calcium and risk of stroke: 2 cohorts of US women and updated meta-analyses. American Journal of Clinical Nutrition, 101, 1269–1277.

Adrogue HJ and Madias NE, 2014. Sodium surfeit and potassium deficit: keys to the pathogenesis of hypertension. Journal of the American Society of Hypertension, 8, 203–213.

Afssa (Agence française de sécurité sanitaire des aliments), 2001. *Apports nutritionnels conseillés pour la population française*. Editions Tec & Doc, Paris, France, 605 pp.

Afssa (Agence française de sécurité sanitaire des aliments), 2009. Étude Individuelle Nationale des Consommations Alimentaires 2 (INCA 2) (2006–2007). Rapport, 228 pp.

Agarwal R, Afzalpurkar R and Fordtran JS, 1994. Pathophysiology of potassium absorption and secretion by the human intestine. Gastroenterology, 107, 548–571.

Allen JC, Keller RP, Archer P and Neville MC, 1991. Studies in human lactation: milk composition and daily secretion rates of macronutrients in the first year of lactation. American Journal of Clinical Nutrition, 54, 69–80.

Appel LJ, Moore TJ, Obarzanek E, Vollmer WM, Svetkey LP, Sacks FM, Bray GA, Vogt TM, Cutler JA, Windhauser MM, Lin PH and Karanja N, 1997. A clinical trial of the effects of dietary patterns on blood pressure. DASH Collaborative Research Group. New England Journal of Medicine, 336, 1117–1124.

Ascherio A, Rimm EB, Giovannucci EL, Colditz GA, Rosner B, Willett WC, Sacks F and Stampfer MJ, 1992. A prospective study of nutritional factors and hypertension among US men. Circulation, 86, 1475–1484.

Ascherio A, Hennekens C, Willett WC, Sacks F, Rosner B, Manson J, Witteman J and Stampfer MJ, 1996. Prospective study of nutritional factors, blood pressure, and hypertension among US women. Hypertension, 27, 1065–1072.

Ascherio A, Rimm EB, Hernan MA, Giovannucci EL, Kawachi I, Stampfer MJ and Willett WC, 1998. Intake of potassium, magnesium, calcium, and fiber and risk of stroke among US men. Circulation, 98, 1198–1204.

Atkinson S, Alston-Mills B, Lönnerdal B and Neville MC, 1995. Major minerals and ionic constituents of human and bovine milk. In: Jensen RJ (ed.). *Handbook of Milk Composition*. Academic Press, California, USA. pp. 593–619.

Atkinson D, Boyd R and Sibley C, 2006. Placental transfer. In: Neill J, Challis J, de Krester D, Pfaff D, Richards J, Plant T, Wassarman P (ed.). *Knobil and Neill's physiology of reproduction*. Volume 2. 3rd Edition. Elsevier Academic Press, USA. pp. 2787–2846.

Aviv A, Hollenberg NK and Weder A, 2004. Urinary potassium excretion and sodium sensitivity in blacks. Hypertension, 43, 707–713.

Baer JD, Fong AKH, Novotny JA and Oexmann MJ, 1999. Compartmental modeling, stable isotopes, and balance studies. In: Dennis BH, Ershow AG, Obarzanek E and Clevidence BA (eds.). *Well-Controlled Diet Studies in Humans: A Practical Guide to Design and Management*. American dietetic association, Chicago, IL, USA. pp. 238–254.

Bailey J, Sands J and Franch H, 2014. Water, electrolytes, and acid-base metabolism. In: Ross C, Caballero B, Cousins R, Tucker K and Ziegler T (eds.). *Modern Nutrition in Health and Disease*, 11th Edition. Williams & Wilkins, Lippincott. pp. 102–132.

Baker LB, Stofan JR, Hamilton AA and Horswill CA, 2009. Comparison of regional patch collection vs. whole body washdown for measuring sweat sodium and potassium loss during exercise. Journal of Applied Physiology, 107, 887–895.

Barcelo P, Wuhl O, Servitge E, Rousaud A and Pak CY, 1993. Randomized double-blind study of potassium citrate in idiopathic hypocitraturic calcium nephrolithiasis. Journal of Urology, 150, 1761–1764.

Barlow RJ, Connell MA and Milne FJ, 1986. A study of 48-hour faecal and urinary electrolyte excretion in normotensive black and white South African males. Journal of Hypertension, 4, 197–200.

Bartley K, Jung M and Yi S, 2014. Diet and blood pressure: differences among whites, blacks and hispanics in New York City 2010. Ethnicity and Disease, 24, 175–181.

Bates B, Lennox A, Prentice A, Bates C and Swan G, 2012. National Diet and Nutrition Survey. Headline results from Years 1, 2 and 3 (combined) of the Rolling Programme (2008/2009 – 2010/11). A survey carried out on behalf of the Department of Health and the Food Standards Agency. 79 pp.

Bauer J and Gerss J, 2011. Longitudinal analysis of macronutrients and minerals in human milk produced by mothers of preterm infants. Clinical Nutrition, 30, 215–220.

Bazzano LA, He J, Ogden LG, Loria C, Vupputuri S, Myers L and Whelton PK, 2001. Dietary potassium intake and risk of stroke in US men and women: National Health and Nutrition Examination Survey I epidemiologic follow-up study. Stroke, 32, 1473–1480.

Binia A, Jaeger J, Hu Y, Singh A and Zimmermann D, 2015. Daily potassium intake and sodium-to-potassium ratio in the reduction of blood pressure: a meta-analysis of randomized controlled trials. Journal of Hypertension, 33, 1509–1520.

Bjorklund KL, Vahter M, Palm B, Grander M, Lignell S and Berglund M, 2012. Metals and trace element concentrations in breast milk of first time healthy mothers: a biological monitoring study. Environmental Health, 11, 92.

van Bommel E and Cleophas T, 2012. Potassium treatment for hypertension in patients with high salt intake: a meta-analysis. International Journal of Clinical Pharmacology and Therapeutics, 50, 478–482.

Brion MJ, Ness AR, Davey Smith G, Emmett P, Rogers I, Whincup P and Lawlor DA, 2008. Sodium intake in infancy and blood pressure at 7 years: findings from the Avon Longitudinal Study of Parents and Children. European Journal of Clinical Nutrition, 62, 1162–1169.

Brown MA, Sinosich MJ, Saunders DM and Gallery ED, 1986. Potassium regulation and progesterone-aldosterone interrelationships in human pregnancy: a prospective study. American Journal of Obstetrics and Gynecology, 155, 349–353.

Buendia JR, Bradlee ML, Daniels SR, Singer MR and Moore LL, 2015. Longitudinal effects of dietary sodium and potassium on blood pressure in adolescent girls. Journal of the American Medical Association Pediatrics, 169, 560–568.

Burgess E, Lewanczuk R, Bolli P, Chockalingam A, Cutler H, Taylor G and Hamet P, 1999. Lifestyle modifications to prevent and control hypertension. 6. Recommendations on potassium, magnesium and calcium. Canadian Hypertension Society, Canadian Coalition for High Blood Pressure Prevention and Control, Laboratory Centre for Disease Control at Health Canada, Heart and Stroke Foundation of Canada. Canadian Medical Association Journal, 160, S35–S45.

Butte NF and Hopkinson JM, 1998. Body composition changes during lactation are highly variable among women. Journal of Nutrition, 128, 381S–385S.

Butte NF, Garza C, Smith EO and Nichols BL, 1984. Human milk intake and growth in exclusively breast-fed infants. Journal of Pediatrics, 104, 187–195.

Butte NF, Hopkinson JM, Wong WW, Smith EO and Ellis KJ, 2000. Body composition during the first 2 years of life: an updated reference. Pediatric Research, 47, 578–585.

Butte NF, Lopez-Alarcon MG and Garza C, 2002. Nutrient adequacy of exclusive breastfeeding for the term infant during the first six months of life. World Health Organization, 57 pp.

Butte NF, Ellis KJ, Wong WW, Hopkinson JM and Smith EO, 2003. Composition of gestational weight gain impacts maternal fat retention and infant birth weight. American Journal of Obstetrics and Gynecology, 189, 1423–1432.

van Buuren S, Schönbeck Y and van Dommelen P, 2012. Collection, collation and analysis of data in relation to reference heights and reference weights for female and male children and adolescents (0-18 years) in the EU, as well as in relation to the age of onset of puberty and the age at which different stages of puberty are reached in adolescents in the EU. Project developed on the procurement project CT/EFSA/NDA/2010/01. EFSA supporting publication 2012:EN-255, 59 pp.

Byatt CM, Millard PH and Levin GE, 1990. Diuretics and electrolyte disturbances in 1000 consecutive geriatric admissions. Journal of the Royal Society of Medicine, 83, 704–708.

Cappuccio FP, Buchanan LA, Ji C, Siani A and Miller MA, 2016. Systematic review and meta-analysis of randomised controlled trials on the effects of potassium supplements on serum potassium and creatinine. BMJ Open, 6, e011716.

Challier JC, Bara M and D'Athis P, 1988. The magnesium, calcium, sodium, potassium and chloride contents of the term human placenta. Magnesium Research, 1, 141–145.

Chalmers J, Morgan T, Doyle A, Dickson B, Hopper J, Mathews J, Matthews G, Moulds R, Myers J and Nowson C, 1986. Australian National Health and Medical Research Council dietary salt study in mild hypertension. Journal of Hypertension, Supplement 4, S629–S637.

Chandra RK, 1984. Physical growth of exclusively breast-fed infants. Nutrition Research, 2, 275–276.

Chatterjee R, Yeh HC, Shafi T, Selvin E, Anderson C, Pankow JS, Miller E and Brancati F, 2010. Serum and dietary potassium and risk of incident type 2 diabetes mellitus: The Atherosclerosis Risk in Communities (ARIC) study. Archives of Internal Medicine, 170, 1745–1751.

Chatterjee R, Colangelo LA, Yeh HC, Anderson CA, Daviglus ML, Liu K and Brancati FL, 2012. Potassium intake and risk of incident type 2 diabetes mellitus: the Coronary Artery Risk Development in Young Adults (CARDIA) Study. Diabetologia, 55, 1295–1303.

Chatterjee R, Biggs ML, de Boer IH, Brancati FL, Svetkey LP, Barzilay J, Djousse L, Ix JH, Kizer JR, Siscovick DS, Mozaffarian D, Edelman D and Mukamal KJ, 2015. Potassium and glucose measures in older adults: the Cardiovascular Health Study. Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 70, 255–261.

Cheung KL and Lafayette RA, 2013. Renal physiology of pregnancy. Advances in Chronic Kidney Disease, 20, 209–214.

Chien KL, Hsu HC, Chen PC, Su TC, Chang WT, Chen MF and Lee YT, 2008. Urinary sodium and potassium excretion and risk of hypertension in Chinese: report from a community-based cohort study in Taiwan. Journal of Hypertension, 26, 1750–1756.
Chu C, Wang Y, Ren KY, Yan DY, Guo TS, Zheng WL, Yuan ZY and Mu JJ, 2016. Genetic variants in adiponectin and blood pressure responses to dietary sodium or potassium interventions: a family-based association study. Journal of Human Hypertension, 30, 563–570.
Colditz GA, Manson JE, Stampfer MJ, Rosner B, Willett WC and Speizer FE, 1992. Diet and risk of clinical diabetes in women. American Journal of Clinical Nutrition, 55, 1018–1023.
Consolazio CF, Matoush LO, Nelson RA, Harding RS and Canham JE, 1963. Excretion of sodium, potassium, magnesium and iron in human sweat and the relation of each to balance and requirements. Journal of Nutrition, 79, 407–415.
Cook NR, Obarzanek E, Cutler JA, Buring JE, Rexrode KM, Kumanyika SK, Appel LJ, Whelton PK and Trials of Hypertension Prevention Collaborative Research G, 2009. Joint effects of sodium and potassium intake on subsequent cardiovascular disease: the Trials of Hypertension Prevention follow-up study. Archives of Internal Medicine, 169, 32–40.
Coruzzi P, Brambilla L, Brambilla V, Gualerzi M, Rossi M, Parati G, Di Rienzo M, Tadonio J and Novarini A, 2001. Potassium depletion and salt sensitivity in essential hypertension. Journal of Clinical Endocrinology and Metabolism, 86, 2857–2862.
Costill DL, 1977. Sweating: its composition and effects on body fluids. Annals of the New York Academy of Sciences, 301, 160–174.
Costill DL, Cote R and Fink WJ, 1982. Dietary potassium and heavy exercise: effects on muscle water and electrolytes. American Journal of Clinical Nutrition, 36, 266–275.
Crook MA, 2012. Potassium. In: Koster J and Wright J (eds.). *Clinical Biochemistry and Metabolic Medicine*. Hodder Arnold, London, UK. pp. 86–94.
Crop MJ, Hoorn EJ, Lindemans J and Zietse R, 2007. Hypokalaemia and subsequent hyperkalaemia in hospitalized patients. Nephrology, Dialysis, Transplantation, 22, 3471–3477.
Cummings JH, Hill MJ, Jenkins DJ, Pearson JR and Wiggins HS, 1976. Changes in fecal composition and colonic function due to cereal fiber. American Journal of Clinical Nutrition, 29, 1468–1473.
Curhan GC, Willett WC, Rimm EB and Stampfer MJ, 1993. A prospective study of dietary calcium and other nutrients and the risk of symptomatic kidney stones. New England Journal of Medicine, 328, 833–838.
Curhan GC, Willett WC, Speizer FE, Spiegelman D and Stampfer MJ, 1997. Comparison of dietary calcium with supplemental calcium and other nutrients as factors affecting the risk for kidney stones in women. Annals of Internal Medicine, 126, 497–504.
D-A-CH (Deutsche Gesellschaft für Ernährung, Österreichische Gesellschaft für Ernährung, Schweizerische Gesellschaft für Ernährung), 2015. Referenzwerte für die Nährstoffzufuhr. 2. Auflage, 1. Ausgabe. DGE, Bonn, Germany.
D'Elia L, Iannotta C, Sabino P and Ippolito R, 2014. Potassium-rich diet and risk of stroke: updated meta-analysis. Nutrition, Metabolism and Cardiovascular Diseases, 24, 585–587.
Devroede GJ and Phillips SF, 1969. Conservation of sodium, chloride, and water by the human colon. Gastroenterology, 56, 101–109.
Dewey KG and Lönnerdal B, 1983. Milk and nutrient intake of breast-fed infants from 1 to 6 months: relation to growth and fatness. Journal of Pediatric Gastroenterology and Nutrition, 2, 497–506.
DH (Department of Health), 1991. Dietary reference values for food energy and nutrients for the United Kingdom. Report of the Panel on Dietary Reference Values of the Committee on Medical Aspects of Food Policy. HMSO, London, UK, 212 pp.
Dickinson HO, Nicolson DJ, Campbell F, Beyer FR and Mason J, 2006. Potassium supplementation for the management of primary hypertension in adults. Cochrane Database of Systematic Reviews, 3, CD004641.
Dittmar M and Reber H, 2004. Validation of different bioimpedance analyzers for predicting cell mass against whole-body counting of potassium (40K) as a reference method. American Journal of Human Biology, 16, 697–703.
EFSA (European Food Safety Authority), 2011a. Report on the development of a food classification and description system for exposure assessment and guidance on its implementation and use. EFSA Journal 2011;9(12):2489, 84 pp. doi:10.2903/j.efsa.2011.2489
EFSA (European Food Safety Authority), 2011b. Use of the EFSA Comprehensive European Food Consumption Database in exposure assessment. EFSA Journal 2011;9(3):2097, 34 pp. doi:10.2903/j.efsa.2011.2097
EFSA (European Food Safety Authority), 2005. Opinion of the Scientific Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the Tolerable Upper Intake Level of potassium. EFSA Journal 2005;3(3):193, 19 pp. doi:10.2903/j.efsa.2005.193
EFSA NDA Panel (EFSA Panel on Dietetic Products, Nutrition and Allergies), 2009. Scientific Opinion on the appropriate age for introduction of complementary feeding of infants. EFSA Journal 2009;7(12):1423, 38 pp. doi:10.2903/j.efsa.2009.1423

EFSA NDA Panel (EFSA Panel on Dietetic Products, Nutrition, and Allergies), 2010. Scientific Opinion on principles for deriving and applying Dietary Reference Values. EFSA Journal 2010;8(3):1458, 30 pp. doi:10.2903/j.efsa.2010.1458

EFSA NDA Panel (EFSA Panel on Dietetic Products, Nutrition and Allergies), 2014. Scientific Opinion on Dietary Reference Values for selenium. EFSA Journal 2014;12(10):3846, 66 pp. doi:10.2903/j.efsa.2014.3846

Ehrlich EN and Lindheimer MD, 1972. Effect of administered mineralocorticoids or ACTH in pregnant women. Attenuation of kaliuretic influence of mineralocorticoids during pregnancy. Journal of Clinical Investigation, 51, 1301–1309.

Elabida B, Edwards A, Salhi A, Azroyan A, Fodstad H, Meneton P, Doucet A, Bloch-Faure M and Crambert G, 2011. Chronic potassium depletion increases adrenal progesterone production that is necessary for efficient renal retention of potassium. Kidney International, 80, 256–262.

Ellis KJ, Shypailo RJ and Schandler RJ, 1993. Body composition of infants: human cadaver studies. In: Ellis KJ and Eastman JD (eds.). *Human Body Composition*. Plenum Press, New York, USA. pp. 147–152.

Ellis KJ, Shypailo RJ, Abrams SA and Wong WW, 2000. The reference child and adolescent models of body composition. A contemporary comparison. Annals of the New York Academy of Sciences, 904, 374–382.

FAO/WHO/UNU (Food and Agriculture Organization of the United Nations/World Health Organization/United Nations University), 2004. Human energy requirements. Report of a Joint FAO/WHO/UNU Expert Consultation, Rome 17-24 October 2001. FAO Food and Nutrition Technical Report Series, 103 pp.

Fly AD, Uhlin KL and Wallace JP, 1998. Major mineral concentrations in human milk do not change after maximal exercise testing. American Journal of Clinical Nutrition, 68, 345–349.

Flynn MA, Woodruff C, Clark J and Chase G, 1972. Total body potassium in normal children. Pediatric Research, 6, 239–245.

Fomon SJ, 1993. *Nutrition of Normal Infants*. Mosby, St Louis, USA, 475 pp.

Fomon SJ, Haschke F, Ziegler EE and Nelson SE, 1982. Body composition of reference children from birth to age 10 years. American Journal of Clinical Nutrition, 35, 1169–1175.

Forbes GB, 1983. Unmeasured losses of potassium in balance studies. American Journal of Clinical Nutrition, 38, 347–348.

Forbes GB, 1987. Techniques for estimating body composition. In: Forbes, GB (ed.). *Human Body Composition: Growth, Aging, Nutrition, and Activity*. Springer-Verlag, New York, USA. pp. 5–100.

Forbes GB, Lantigua R, Amatruda JM and Lockwood DH, 1981. Errors in potassium balance. American Journal of Clinical Nutrition, 34, 105–109.

Ford ES and Cooper RS, 1991. Risk factors for hypertension in a national cohort study. Hypertension, 18, 598–606.

Forsum E, Sadurskis A and Wager J, 1988. Resting metabolic rate and body composition of healthy Swedish women during pregnancy. American Journal of Clinical Nutrition, 47, 942–947.

Frassetto L, Morris RC Jr and Sebastian A, 2005. Long-term persistence of the urine calcium-lowering effect of potassium bicarbonate in postmenopausal women. Journal of Clinical Endocrinology and Metabolism, 90, 831–834.

Frassetto LA, Hardcastle AC, Sebastian A, Aucott L, Fraser WD, Reid DM and Macdonald HM, 2012. No evidence that the skeletal non-response to potassium alkali supplements in healthy postmenopausal women depends on blood pressure or sodium chloride intake. European Journal of Clinical Nutrition, 66, 1315–1322.

Freedman LS, Midthune D, Carroll RJ, Krebs-Smith S, Subar AF, Troiano RP, Dodd K, Schatzkin A, Bingham SA, Ferrari P and Kipnis V, 2004. Adjustments to improve the estimation of usual dietary intake distributions in the population. Journal of Nutrition, 134, 1836–1843.

Freedman LS, Commins JM, Moler JE, Willett W, Tinker LF, Subar AF, Spiegelman D, Rhodes D, Potischman N, Neuhouser ML, Moshfegh AJ, Kipnis V, Arab L and Prentice RL, 2015. Pooled results from 5 validation studies of dietary self-report instruments using recovery biomarkers for potassium and sodium intake. American Journal of Epidemiology, 181, 473–487.

Freitas RN, Khaw KT, Wu K, Bowman R, Jeffery H, Luben R, Wareham NJ and Bingham SA, 2009. A HMGCR polymorphism is associated with relations between blood pressure and urinary sodium and potassium ratio in the Epic-Norfolk Study. Journal of the American Society of Hypertension, 3, 238–244.

FSANZ (Food Standards Australia New Zealand), 2014. Systematic review of the evidence for a relationship between potassium and blood pressure. 28 pp.

Geleijnse JM, Grobbee DE and Hofman A, 1990. Sodium and potassium intake and blood pressure change in childhood. British Medical Journal, 300, 899–902.

Geleijnse JM, Witteman JC, Hofman A and Grobbee DE, 1997. Electrolytes are associated with blood pressure at old age: the Rotterdam Study. Journal of Human Hypertension, 11, 421–423.

Geleijnse JM, Kok FJ and Grobbee DE, 2003. Blood pressure response to changes in sodium and potassium intake: a metaregression analysis of randomised trials. Journal of Human Hypertension, 17, 471–480.

Geleijnse JM, Witteman JC, Stijnen T, Kloos MW, Hofman A and Grobbee DE, 2007. Sodium and potassium intake and risk of cardiovascular events and all-cause mortality: the Rotterdam Study. European Journal of Epidemiology, 22, 763–770.

Giebisch G, 1998. Renal potassium transport: mechanisms and regulation. American Journal of Physiology, 274, F817–F833.

Giebisch G, 2004. Challenges to potassium metabolism: internal distribution and external balance. Wiener Klinische Wochenschrift, 116, 353–366.
Gijsbers L, Dower JI, Mensink M, Siebelink E, Bakker SJ and Geleijnse JM, 2015. Effects of sodium and potassium supplementation on blood pressure and arterial stiffness: a fully controlled dietary intervention study. Journal of Human Hypertension, 29, 592–598.
Godfrey BE and Wadsworth GR, 1970. Total body potassium in pregnant women. Journal of Obstetrics and Gynaecology of the British Commonwealth, 77, 244–246.
Green DM, Ropper AH, Kronmal RA, Psaty BM and Burke GL and Cardiovascular Health Study, 2002. Serum potassium level and dietary potassium intake as risk factors for stroke. Neurology, 59, 314–320.
Grobbee DE, Hofman A, Roelandt JT, Boomsma F, Schalekamp MA and Valkenburg HA, 1987. Sodium restriction and potassium supplementation in young people with mildly elevated blood pressure. Journal of Hypertension, 5, 115–119.
Gross SJ, David RJ, Bauman L and Tomarelli RM, 1980. Nutritional composition of milk produced by mothers delivering preterm. Journal of Pediatrics, 96, 641–644.
Grossman AN, Opie LH, Beshansky JR, Ingwall JS, Rackley CE and Selker HP, 2013. Glucose-insulin-potassium revived: current status in acute coronary syndromes and the energy-depleted heart. Circulation, 127, 1040–1048.
Gu D, He J, Wu X, Duan X and Whelton PK, 2001. Effect of potassium supplementation on blood pressure in Chinese: a randomized, placebo-controlled trial. Journal of Hypertension, 19, 1325–1331.
Gumz ML, Rabinowitz L and Wingo CS, 2015. An integrated view of potassium homeostasis. New England Journal of Medicine, 373, 1787–1788.
Guyton AC and Hall JE, 2006. Renal regulation of potassium, calcium, phosphate, and magnesium; integration of renal mechanisms for control of blood volume and extracellular fluid volume. In: Schmitt W and Gruliow R (eds.). *Textbook of Medical Physiology*. Elsevier Saunders, Philadelphia, PA, USA. pp. 365–382.
Haddy FJ, Vanhoutte PM and Feletou M, 2006. Role of potassium in regulating blood flow and blood pressure. American Journal of Physiology Regulatory Integrative and Comparative Physiology, 290, R546–R552.
Hansen RD and Allen BJ, 1996. Calibration of a total body potassium monitor with an anthropomorphic phantom. Physics in Medicine and Biology, 41, 2447–2462.
Hayhoe RP, Lentjes MA, Luben RN, Khaw KT and Welch AA, 2015. Dietary magnesium and potassium intakes and circulating magnesium are associated with heel bone ultrasound attenuation and osteoporotic fracture risk in the EPIC-Norfolk cohort study. American Journal of Clinical Nutrition, 102, 376–384.
He FJ, Marciniak M, Carney C, Markandu ND, Anand V, Fraser WD, Dalton RN, Kaski JC and MacGregor GA, 2010. Effects of potassium chloride and potassium bicarbonate on endothelial function, cardiovascular risk factors, and bone turnover in mild hypertensives. Hypertension, 55, 681–688.
He J, Gu D, Kelly TN, Hixson JE, Rao DC, Jaquish CE, Chen J, Zhao Q, Gu C, Huang J, Shimmin LC, Chen JC, Mu J, Ji X, Liu DP and Whelton PK and GenSalt Collaborative Research Group, 2011. Genetic variants in the renin-angiotensin-aldosterone system and blood pressure responses to potassium intake. Journal of Hypertension, 29, 1719–1730.
Heinig MJ, Nommsen LA, Peerson JM, Lönnerdal B and Dewey KG, 1993. Energy and protein intakes of breast-fed and formula-fed infants during the first year of life and their association with growth velocity: the DARLING Study. American Journal of Clinical Nutrition, 58, 152–161.
Heitzmann D and Warth R, 2008. Physiology and pathophysiology of potassium channels in gastrointestinal epithelia. Physiological Reviews, 88, 1119–1182.
Helldán A, Raulio S, Kosola M, Tapanainen H, Ovaskainen ML and Virtanen S, 2013. Finravinto 2012 - tutkimus - The National FINDIET 2012 Survey. THL. Raportti 16/2013, 217 pp.
Hirvonen T, Pietinen P, Virtanen M, Albanes D and Virtamo J, 1999. Nutrient intake and use of beverages and the risk of kidney stones among male smokers. American Journal of Epidemiology, 150, 187–194.
Hohler CW 2nd, Bardawil WA and Mitchell GW Jr, 1972. Placental weight and water content relative to blood types of human mothers and their offspring. Obstetrics and Gynecology, 40, 799–806.
Holbrook JT, Patterson KY, Bodner JE, Douglas LW, Veillon C, Kelsay JL, Mertz W and Smith JC Jr, 1984. Sodium and potassium intake and balance in adults consuming self-selected diets. American Journal of Clinical Nutrition, 40, 786–793.
Holt C, 1993. Interrelationships of the concentrations of some ionic constituents of human milk and comparison with cow and goat milks. Comparative Biochemistry and Physiology. Comparative Physiology, 104, 35–41.
Hooft van Huysduynen EJ, Hulshof PJ, van Lee L, Geelen A, Feskens EJ, van 't Veer P, van Woerkum CJ and de Vries JH, 2014. Evaluation of using spot urine to replace 24 h urine sodium and potassium excretions. Public Health Nutrition, 17, 2505–2511.
Hoppu U, Lehtisalo J, Kujala J, Keso T, Garam S, Tapanainen H, Uutela A, Laatikainen T, Rauramo U and Pietinen P, 2010. The diet of adolescents can be improved by school intervention. Public Health Nutrition, 13, 973–979.
Horn R, Roux B and Aqvist J, 2014. Permeation redux: thermodynamics and kinetics of ion movement through potassium channels. Biophysical Journal, 106, 1859–1863.
Hu G, Jousilahti P, Peltonen M, Lindstrom J and Tuomilehto J, 2005. Urinary sodium and potassium excretion and the risk of type 2 diabetes: a prospective study in Finland. Diabetologia, 48, 1477–1483.

Ifudu O, Markell MS and Friedman EA, 1992. Unrecognized pseudohyperkalemia as a cause of elevated potassium in patients with renal disease. American Journal of Nephrology, 12, 102–104.
Intersalt Cooperative Research Group, 1988. Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion. British Medical Journal, 297, 319–328.
IOM (Institute of Medicine), 2000. *The role of nutrition in maintaining health in the nation's elderly*. National Academy Press, Washington DC, USA, 366 pp.
IOM (Institute of Medicine), 2005. *Dietary Reference Intakes for water, potassium, sodium, chloride, and sulfate*. National Academies Press, Washington, DC, USA, 617 pp.
Isaksson B and Sjogren B, 1963. Indirect estimation of dermal losses of potassium in human metabolic balance studies. Scandinavian Journal of Clinical and Laboratory Investigation, 15(Suppl 69), 108–113.
Iso H, Stampfer MJ, Manson JE, Rexrode K, Hennekens CH, Colditz GA, Speizer FE and Willett WC, 1999. Prospective study of calcium, potassium, and magnesium intake and risk of stroke in women. Stroke, 30, 1772–1779.
IUNA (Irish Universities Nutrition Alliance), 2011. National Adult Nutrition Survey. Summary Report March 2011, 37 pp.
Jaipakdee S, Prasongwatana V, Premgamone A, Reungjui S, Tosukhowong P, Tungsanga K, Suwantrai S, Noppawinyoowong C, Maskasame S and Sriboonlue P, 2004. The effects of potassium and magnesium supplementations on urinary risk factors of renal stone patients. Journal of the Medical Association of Thailand, 87, 255–263.
Jasani BM and Edmonds CJ, 1971. Kinetics of potassium distribution in man using isotope dilution and whole-body counting. Metabolism, 20, 1099–1106.
Jehle S, Hulter HN and Krapf R, 2013. Effect of potassium citrate on bone density, microarchitecture, and fracture risk in healthy older adults without osteoporosis: a randomized controlled trial. Journal of Clinical Endocrinology and Metabolism, 98, 207–217.
Jones G, Riley MD and Whiting S, 2001. Association between urinary potassium, urinary sodium, current diet, and bone density in prepubertal children. American Journal of Clinical Nutrition, 73, 839–844.
Jula A, Rönnemaa T, Rastas M, Karvetti RL and Maki J, 1990. Long-term nopharmacological treatment for mild to moderate hypertension. Journal of Internal Medicine, 227, 413–421.
Kawasaki T, Itoh K, Uezono K and Sasaki H, 1993. A simple method for estimating 24 h urinary sodium and potassium excretion from second morning voiding urine specimen in adults. Clinical and Experimental Pharmacology and Physiology, 20, 7–14.
Kee JLF, Paulanka BJ and Polek C, 2010. Potassium imbalances. In: Helba S and Bellegarde W (eds.). *Handbook of Fluid, Electrolyte, and Acid-Base Imbalances*. Delmar Gengage Learning, New York, USA. pp. 54–73.
Keenan BS, Buzek SW, Garza C, Potts E and Nichols BL, 1982. Diurnal and longitudinal variations in human milk sodium and potassium: implication for nutrition and physiology. American Journal of Clinical Nutrition, 35, 527–534.
Keenan BS, Buzek SW and Garza C, 1983. Cortisol and its possible role in regulation of sodium and potassium in human milk. American Journal of Physiology, 244, E253–E261.
Kelly TN, Hixson JE, Rao DC, Mei H, Rice TK, Jaquish CE, Shimmin LC, Schwander K, Chen CS, Liu D, Chen J, Bormans C, Shukla P, Farhana N, Stuart C, Whelton PK, He J and Gu D, 2010. Genome-wide linkage and positional candidate gene study of blood pressure response to dietary potassium intervention: the genetic epidemiology network of salt sensitivity study. Circulation. Cardiovascular Genetics, 3, 539–547.
Kersting M and Clausen K, 2003. *Ernährungsphysiologische Auswertung einer repräsentativen Verzehrsstudie bei Säuglingen und Kleinkindern VELS mit dem Instrumentarium der DONALD Studie*. Forschungsinstitut für Kinderernährung, Dortmund, Germany, 103 pp.
Khaw KT and Barrett-Connor E, 1987. Dietary potassium and stroke-associated mortality. A 12-year prospective population study. New England Journal of Medicine, 316, 235–240.
Kieneker LM, Gansevoort RT, Mukamal KJ, de Boer RA, Navis G, Bakker SJ and Joosten MM, 2014. Urinary potassium excretion and risk of developing hypertension: the prevention of renal and vascular end-stage disease study. Hypertension, 64, 769–776.
Kieneker LM, Gansevoort RT, de Boer RA, Brouwers FP, Feskens EJ, Geleijnse JM, Navis G, Bakker SJ and Joosten MM and Prevend Study Group, 2016. Urinary potassium excretion and risk of cardiovascular events. American Journal of Clinical Nutrition, 103, 1204–1212.
Kilding AE, Tunstall H, Wraith E, Good M, Gammon C and Smith C, 2009. Sweat rate and sweat electrolyte composition in international female soccer players during game specific training. International Journal of Sports Medicine, 30, 443–447.
Kirkendall AM, Connor WE, Abboud F, Rastogi SP, Anderson TA and Fry M, 1976. The effect of dietary sodium chloride on blood pressure, body fluids, electrolytes, renal function, and serum lipids of normotensive man. Journal of Laboratory and Clinical Medicine, 87, 411–434.
Knuiman JT, Hautvast JG, Zwiauer KF, Widhalm K, Desmet M, De Backer G, Rahneva RR, Petrova VS, Dahl M and Viikari J, 1988. Blood pressure and excretion of sodium, potassium, calcium and magnesium in 8- and 9-year old boys from 19 European centres. European Journal of Clinical Nutrition, 42, 847–855.

Kodama N, Morikuni E, Matsuzaki N, Yoshioka YH, Takeyama H, Yamada H, Kitajima H and Nishimuta M, 2005. Sodium and potassium balances in Japanese young adults. Journal of Nutritional Sciences and Vitaminology, 51, 161–168.
Krijthe BP, Heeringa J, Kors JA, Hofman A, Franco OH, Witteman JC and Stricker BH, 2013. Serum potassium levels and the risk of atrial fibrillation: the Rotterdam Study. International Journal of Cardiology, 168, 5411–5415.
Krishna GG, Miller E and Kapoor S, 1989. Increased blood pressure during potassium depletion in normotensive men. New England Journal of Medicine, 320, 1177–1182.
Kristbjornsdottir OK, Halldorsson TI, Thorsdottir I and Gunnarsdottir I, 2012. Association between 24-hour urine sodium and potassium excretion and diet quality in six-year-old children: a cross sectional study. Nutrition Journal, 11, 94.
Lambert H, Frassetto L, Moore JB, Torgerson D, Gannon R, Burckhardt P and Lanham-New S, 2015. The effect of supplementation with alkaline potassium salts on bone metabolism: a meta-analysis. Osteoporosis International, 26, 1311–1318.
Langford HG, Cushman WC and Hsu H, 1991. Chronic effect of KCl on black-white differences in plasma renin activity, aldosterone, and urinary electrolytes. American Journal of Hypertension, 4, 399–403.
Larsson SC, Virtanen MJ, Mars M, Mannisto S, Pietinen P, Albanes D and Virtamo J, 2008. Magnesium, calcium, potassium, and sodium intakes and risk of stroke in male smokers. Archives of Internal Medicine, 168, 459–465.
Larsson SC, Orsini N and Wolk A, 2011a. Dietary potassium intake and risk of stroke: a dose-response meta-analysis of prospective studies. Stroke, 42, 2746–2750.
Larsson SC, Virtamo J and Wolk A, 2011b. Potassium, calcium, and magnesium intakes and risk of stroke in women. American Journal of Epidemiology, 174, 35–43.
LASER Analytica, 2014. Comprehensive literature search and review of breast milk composition as preparatory work for the setting of dietary reference values for vitamins and minerals. EFSA supporting publication 2014: EN-629, 154 pp.
Lee CN, Reed DM, MacLean CJ, Yano K and Chiu D, 1988. Dietary potassium and stroke. New England Journal of Medicine, 318, 995–996.
Lehnhardt A and Kemper MJ, 2011. Pathogenesis, diagnosis and management of hyperkalemia. Pediatric Nephrology, 26, 377–384.
Lemann J Jr, Pleuss JA, Gray RW and Hoffmann RG, 1991. Potassium administration reduces and potassium deprivation increases urinary calcium excretion in healthy adults [corrected]. Kidney International, 39, 973–983.
Lemons JA, Moye L, Hall D and Simmons M, 1982. Differences in the composition of preterm and term human milk during early lactation. Pediatric Research, 16, 113–117.
Lindheimer MD, Richardson DA, Ehrlich EN and Katz AI, 1987. Potassium homeostasis in pregnancy. Journal of Reproductive Medicine, 32, 517–522.
Liu L, Liu L, Ding Y, Huang Z, He B, Sun S, Zhao G, Zhang H, Miki T, Mizushima S, Ikeda K, Nara Y and Yamori Y, 2001. Ethnic and environmental differences in various markers of dietary intake and blood pressure among Chinese Han and three other minority peoples of China: results from the WHO Cardiovascular Diseases and Alimentary Comparison (CARDIAC) Study. Hypertension Research, 24, 315–322.
Liu F, Zheng S, Mu J, Chu C, Wang L, Wang Y, Xiao H, Wang D, Cao Y, Ren K, Liu E and Yuan Z, 2013. Common variation in with no-lysine kinase 1 (WNK1) and blood pressure responses to dietary sodium or potassium interventions - family-based association study. Circulation Journal, 77, 169–174.
Lorenz J, 2012. Potassium metabolism. In: Oh W, Guignard J-P, Baumgart S (eds.). *Nephrology and fluid/electrolyte physiology. Second edition. Neonatology questions and controversies*. Elsevier Saunders, Philadelphia, USA. pp. 61–73.
Lote C, 2007. Regulation and disorders of plasma potassium. Surgery, 25, 368–674.
Luft FC, Rankin LI, Bloch R, Weyman AE, Willis LR, Murray RH, Grim CE and Weinberger MH, 1979. Cardiovascular and humoral responses to extremes of sodium intake in normal black and white men. Circulation, 60, 697–706.
Luft FC, Weinberger MH and Grim CE, 1982. Sodium sensitivity and resistance in normotensive humans. American Journal of Medicine, 72, 726–736.
Maalouf NM, Moe OW, Adams-Huet B and Sakhaee K, 2011. Hypercalciuria associated with high dietary protein intake is not due to acid load. Journal of Clinical Endocrinology and Metabolism, 96, 3733–3740.
Macdonald HM, New SA, Golden MH, Campbell MK and Reid DM, 2004. Nutritional associations with bone loss during the menopausal transition: evidence of a beneficial effect of calcium, alcohol, and fruit and vegetable nutrients and of a detrimental effect of fatty acids. American Journal of Clinical Nutrition, 79, 155–165.
Macdonald HM, Black AJ, Aucott L, Duthie G, Duthie S, Sandison R, Hardcastle AC, Lanham New SA, Fraser WD and Reid DM, 2008. Effect of potassium citrate supplementation or increased fruit and vegetable intake on bone metabolism in healthy postmenopausal women: a randomized controlled trial. American Journal of Clinical Nutrition, 88, 465–474.
Malhotra MS, Sridharan K and Venkataswamy Y, 1976. Potassium losses in sweat under heat stress. Aviation Space and Environmental Medicine, 47, 503–504.

Malhotra MS, Sridharan K, Venkataswamy Y, Rai RM, Pichan G, Radhakrishnan U and Grover SK, 1981. Effect of restricted potassium intake on its excretion and on physiological responses during heat stress. European Journal of Applied Physiology and Occupational Physiology, 47, 169–179.
Matlou SM, Isles CG, Higgs A, Milne FJ, Murray GD, Schultz E and Starke IF, 1986. Potassium supplementation in blacks with mild to moderate essential hypertension. Journal of Hypertension, 4, 61–64.
Matthesen SK, Larsen T, Vase H, Lauridsen TG and Pedersen EB, 2012. Effect of potassium supplementation on renal tubular function, ambulatory blood pressure and pulse wave velocity in healthy humans. Scandinavian Journal of Clinical and Laboratory Investigation, 72, 78–86.
Maughan RJ, Dargavel LA, Hares R and Shirreffs SM, 2009. Water and salt balance of well-trained swimmers in training. International Journal of Sport Nutrition and Exercise Metabolism, 19, 598–606.
McDonough AA and Nguyen MT, 2012. How does potassium supplementation lower blood pressure?. American Journal of Physiology, Renal Physiology, 302, F1224–F1225.
Meneton P, Schultheis PJ, Greeb J, Nieman ML, Liu LH, Clarke LL, Duffy JJ, Doetschman T, Lorenz JN and Shull GE, 1998. Increased sensitivity to K+ deprivation in colonic H, K-ATPase-deficient mice. Journal of Clinical Investigation, 101, 536–542.
Mensink GB, Heseker H, Richter A, Stahl A and Vohmann C (Robert Koch-Institut & Universität Paderborn), 2007. Ernährungsstudie als KIGGS-Modul (EsKiMo). 143 pp.
Mente A, O'Donnell MJ, Dagenais G, Wielgosz A, Lear SA, McQueen MJ, Jiang Y, Xingyu W, Jian B, Calik KB, Akalin AA, Mony P, Devanath A, Yusufali AH, Lopez-Jaramillo P, Avezum A Jr, Yusoff K, Rosengren A, Kruger L, Orlandini A, Rangarajan S, Teo K and Yusuf S, 2014. Validation and comparison of three formulae to estimate sodium and potassium excretion from a single morning fasting urine compared to 24-h measures in 11 countries. Journal of Hypertension, 32, 1005–1014; discussion 1015.
Mertz W, 1987. Use and misuse of balance studies. Journal of Nutrition, 117, 1811–1813.
Michel A, Martin-Perez M, Ruigomez A and Garcia Rodriguez LA, 2015. Risk factors for hyperkalaemia in a cohort of patients with newly diagnosed heart failure: a nested case-control study in UK general practice. European Journal of Heart Failure, 17, 205–213.
Mickelsen O, Makdani D, Gill JL and Frank RL, 1977. Sodium and potassium intakes and excretions of normal men consuming sodium chloride or a 1:1 mixture of sodium and potassium chlorides. American Journal of Clinical Nutrition, 30, 2033–2040.
Miller JZ, Weinberger MH and Christian JC, 1987. Blood pressure response to potassium supplementation in normotensive adults and children. Hypertension, 10, 437–442.
Moniz CF, Nicolaides KH, Bamforth FJ and Rodeck CH, 1985. Normal reference ranges for biochemical substances relating to renal, hepatic, and bone function in fetal and maternal plasma throughout pregnancy. Journal of Clinical Pathology, 38, 468–472.
Montain SJ, Cheuvront SN and Lukaski HC, 2007. Sweat mineral-element responses during 7 h of exercise-heat stress. International Journal of Sport Nutrition and Exercise Metabolism, 17, 574–582.
Montasser ME, Shimmin LC, Gu D, Chen J, Gu C, Kelly TN, Jaquish CE, Rice T, Rao DC, Cao J, Chen J, Liu DP, Whelton P, He J and Hixson JE, 2010. Blood pressure response to potassium supplementation is associated with genetic variation in endothelin 1 and interactions with E selectin in rural Chinese. Journal of Hypertension, 28, 748–755.
Morris RC Jr, Sebastian A, Forman A, Tanaka M and Schmidlin O, 1999. Normotensive salt sensitivity: effects of race and dietary potassium. Hypertension, 33, 18–23.
Murakami K, Sasaki S, Takahashi Y, Uenishi K, Yamasaki M, Hayabuchi H, Goda T, Oka J, Baba K, Ohki K, Kohri T, Watanabe R and Sugiyama Y, 2007. Misreporting of dietary energy, protein, potassium and sodium in relation to body mass index in young Japanese women. European Journal of Clinical Nutrition, 62, 111–118.
Murphy AJ, Ellis KJ, Kurpad AV, Preston T and Slater C, 2014. Total body potassium revisited. European Journal of Clinical Nutrition, 68, 153–154.
Nagra SA, 1989. Longitudinal study in biochemical composition of human milk during first year of lactation. Journal of Tropical Pediatrics, 35, 126–128.
Naismith DJ and Braschi A, 2003. The effect of low-dose potassium supplementation on blood pressure in apparently healthy volunteers. British Journal of Nutrition, 90, 53–60.
Neville MC, Keller R, Seacat J, Lutes V, Neifert M, Casey C, Allen J and Archer P, 1988. Studies in human lactation: milk volumes in lactating women during the onset of lactation and full lactation. American Journal of Clinical Nutrition, 48, 1375–1386.
New SA, Bolton-Smith C, Grubb DA and Reid DM, 1997. Nutritional influences on bone mineral density: a cross-sectional study in premenopausal women. American Journal of Clinical Nutrition, 65, 1831–1839.
New SA, Robins SP, Campbell MK, Martin JC, Garton MJ, Bolton-Smith C, Grubb DA, Lee SJ and Reid DM, 2000. Dietary influences on bone mass and bone metabolism: further evidence of a positive link between fruit and vegetable consumption and bone health? American Journal of Clinical Nutrition, 71, 142–151.
New SA, MacDonald HM, Campbell MK, Martin JC, Garton MJ, Robins SP and Reid DM, 2004. Lower estimates of net endogenous non-carbonic acid production are positively associated with indexes of bone health in premenopausal and perimenopausal women. American Journal of Clinical Nutrition, 79, 131–138.

Nijsten MW, de Smet BJ and Dofferhoff AS, 1991. Pseudohyperkalemia and platelet counts. New England Journal of Medicine, 325, 1107.
Nishimuta M, Kodama N, Shimada M, Yoshitake Y, Matsuzaki N and Morikuni E, 2012. Estimated equilibrated dietary intakes for nine minerals (Na, K, Ca, Mg, P, Fe, Zn, Cu, and Mn) adjusted by mineral balance medians in young Japanese females. Journal of Nutritional Science and Vitaminology, 58, 118–128.
Nordic Council of Ministers, 2004. Nordic Nutrition Recommendations 2004. Integrating nutrition and physical activity. 435 pp.
Nordic Council of Ministers, 2014. Nordic Nutrition Recommendations 2012. Integrating nutrition and physical activity. Copenhagen, Denmark, 627 pp.
O'Donnell MJ, Yusuf S, Mente A, Gao P, Mann JF, Teo K, McQueen M, Sleight P, Sharma AM, Dans A, Probstfield J and Schmieder RE, 2011. Urinary sodium and potassium excretion and risk of cardiovascular events. Journal of the American Medical Association, 306, 2229–2238.
O'Donnell M, Mente A, Rangarajan S, McQueen MJ, Wang X, Liu L, Yan H, Lee SF, Mony P, Devanath A, Rosengren A, Lopez-Jaramillo P, Diaz R, Avezum A, Lanas F, Yusoff K, Iqbal R, Ilow R, Mohammadifard N, Gulec S, Yusufali AH, Kruger L, Yusuf R, Chifamba J, Kabali C, Dagenais G, Lear SA, Teo K, Yusuf S and PURE Investigators, 2014. Urinary sodium and potassium excretion, mortality, and cardiovascular events. New England Journal of Medicine, 371, 612–623.
Page MJ and Di Cera E, 2006. Role of Na+ and K+ in enzyme function. Physiological Reviews, 86, 1049–1092.
Paice B, Gray JM, McBride D, Donnelly T and Lawson DH, 1983. Hyperkalaemia in patients in hospital. British Medical Journal (Clinical Research Edition), 286, 1189–1192.
Palacios C, Wigertz K, Martin BR, Braun M, Pratt JH, Peacock M and Weaver CM, 2010. Racial differences in potassium homeostasis in response to differences in dietary sodium in girls. American Journal of Clinical Nutrition, 91, 597–603.
Palmer BF, 2014. Regulation of potassium homeostasis. Clinical Journal of the American Society of Nephrology, 10, 1050–1060.
Parr RM, DeMaeyer EM, Iyengar VG, Byrne AR, Kirkbright GF, Schoch G, Niinisto L, Pineda O, Vis HL and Hofvander Y, 1991. Minor and trace elements in human milk from Guatemala, Hungary, Nigeria, Philippines, Sweden, and Zaire. Results from a WHO/IAEA joint project. Biological Trace Element Research, 29, 51–75.
Penney MD, 2008. Sodium, water and potassium. In: Marshall WJ and Bangert SK (eds.). *Clinical Biochemistry: Metabolic and Clinical Aspects*. Churchill Livingstone Elsevier, Philadelphia, USA. pp. 28–66.
Pepin J and Shields C, 2012. Advances in diagnosis and management of hypokalemic and hyperkalemic emergencies. Emergency Medicine Practice, 14, 1–17; quiz 17–18.
Perez V and Chang ET, 2014. Sodium-to-potassium ratio and blood pressure, hypertension, and related factors. Advances in nutrition, 5, 712–741.
Phillips R, Hanchanale VS, Myatt A, Somani B, Nabi G and Biyani CS, 2015. Citrate salts for preventing and treating calcium containing kidney stones in adults. Cochrane Database of Systematic Reviews, 10, CD010057.
Picciano MF, Calkins EJ, Garrick JR and Deering RH, 1981. Milk and mineral intakes of breastfed infants. Acta Paediatrica Scandinavica, 70, 189–194.
Pietinen P, 1982. Estimating sodium intake from food composition data. Annals of Nutrition and Metabolism, 26, 90–99.
Pratt JH, Manatunga AK, Hanna MP and Ambrosius WT, 1997. Effect of administered potassium on the renin-aldosterone axis in young blacks compared with whites. Journal of Hypertension, 15, 877–883.
Rastegar A, 1990. Serum potassium. In: Walker HK, Hall WD, Hurst JW (eds.). *Clinical methods: the history, physical, and laboratory examinations*. Butterworths, Boston, USA. pp. 884–887.
Rodenburg EM, Visser LE, Hoorn EJ, Ruiter R, Lous JJ, Hofman A, Uitterlinden AG and Stricker BH, 2014. Thiazides and the risk of hypokalemia in the general population. Journal of Hypertension, 32, 2092–2097; discussion 2097.
Roe MA, Bell S, Oseredczuk M, Christensen T, Westenbrink S, Pakkala H, Presser K and Finglas PM, 2013. Updated food composition database for nutrient intake. Project developed on the procurement project CFT/EFSA/DCM/2011/03. EFSA Supporting publication 2013:EN-355, 21 pp.
Rose G, 1986. Desirability of changing potassium intake in the community. In: Whelton PK, Whelton AK and Walker WG (eds.). *Potassium in Cardiovascular and Renal Disease*. Marcel Dekker, New York, USA. pp. 411–416.
van Rossum CTM, Fransen HP, Verkaik-Kloosterman J, Buurma-Rethans EJM and Ocké MC, 2011. Dutch National Food Consumption Survey 2007–2010: diet of children and adults aged 7 to 69 years. RIVM Report number: 350050006/2011, National Institute for Public Health and the Environment, 143 pp.
Sacks FM, Willett WC, Smith A, Brown LE, Rosner B and Moore TJ, 1998. Effect on blood pressure of potassium, calcium, and magnesium in women with low habitual intake. Hypertension, 31, 131–138.
Sacks FM, Svetkey LP, Vollmer WM, Appel LJ, Bray GA, Harsha D, Obarzanek E, Conlin PR, Miller ER 3rd, Simons-Morton DG, Karanja N and Lin PH and Group DA-SCR, 2001. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH-Sodium Collaborative Research Group. New England Journal of Medicine, 344, 3–10.

Sakhaee K, Alpern R, Jacobson HR and Pak CY, 1991. Contrasting effects of various potassium salts on renal citrate excretion. Journal of Clinical Endocrinology and Metabolism, 72, 396–400.
Sandle GI and Hunter M, 2010. Apical potassium (BK) channels and enhanced potassium secretion in human colon. QJM, 103, 85–89.
Sandle GI, Gaiger E, Tapster S and Goodship TH, 1986. Enhanced rectal potassium secretion in chronic renal insufficiency: evidence for large intestinal potassium adaptation in man. Clinical Science, 71, 393–401.
Sansom SC and Welling PA, 2007. Two channels for one job. Kidney International, 72, 529–530.
SCF (Scientific Committee for Food), 1993. *Nutrient and energy intakes for the European Community. Reports of the Scientific Committee for Food, 31st Series*. Food - Science and Technique, European Commission, Luxembourg. 248 pp.
Sebastian A, McSherry E and Morris RC Jr, 1971. Renal potassium wasting in renal tubular acidosis (RTA): its occurrence in types 1 and 2 RTA despite sustained correction of systemic acidosis. Journal of Clinical Investigation, 50, 667–678.
Sebastian A, Hernandez RE, Portale AA, Colman J, Tatsuno J and Morris RC Jr, 1990. Dietary potassium influences kidney maintenance of serum phosphorus concentration. Kidney International, 37, 1341–1349.
Seth A, Mossavar-Rahmani Y, Kamensky V, Silver B, Lakshminarayan K, Prentice R, Van Horn L and Wassertheil-Smoller S, 2014. Potassium intake and risk of stroke in women with hypertension and nonhypertension in the Women's Health Initiative. Stroke, 45, 2874–2880.
Sette S, Le Donne C, Piccinelli R, Arcella D, Turrini A and Leclercq C and Group I-SS, 2011. The third Italian National Food Consumption Survey, INRAN-SCAI 2005-06 - part 1: nutrient intakes in Italy. Nutrition, Metabolism and Cardiovascular Diseases, 21, 922–932.
Sevastos N, Theodossiades G and Archimandritis AJ, 2008. Pseudohyperkalemia in serum: a new insight into an old phenomenon. Clinical Medicine and Research, 6, 30–32.
Shirreffs S and Maughan R, 2005. Water-electrolyte balance. In: Caballero B, Allen L and Prentice A (eds.). *Encyclopedia of Human Nutrition*. Elsevier, Oxford, UK. pp. 100–105.
Sinaiko AR, Gomez-Marin O and Prineas RJ, 1993. Effect of low sodium diet or potassium supplementation on adolescent blood pressure. Hypertension, 21, 989–994.
Sluijs I, Czernichow S, Beulens JW, Boer JM, van der Schouw YT, Verschuren WM and Grobbee DE, 2014. Intakes of potassium, magnesium, and calcium and risk of stroke. Stroke, 45, 1148–1150.
Sorensen MV, Matos JE, Praetorius HA and Leipziger J, 2010. Colonic potassium handling. Pflügers Archiv - European Journal of Physiology, 459, 645–656.
Squires RD and Huth EJ, 1959. Experimental potassium depletion in normal human subjects. I. Relation of ionic intakes to the renal conservation of potassium. Journal of Clinical Investigation, 38, 1134–1148.
Sriboonlue P, Prasongwatana V, Suwantrai S, Bovornpadungkitti S, Tungsanga K and Tosukhowong P, 1999. Potassium needed for maintaining its balance in healthy male subjects residing in an area of low potassium intake and with a high environmental temperature. Journal of the Medical Association of Thailand, 82, 690–700.
Stamler J, Brown IJ, Yap IK, Chan Q, Wijeyesekera A, Garcia-Perez I, Chadeau-Hyam M, Ebbels TM, De Iorio M, Posma J, Daviglus ML, Carnethon M, Holmes E, Nicholson JK and Elliott P and Intermap Research Group, 2013. Dietary and urinary metabonomic factors possibly accounting for higher blood pressure of black compared with white Americans: results of International Collaborative Study on macro-/micronutrients and blood pressure. Hypertension, 62, 1074–1080.
Strazzullo P, Siani A and Russo P, 2000. Salt-sensitivity of blood pressure: a paradigm of gene-environment interaction. Italian Heart Journal, 1(Suppl 3), S15–S19.
Subudhi AW, Askew EW and Luetkemeier MJ, 2005. Dehydration. In: Caballero B, Allen L and Prentice A (eds.). *Encyclopedia of Human Nutrition*. Elsevier, Oxford, UK. pp. 518–525.
Tanaka T, Okamura T, Miura K, Kadowaki T, Ueshima H, Nakagawa H and Hashimoto T, 2002. A simple method to estimate populational 24-h urinary sodium and potassium excretion using a casual urine specimen. Journal of Human Hypertension, 16, 97–103.
Tasevska N, Runswick SA and Bingham SA, 2006. Urinary potassium is as reliable as urinary nitrogen for use as a recovery biomarker in dietary studies of free living individuals. Journal of Nutrition, 136, 1334–1340.
Taylor EN, Stampfer MJ and Curhan GC, 2004. Dietary factors and the risk of incident kidney stones in men: new insights after 14 years of follow-up. Journal of the American Society of Nephrology, 15, 3225–3232.
Toraya T, Honda S and Mori K, 2010. Coenzyme B12-dependent diol dehydratase is a potassium ion-requiring calcium metalloenzyme: evidence that the substrate-coordinated metal ion is calcium. Biochemistry, 49, 7210–7217.
Tosukhowong P, Borvonpadungkitti S, Prasongwatana V, Tungsanga K, Jutuporn S, Dissayabutr T, Reungjui S and Sriboonlue P, 2002. Urinary citrate excretion in patients with renal stone: roles of leucocyte ATP citrate lyase activity and potassium salts therapy. Clinica Chimica Acta, 325, 71–78.
Townsend N, Wilson L, Bhatnagar P, Wickramasinghe K, Rayner M and Nichols M, 2016. Cardiovascular disease in Europe: epidemiological update 2016. European Heart Journal, pii: ehw334. [Epub ahead of print]

Tucker KL, Hannan MT, Chen H, Cupples LA, Wilson PW and Kiel DP, 1999. Potassium, magnesium, and fruit and vegetable intakes are associated with greater bone mineral density in elderly men and women. American Journal of Clinical Nutrition, 69, 727–736.

Tunstall-Pedoe H, Woodward M, Tavendale R, A'Brook R and McCluskey MK, 1997. Comparison of the prediction by 27 different factors of coronary heart disease and death in men and women of the Scottish Heart Health Study: cohort study. British Medical Journal, 315, 722–729.

Turban S, Thompson CB, Parekh RS and Appel LJ, 2013. Effects of sodium intake and diet on racial differences in urinary potassium excretion: results from the Dietary Approaches to Stop Hypertension (DASH)-Sodium trial. American Journal of Kidney Diseases, 61, 88–95.

Türk C, Knoll T, Petrik A, Sarica K, Skolarikos A, Straub M and Seitz C, 2015. Guidelines on Urolithiasis. European Association of Urology, 82 pp.

Tyson I, Genna S, Jones RL, Bikerman V and Burrows BA, 1970. Body potassium measurements with a total-body counter. Journal of Nuclear Medicine, 11, 255–259.

Umesawa M, Iso H, Date C, Yamamoto A, Toyoshima H, Watanabe Y, Kikuchi S, Koizumi A, Kondo T, Inaba Y, Tanabe N, Tamakoshi A and Group JS, 2008. Relations between dietary sodium and potassium intakes and mortality from cardiovascular disease: the Japan Collaborative Cohort Study for Evaluation of Cancer Risks. American Journal of Clinical Nutrition, 88, 195–202.

Vinceti M, Filippini T, Crippa A, de Sesmaisons A, Wise L and Orsini N, 2016. A meta-analysis of potassium intake and the risk of stroke. Journal of the American Heart Association, 5, e004210. doi: 10.1161/JAHA.116.004210

Voors AW, Dalferes ER Jr, Frank GC, Aristimuno GG and Berenson GS, 1983. Relation between ingested potassium and sodium balance in young Blacks and whites. American Journal of Clinical Nutrition, 37, 583–594.

Wack RP, Lien EL, Taft D and Roscelli JD, 1997. Electrolyte composition of human breast milk beyond the early postpartum period. Nutrition, 13, 774–777.

Wang Z, Heshka S, Pietrobelli A, Chen Z, Silva AM, Sardinha LB, Wang J, Gallager D and Heymsfield SB, 2007. A new total body potassium method to estimate total body skeletal muscle mass in children. Journal of Nutrition, 137, 1988–1991.

Weinberger MH, 1996. Salt sensitivity of blood pressure in humans. Hypertension, 27, 481–490.

Weiner ID, Linas SL and Wingo CS, 2010. Disorders of potassium metabolism. In: Johnson R, Fluege J and Feehally J (eds.). *Comprehensive Clinical Nephrology*, 4th Edition. Elsevier Saunders, Philadelphia, USA. pp. 118–129.

Weng LC, Yeh WT, Bai CH, Chen HJ, Chuang SY, Chang HY, Lin BF, Chen KJ and Pan WH, 2008. Is ischemic stroke risk related to folate status or other nutrients correlated with folate intake? Stroke, 39, 3152–3158.

Weschler LB, 2008. Sweat electrolyte concentrations obtained from within occlusive coverings are falsely high because sweat itself leaches skin electrolytes. Journal of Applied Physiology, 105, 1376–1377.

West TE and von Saint Andre-von Arnim A, 2014. Clinical presentation and management of severe Ebola virus disease. Annals of the American Thoracic Society, 11, 1341–1350.

Whelton PK, Buring J, Borhani NO, Cohen JD, Cook N, Cutler JA, Kiley JE, Kuller LH, Satterfield S, Sacks FM, Taylor JO and Trials of Hypertension Prevention (TOPH) collaborative research group, 1995. The effect of potassium supplementation in persons with a high-normal blood pressure. Results from phase I of the Trials of Hypertension Prevention (TOHP). Trials of Hypertension Prevention (TOHP) Collaborative Research Group. Annals of Epidemiology, 5, 85–95.

Whelton PK, He J, Cutler JA, Brancati FL, Appel LJ, Follmann D and Klag MJ, 1997. Effects of oral potassium on blood pressure. Meta-analysis of randomized controlled clinical trials. Journal of the American Medical Association, 277, 1624–1632.

WHO (World Health Organization), 2010. *Global status report on noncommunicable diseases 2010*. World Health Organisation, Geneva, Switzerland, 162 pp.

WHO (World Health Organisation), 2012a. *Potassium intake for adults and children*. WHO, Geneva, Switzerland, 42 pp.

WHO (World Health Organisation), 2012b. *Effect of increased potassium intake on blood pressure, renal function, blood lipids and other potential adverse effects*. World Health Organisation, Geneva, Switzerland, 122 pp.

WHO (World Health Organisation), 2012c. *Effect of increased potassium intake on blood pressure and potential adverse effects in children*. World Health Organisation, Geneva, Switzerland, 50 pp.

WHO (World Health Organisation), 2012d. *Effect of increased potassium intake on cardiovascular disease, coronary heart disease and stroke*. World Health Organisation, Geneva, Switzerland, 42 pp.

WHO Multicentre Growth Reference Study Group (World Health Organization), 2006. WHO (World Health Organization) Child Growth Standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development. 336 pp.

Widdowson EM, 1980. Chemical composition and nutritional needs of the fetus at different stages of gestation. In: Aerbi H and Whitehead R (eds.). *Maternal Nutrition During Pregnancy and Lactation*. Hans Huber, Bern, Switzerland. pp. 39–48.

Widdowson EM and Spray CM, 1951. Chemical development in utero. Archives of Disease in Childhood, 26, 205–214.

Wilson DK, Sica DA, Devens M and Nicholson SC, 1996. The influence of potassium intake on dipper and nondipper blood pressure status in an African-American adolescent population. Blood Pressure Monitoring, 1, 447–455.
Wilson DK, Sica DA and Miller SB, 1999. Effects of potassium on blood pressure in salt-sensitive and salt-resistant black adolescents. Hypertension, 34, 181–186.
Witczak A and Jarnuszewska A, 2011. The content of selected mineral nutrients in infant and follow-on formulae available at retail stores in Szczecin. Roczniki Panstwowego Zakladu Higieny, 62, 257–262.
Witteman JC, Willett WC, Stampfer MJ, Colditz GA, Sacks FM, Speizer FE, Rosner B and Hennekens CH, 1989. A prospective study of nutritional factors and hypertension among US women. Circulation, 80, 1320–1327.
Wong CM, O'Connor DT, Martinez JA, Kailasam MT and Parmer RJ, 2003. Diminished renal kallikrein responses to mineralocorticoid stimulation in African Americans: determinants of an intermediate phenotype for hypertension. American Journal of Hypertension, 16, 281–289.
Yoshida M, Fukuwatari T, Sakai J, Tsuji T and Shibata K, 2012. Correlation between mineral intake and urinary excretion in free-living Japanese young women. Food and Nutrition Sciences, 3, 123–128.
Young VR, 1986. Nutritional balance studies: indicators of human requirements or of adaptive mechanisms? Journal of Nutrition, 116, 700–703.
Zhao Q, Gu D, Kelly TN, Hixson JE, Rao DC, Jaquish CE, Chen J, Huang J, Chen CS, Gu CC, Whelton PK and He J, 2010. Association of genetic variants in the apelin-APJ system and ACE2 with blood pressure responses to potassium supplementation: the GenSalt study. American Journal of Hypertension, 23, 606–613.
Ziegler EE, O'Donnell AM, Nelson SE and Fomon SJ, 1976. Body composition of the reference fetus. Growth, 40, 329–341.
Zwiauer K, Eberlein G and Widhalm K, 1991. Inverse relationship between diastolic blood pressure and urinary excretion of potassium in girls aged 8 to 9 years—a preliminary communication. Wiener Klinische Wochenschrift, 103, 519–523.

Abbreviations

AAS	atomic absorption spectroscopy
Afssa	Agence française de sécurité sanitaire des aliments
AI	adequate intake
AR	average requirement
ATP	adenosine triphosphate
BMD	bone mineral density
BMI	body mass index
bw	body weight
CI	confidence interval
COMA	Committee on Medical Aspects of Food Policy
D-A-CH	Deutschland-Austria-Confoederatio Helvetica
DBP	diastolic blood pressure
DH	Department of Health
DIPP	type 1 Diabetes Prediction and Prevention survey
DNFCS	Dutch National Food Consumption Survey
DNSIYC	Diet and Nutrition Survey of Infants and Young Children
DRV	dietary reference value
EPIC	European Prospective Investigation into Cancer and Nutrition study
EsKiMo	Ernährungsstudie als KIGGS-Modul
FAO	Food and Agriculture Organization
FC_PREGNANTWOMEN	food consumption of pregnant women in Latvia
FFQ	food frequency questionnaire
FINDIET	National dietary survey of Finland
FSANZ	Food Standards Australia New Zealand
HMGCR	3-hydroxy-3-methylglutaryl-CoA reductase
HR	hazard ratio
I^2	heterogeneity index
ICP-AES	inductively coupled plasma–atomic emission spectroscopy
ICP-MS	inductively coupled plasma–mass spectrometry
INCA	Etude Individuelle Nationale des Consommations Alimentaires
INRAN-SCAI	Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione – Studio sui Consumi Alimentari in Italia
IOM	US Institute of Medicine of the National Academy of Sciences

IQR	interquartile range
LRNI	Lower Reference Nutrient Intake
NANS	National Adult Nutrition Survey
NDNS	UK National Diet and Nutrient Survey
NHANES	US National Health and Nutrition Examination Survey
NHS	Nurses' Health Study
NNR	Nordic Nutrition Recommendations
NTX	urinary collagen type 1 cross-linked N-telopeptide
NWSSP	Nutrition and Wellbeing of Secondary School Pupils
PREVEND	Prevention of Renal and Vascular End-Stage Disease study
PRI	population reference intake
PURE	Prospective Urban Rural Epidemiology study
RCT	randomised controlled trial
RNI	Recommended Nutrient Intake
RR	Relative risk
SBP	systolic blood pressure
SCF	Scientific Committee for Food
SD	standard deviation
SEM	standard error of the mean
SM	skeletal muscle
SNP	single nucleotide polymorphism
TBK	total body potassium
UL	tolerable upper intake level
UNU	United Nations University
VELS	Verzehrsstudie zur Ermittlung der Lebensmittelaufnahme von Säuglingen und Kleinkindern für die Abschätzung eines akuten Toxizitätsrisikos durch Rückstände von Pflanzenschutzmitteln
WHI	Women's Health Initiative study
WHO	World Health Organization

Appendix A – Potassium concentration in breast milk from mothers of term infants in Western countries

Reference	Number of women (number of samples)	Country	Stage of lactation	Potassium concentration (mg/L)		Analytical method
				Mean ± SD	Median	
Bauer and Gerss (2011)	10	Germany	1–8 weeks	450 ± 74		Absorption spectrometry and colorimetry
Bjorklund et al. (2012)	60 (60)	Sweden	2–3 weeks	633 ± 40	636 (range: 549–729)	ICP-MS
Fly et al. (1998)	14 (28)	USA	2–8 months	459 ± 24 (at rest) 445 ± 15 (after exercise)		ICP-AES
Holt (1993)	4 (28)	UK	5–16 weeks	594 ± 86		Flame photometry
Keenan et al. (1982)	28 (40)	USA	3.5–6 weeks 8.5–18 weeks 20–32 weeks	592 ± 70 538 ± 50 519 ± 43		Flame photometry
Parr et al. (1991)	(71)	Hungary	3 months		554	AAS
	(29)	Sweden			548	
Wack et al. (1997)	30 (140)	USA	0–60 days 61–120 days 121–180 days 181–240 days 241–300 days 301–360 days > 360 days	585 ± 124 490 ± 85 485 ± 66 473 ± 63 470 ± 72 445 ± 53 461 ± 89		ICP-AES
Witczak and Jarnuszewska (2011)	(9)	Poland	5–6 months	520		ICP-AES

Studies were identified by a comprehensive literature search for publications from October 2010 to January 2014 (LASER Analytica, 2014) and additional searches of the literature before these dates. If studies did not report whether infants were born at term or not, it was presumed that infants were born at term.
AAS: atomic absorption spectroscopy; ICP-AES: inductively coupled plasma atomic emission spectroscopy; ICP-MS: inductively coupled plasma mass spectrometry.

Appendix B – Dietary surveys in the EFSA Comprehensive European Food Consumption Database included in the nutrient intake calculation and number of subjects in the different age classes

Country	Dietary survey (year)	Year	Method	Days	Age (years)	Number of subjects						
						Infants	Children	Children	Children	Adults	Adults	Adults
						< 1 year	1–< 3 years	3–< 10 years	10–< 18 years	18–< 65 years	65–< 75 years	≥ 75 years
Finland/1	NWSSP	2007–2008	48–h dietary recall[a]	2 × 2[a]	13–15				306			
Finland/2	FINDIET2012	2012	48–h dietary recall[a]	2[a]	25–74					1,295	413	
Finland/3	DIPP	2000–2010	Dietary record	3	< 1–6	499	500	750				
France	INCA2	2006–2007	Dietary record	7	3–79			482	973	2,276	264	84
Germany/1	EsKiMo	2006	Dietary record	3	6–11			835	393			
Germany/2	VELS	2001–2002	Dietary record	6	< 1–4	158	348[b]	296[b]				
Ireland	NANS	2008–2010	Dietary record	4	18–90					1,274	149	77
Italy	INRAN–SCAI	2005–2006	Dietary record	3	< 1–98	16[c]	36[c]	193	247	2,313	290	228
Latvia	FC_PREGNANTWOMEN	2011	24–h dietary recall	2	15–45				12[c]	991[b]		
Netherlands	DNFCS	2007–2010	24–h dietary recall	2	7–69			447	1,142	2,057	173	
Sweden	Riksmaten	2010–2011	Dietary records (web)[d]	4	18–80					1,430	295	72
United Kingdom/1	DNSIYC	2011	Dietary record	4	0.3–1.5	1,369	1,314					
United Kingdom/2	NDNS Rolling Programme (Years 1–3)	2008–2011	Dietary record	4	1–94		185	651	666	1,266	166	139

DIPP: type 1 Diabetes Prediction and Prevention survey; DNFCS: Dutch National Food Consumption Survey; DNSIYC: Diet and Nutrition Survey of Infants and Young Children; EsKiMo: Ernährungsstudie als KIGGS-Modul; FINDIET: the national dietary survey of Finland; INCA: étude Individuelle Nationale des Consommations Alimentaires; INRAN-SCAI: Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione – Studio sui Consumi Alimentari in Italia; FC_PREGNANTWOMEN: food consumption of pregnant women in Latvia; NANS: National Adult Nutrition Survey; NDNS: National Diet and Nutrition Survey; NWSSP: Nutrition and Wellbeing of Secondary School Pupils; VELS: Verzehrsstudie zur Ermittlung der Lebensmittelaufnahme von Säuglingen und Kleinkindern für die Abschätzung eines akuten Toxizitätsrisikos durch Rückstände von Pflanzenschutzmitteln.

(a): A 48-h dietary recall comprises two consecutive days.

(b): Four subjects from the VELS study (one toddler and three other children) and one subject from the Latvian study (one adult) were not considered in the assessment due to the fact that only one 24-h dietary recall day was available.

(c): 5th or 95th percentile intakes calculated from fewer than 60 subjects require cautious interpretation, as the results may not be statistically robust (EFSA, 2011b) and, therefore, for these dietary surveys/age classes, the 5th and 95th percentile estimates will not be presented in the intake results.

(d): The Swedish dietary records were introduced through the Internet.

Appendix C – Potassium intakes (mg/day and mg/MJ) in males in different surveys, estimated by EFSA according to age classes and country

Age class	Country	Survey	Intakes expressed in mg/day					Intakes expressed in mg/MJ				
			n	Average	Median	P5	P95	n	Average	Median	P5	P95
< 1 year[a]	Germany	VELS	84	1,408	1,404	914	1,882	84	439	447	300	554
	Finland	DIPP_2001_2009	247[b]	873	914	160	1,533	247[b]	496	450	295	916
	United Kingdom	DNSIYC_2011	699	1,535	1,531	916	2,174	699	453	463	307	569
	Italy	INRAN_SCAI_2005_06	9	821	782	[c]	[c]	9	279	250	[c]	[c]
1 to < 3 years	Germany	VELS	174	1,680	1,600	992	2,457	174	361	354	229	506
	Finland	DIPP_2001_2009	245	1,792	1,753	960	2,616	245	494	488	322	673
	United Kingdom	NDNS RollingProgramme years 1–3	107	2,005	1,985	1,300	3,301	107	411	408	301	521
	United Kingdom	DNSIYC_2011	663	1,794	1,777	1,115	2,595	663	431	430	314	563
	Italy	INRAN_SCAI_2005_06	20	1,974	1,853	[c]	[c]	20	417	400	[c]	[c]
3 to < 10 years	Germany	EsKiMo	426	2,499	2,493	1,596	3,554	426	330	326	221	445
	Germany	VELS	146	1,857	1,738	1,176	2,931	146	331	322	233	455
	Finland	DIPP_2001_2009	381	2,749	2,667	1,808	3,906	381	469	471	348	596
	France	INCA2	239	2,094	2,040	1,283	3,080	239	338	329	242	479
	United Kingdom	NDNS RollingProgramme years 1–3	326	2,234	2,210	1,408	3,156	326	356	352	255	464
	Italy	INRAN_SCAI_2005_06	94	2,538	2,512	1,537	3,880	94	348	332	231	482
	Netherlands	DNFCS 2007-2010	231	2,457	2,408	1,458	3,676	231	285	284	195	394
10 to < 18 years	Germany	EsKiMo	197	2,578	2,546	1,601	3,756	197	319	316	221	428
	Finland	NWSSP07_08	136	3,712	3,617	2,323	5,295	136	454	451	323	580
	France	INCA2	449	2,464	2,398	1,457	3,692	449	315	308	228	422
	United Kingdom	NDNS RollingProgramme years 1–3	340	2,597	2,535	1,551	3,959	340	322	316	222	439
	Italy	INRAN_SCAI_2005_06	108	3,144	3,087	1,846	4,719	108	326	311	229	463
	Netherlands	DNFCS 2007-2010	566	2,983	2,855	1,591	4,729	566	280	278	183	396

Age class	Country	Survey	Intakes expressed in mg/day					Intakes expressed in mg/MJ				
			n	Average	Median	P5	P95	n	Average	Median	P5	P95
18 to < 65 years	Finland	FINDIET2012	585	3,991	3,856	2,298	6,059	585	439	428	288	606
	France	INCA2	936	2,964	2,901	1,583	4,481	936	341	334	237	468
	United Kingdom	NDNS RollingProgramme years 1–3	560	3,203	3,178	1,780	4,976	560	368	363	247	516
	Ireland	NANS_2012	634	3,827	3,770	2,107	5,658	634	385	376	267	516
	Italy	INRAN_SCAI_2005_06	1,068	3,043	2,963	1,809	4,631	1,068	339	327	228	480
	Netherlands	DNFCS 2007–2010	1,023	3,799	3,663	2,186	5,708	1,023	343	329	227	512
	Sweden	Riksmaten 2010	623	3,835	3,734	2,043	5,846	623	393	389	260	527
65 to < 75 years	Finland	FINDIET2012	210	3,675	3,521	2,086	5,722	210	460	443	281	671
	France	INCA2	111	3,209	3,111	1,872	4,795	111	374	363	267	510
	United Kingdom	NDNS RollingProgramme years 1–3	75	3,391	3,344	1,543	4,970	75	410	410	272	565
	Ireland	NANS_2012	72	3,511	3,685	1,833	5,040	72	409	390	280	574
	Italy	INRAN_SCAI_2005_06	133	3,135	3,060	1,910	4,284	133	363	341	264	526
	Netherlands	DNFCS 2007–2010	91	3,529	3,548	2,043	5,014	91	390	376	276	564
	Sweden	Riksmaten 2010	127	3,819	3,768	2,152	5,984	127	444	437	345	600
≥ 75 years	France	INCA2	40	2,856	2,720	(c)	(c)	40	375	366	(c)	(c)
	United Kingdom	NDNS RollingProgramme years 1–3	56	2,884	2,803	(c)	(c)	56	404	407	(c)	(c)
	Ireland	NANS_2012	34	3,164	3,075	(c)	(c)	34	411	423	(c)	(c)
	Italy	INRAN_SCAI_2005_06	69	3,095	3,186	1,860	4,632	69	359	351	252	468
	Sweden	Riksmaten 2010	42	3,634	3,743	(c)	(c)	42	436	429	(c)	(c)

n: number of individuals; P5: 5th percentile; P95: 95th percentile.
DIPP: type 1 Diabetes Prediction and Prevention survey; DNFCS: Dutch National Food Consumption Survey; DNSIYC: Diet and Nutrition Survey of Infants and Young Children; EsKiMo: Ernährungsstudie als KIGGS-Modul; FINDIET: the national dietary survey of Finland; INCA: étude Individuelle Nationale des Consommations Alimentaires; INRAN-SCAI: Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione - Studio sui Consumi Alimentari in Italia; FC_PREGNANTWOMEN: food consumption of pregnant women in Latvia; NANS: National Adult Nutrition Survey; NDNS: National Diet and Nutrition Survey; NWSSP: Nutrition and Wellbeing of Secondary School Pupils; VELS: Verzehrsstudie zur Ermittlung der Lebensmittelaufnahme von Säuglingen und Kleinkindern für die Abschätzung eines akuten Toxizitätsrisikos durch Rückstände von Pflanzenschutzmitteln.
(a): The proportions of breast-fed infants were 58% in the Finnish survey, 40% in the German survey, 44% in the Italian survey and 21% in the UK survey. Most infants were partially breast-fed. For the Italian and German surveys, breast milk intake estimates were derived from the number of breastfeeding events recorded per day multiplied by standard breast milk amounts consumed on an eating occasion at different ages. For the UK survey, the amount of breast milk consumed was either directly quantified by the mother (expressed breast milk) or extrapolated from the duration of each breastfeeding event. As no information on the breastfeeding events was reported in the Finnish survey, breast milk intake was not taken into consideration in the intake estimates of Finnish infants.
(b): n = 245 for estimated intake expressed in mg/MJ.
(c): 5th or 95th percentile intakes calculated from fewer than 60 subjects require cautious interpretation, as the results may not be statistically robust (EFSA, 2011b) and, therefore, for these dietary surveys/age classes, the 5th and 95th percentile estimates will not be presented in the intake results.

Appendix D – Potassium intakes (mg/day and mg/MJ) in females in different surveys, estimated by EFSA according to age classes and country

Age class	Country	Survey	Intakes expressed in mg/day					Intakes expressed in mg/MJ				
			n	Average	Median	P5	P95	n	Average	Median	P5	P95
< 1 year[a]	Germany	VELS	75	1,252	1,276	857	1,679	75	434	437	287	562
	Finland	DIPP_2001_2009	253[b]	826	833	176	1,543	253[b]	546	474	303	972
	United Kingdom	DNSIYC_2011	670	1,370	1,360	741	2,058	670	449	457	266	583
	Italy	INRAN_SCAI_2005_06	7	1,175	1,304	(c)	(c)	7	397	390	(c)	(c)
1 to < 3 years	Germany	VELS	174	1,516	1,510	949	2,195	174	356	350	241	507
	Finland	DIPP_2001_2009	255	1,690	1,648	826	2,555	255	495	496	337	661
	United Kingdom	NDNS RollingProgramme years 1–3	78	1,752	1,741	1,090	2,502	78	390	396	267	498
	United Kingdom	DNSIYC_2011	651	1,688	1,683	1,016	2,416	651	429	426	302	554
	Italy	INRAN_SCAI_2005_06	16	1,789	1,710	(c)	(c)	16	383	375	(c)	(c)
3 to < 10 years	Germany	EsKiMo	409	2,324	2,251	1,419	3,489	409	343	339	240	461
	Germany	VELS	147	1,668	1,630	987	2,390	147	324	318	219	458
	Finland	DIPP_2001_2009	369	2,492	2,448	1,680	3,535	369	473	468	352	614
	France	INCA2	243	1,939	1,894	1,269	2,693	243	350	343	261	459
	United Kingdom	NDNS RollingProgramme years 1–3	325	2,126	2,105	1,314	3,074	325	358	351	259	467
	Italy	INRAN_SCAI_2005_06	99	2,417	2,349	1,274	3,389	99	336	333	245	482
	Netherlands	DNFCS 2007–2010	216	2,306	2,270	1,397	3,355	216	284	274	193	413
10 to < 18 years	Germany	EsKiMo	196	2,450	2,363	1,402	3,730	196	330	319	217	463
	Finland	NWSSP07_08	170	3,057	3,050	1,719	4,649	170	464	470	331	597
	France	INCA2	524	2,093	2,071	1,185	3,015	524	333	324	236	454
	United Kingdom	NDNS RollingProgramme years 1–3	326	2,202	2,157	1,268	3,365	326	329	320	225	477
	Italy	INRAN_SCAI_2005_06	139	2,685	2,523	1,588	4,150	139	339	330	214	484
	Latvia	FC_PREGNANTWOMEN_2011[d]	12	3,692	3,603	(c)	(c)	12	373	376	(c)	(c)
	Netherlands	DNFCS 2007–2010	576	2 579	2 528	1,473	3 920	576	294	284	185	432

Age class	Country	Survey	Intakes expressed in mg/day					Intakes expressed in mg/MJ				
			n	Average	Median	P5	P95	n	Average	Median	P5	P95
18 to < 65 years	Finland	FINDIET2012	710	3,297	3,237	1,885	4,997	710	467	452	310	684
	France	INCA2	1,340	2,487	2,414	1,381	3,830	1,340	389	375	264	573
	United Kingdom	NDNS RollingProgramme years 1–3	706	2,673	2,645	1,481	3,994	706	408	395	265	598
	Ireland	NANS_2012	640	2,982	2,896	1,726	4,522	640	408	396	276	579
	Italy	INRAN_SCAI_2005_06	1,245	2,715	2,659	1,535	4,024	1,245	377	359	248	566
	Latvia	FC_PREGNANTWOMEN_2011[(d)]	990	3,452	3,384	2,165	5,048	990	412	402	264	603
	Netherlands	DNFCS 2007–2010	1,034	3,061	2,973	1,722	4,719	1,034	377	364	225	573
	Sweden	Riksmaten 2010	807	3,179	3,080	1,843	4,772	807	435	411	282	592
65 to < 75 years	Finland	FINDIET2012	203	3,031	2,962	1,935	4,494	203	497	483	334	683
	France	INCA2	153	2,562	2,503	1,485	3,752	153	413	403	281	563
	United Kingdom	NDNS RollingProgramme years 1–3	91	2,781	2,698	1,708	4,016	91	465	436	314	679
	Ireland	NANS_2012	77	3,201	3,071	1,855	4,851	77	474	473	334	626
	Italy	INRAN_SCAI_2005_06	157	2,791	2,751	1,463	4,110	157	410	385	268	660
	Netherlands	DNFCS 2007–2010	82	3,050	2,895	1,804	4,369	82	428	407	268	604
	Sweden	Riksmaten 2010	168	3,262	3,160	2,001	4,595	168	470	463	360	597
≥ 75 years	France	INCA2	44	2,463	2,465	[(c)]	[(c)]	44	414	397	[(c)]	[(c)]
	United Kingdom	NDNS RollingProgramme years 1–3	83	2,731	2,750	1,692	3,512	83	459	454	319	635
	Ireland	NANS_2012	43	2,924	2,948	[(c)]	[(c)]	43	471	464	[(c)]	[(c)]
	Italy	INRAN_SCAI_2005_06	159	2,602	2,580	1,604	3,767	159	394	384	253	588
	Sweden	Riksmaten 2010	30	3,339	3,180	[(c)]	[(c)]	30	484	484	[(c)]	[(c)]

n: number of individuals; P5: 5th percentile; P95: 95th percentile.

DIPP: type 1 Diabetes Prediction and Prevention survey; DNFCS: Dutch National Food Consumption Survey; DNSIYC: Diet and Nutrition Survey of Infants and Young Children; EsKiMo: Ernährungsstudie als KIGGS-Modul; FINDIET: the national dietary survey of Finland; INCA: étude Individuelle Nationale des Consommations Alimentaires; INRAN-SCAI: Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione - Studio sui Consumi Alimentari in Italia; FC_PREGNANTWOMEN: food consumption of pregnant women in Latvia; NANS: National Adult Nutrition Survey; NDNS: National Diet and Nutrition Survey; NWSSP: Nutrition and Wellbeing of Secondary School Pupils; VELS: Verzehrsstudie zur Ermittlung der Lebensmittelaufnahme von Säuglingen und Kleinkindern für die Abschätzung eines akuten Toxizitätsrisikos durch Rückstände von Pflanzenschutzmitteln.

(a): The proportions of breast-fed infants were 58% in the Finnish survey, 40% in the German survey, 44% in the Italian survey and 21% in the UK survey. Most infants were partially breast-fed. For the Italian and German surveys, breast milk intake estimates were derived from the number of breastfeeding events recorded per day multiplied by standard breast milk amounts consumed on an eating occasion at different ages. For the UK survey, the amount of breast milk consumed was either directly quantified by the mother (expressed breast milk) or extrapolated from the duration of each breastfeeding event. As no information on the breastfeeding events was reported in the Finnish survey, breast milk intake was not taken into consideration in the intake estimates of Finnish infants.

(b): n = 251 for estimated intake expressed in mg/MJ.

(c): 5th or 95th percentile intakes calculated from fewer than 60 subjects require cautious interpretation, as the results may not be statistically robust (EFSA, 2011b) and, therefore, for these dietary surveys/age classes, the 5th and 95th percentile estimates will not be presented in the intake results.

(d): Pregnant women only.

Appendix E – Minimum and maximum percentage contribution of different food groups (FoodEx2 level1) to potassium intakes in males

Food groups	Age (years)						
	< 1 year	1 to < 3 years	3 to < 10 years	10 to < 18 years	18 to < 65 years	65 to < 75 years	≥ 75 years
Additives, flavours, baking and processing aids	< 1	< 1	0	< 1–1	< 1	< 1	0
Alcoholic beverages	< 1	< 1	< 1	< 1–1	3–7	2–7	2–7
Animal and vegetable fats and oils	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Coffee, cocoa, tea and infusions	< 1–2	< 1–5	1–8	2–6	5–13	5–14	4–12
Composite dishes	< 1–4	< 1–7	< 1–7	< 1–10	< 1–13	< 1–12	< 1–12
Eggs and egg products	< 1	< 1–1	< 1–1	< 1–1	< 1–1	< 1–1	< 1–1
Fish, seafood, amphibians, reptiles and invertebrates	< 1–1	< 1–4	< 1–4	< 1–4	1–4	2–5	2–5
Food products for young population	20–54	3–16	< 1–1	< 1	< 1	–	–
Fruit and fruit products	5–14	9–14	6–11	4–9	4–11	6–14	6–14
Fruit and vegetable juices and nectars	< 1–2	1–8	4–10	4–10	1–6	1–5	1–3
Grains and grain-based products	3–6	8–14	9–19	11–20	11–15	11–17	12–19
Human milk	< 1–26	< 1–1	–	–	–	–	–
Legumes, nuts, oilseeds and spices	< 1–2	1–3	1–4	1–4	1–4	1–4	1–3
Meat and meat products	< 1–4	4–8	6–13	8–16	9–15	8–13	7–12
Milk and dairy products	7–18	25–34	17–36	13–30	9–19	8–18	10–14
Products for non-standard diets, food imitates and food supplements or fortifying agents	< 1	0	< 1–1	< 1–1	< 1–2	< 1	< 1–1
Seasoning, sauces and condiments	< 1–1	< 1–1	< 1–2	< 1–2	< 1–3	< 1–1	< 1–1
Starchy roots or tubers and products thereof, sugar plants	1–21	6–19	10–18	12–21	9–19	9–18	12–19
Sugar, confectionery and water-based sweet desserts	< 1	< 1–1	1–4	1–4	< 1–1	< 1–1	< 1–1
Vegetables and vegetable products	1–15	5–10	7–16	7–19	5–24	5–24	6–22
Water and water-based beverages	< 1	< 1–1	< 1–2	< 1–2	< 1–4	< 1–2	< 1–2

'–' means that there was no consumption event of the food group for the age and sex group considered, whereas '0' means that there were some consumption events, but that the food group does not contribute to potassium intake in the age and sex group considered.

Appendix F – Minimum and maximum percentage contribution of different food groups (FoodEx2 level1) to potassium intakes in females

Food groups	Age (years)						
	< 1 year	1 to < 3 years	3 to < 10 years	10 to < 18 years	18 to < 65 years	65 to < 75 years	≥ 75 years
Additives, flavours, baking and processing aids	< 1	0	0	< 1–1	< 1	< 1	0
Alcoholic beverages	< 1	< 1	< 1	< 1	< 1–3	1–3	1–2
Animal and vegetable fats and oils	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Coffee, cocoa, tea and infusions	< 1–15[(a)]	< 1–5	1–8	2–6	4–15	4–17	4–12
Composite dishes	< 1–2	< 1–7	< 1–7	< 1–10	< 1–14	< 1–12	< 1–14
Eggs and egg products	< 1	< 1–1	< 1–1	< 1–1	< 1–1	< 1–1	< 1–1
Fish, seafood, amphibians, reptiles and invertebrates	0	< 1–6	< 1–3	< 1–4	1–4	1–5	1–5
Food products for young population	19–57	3–16	< 1–1	< 1	< 1	–	< 1
Fruit and fruit products	8–12	9–14	7–12	6–15	7–13	9–16	9–17
Fruit and vegetable juices and nectars	< 1–2	1–7	3–10	3–10	2–6	1–4	2–4
Grains and grain-based products	4–6	9–14	9–18	12–19	12–23	10–16	10–18
Human milk	< 1–9	< 1–1	–	–	–	–	–
Legumes, nuts, oilseeds and spices	< 1–2	1–3	1–4	1–3	2–4	1–3	1–2
Meat and meat products	1–4	4–7	5–14	7–14	8–12	7–11	6–11
Milk and dairy products	4–22	23–38	17–37	11–27	10–20	10–18	12–16
Products for non-standard diets, food imitates and food supplements or fortifying agents	< 1	< 1	0–1	< 1–1	< 1–2	< 1–1	< 1–1
Seasoning, sauces and condiments	< 1–1	< 1–1	< 1–2	< 1–2	< 1–2	< 1–1	< 1–1
Starchy roots or tubers and products thereof, sugar plants	4–20	6–17	10–19	11–23	8–17	9–15	10–13
Sugar, confectionery and water-based sweet desserts	< 1–1	< 1–1	1–3	1–4	< 1–5	< 1–1	< 1–1
Vegetables and vegetable products	4–17	6–12	8–16	8–20	7–24	7–24	7–22
Water and water-based beverages	< 1–1	< 1–1	< 1–3	< 1–2	< 1–4	< 1–3	< 1–3

'–' means that there was no consumption event of the food group for the age and sex group considered, whereas '0' means that there were some consumption events, but that the food group does not contribute to potassium intake in the age and sex group considered.

(a): The value of 15% comes from the INRAN_SCAI_2005_06 survey (n girls < 1 year = 7) and originates from one subject who drank small amounts of tea on each of the 3 days of the survey.

Appendix G – Comparison between EFSA intake estimates and published estimates from the same survey

Country	Survey (age range)	Reference	Percentage of published intake[(a)]
Finland	NWSSP (13–15 years)	Hoppu et al. (2010)	102–103
	FINDIET 2012 (25–74 years)	Helldán et al. (2013)	95–97
France	INCA2 (3–17 years)	Afssa (2009)	92–102
Germany	EsKiMo (6–11 years)	Mensink et al. (2007)	105–112
	VELS (< 1–4 years)	Kersting and Clausen (2003)	97–105[(b)]
Ireland	NANS (18–90 years)	IUNA (2011)	101–107
Italy	INRAN-SCAI (1 month–98 years)	Sette et al. (2011)	95–109
Netherlands	DNFCS 2007_2010 (7–69 years)	van Rossum et al. (2011)	96–99
UK	NDNS years 1–3 (3–94 years)	Bates et al. (2012)	97–107

DNFCS: Dutch National Food Consumption Survey; EsKiMo: Ernährungsstudie als KIGGS-Modul; FINDIET: the national dietary survey of Finland; INCA: étude Individuelle Nationale des Consommations Alimentaires; INRAN-SCAI: Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione - Studio sui Consumi Alimentari in Italia; NANS: National Adult Nutrition Survey; NWSSP: Nutrition and Wellbeing of Secondary School Pupils; VELS: Verzehrsstudie zur Ermittlung der Lebensmittelaufnahme von Säuglingen und Kleinkindern für die Abschätzung eines akuten Toxizitätsrisikos durch Rückstände von Pflanzenschutzmitteln.

(a): Range over different age groups in a specific survey.

(b): For the VELS survey, the comparison refers to median values, as average potassium intake estimates were not available in the literature.

Appendix H – Meta-analyses of prospective cohort studies on potassium intake and risk of total stroke

Individual studies	Country	Larsson et al. (2011a)	Aburto et al. (2013), WHO (2012d)	D'Elia et al. (2014)	Adebamowo et al. (2015b)	Vinceti et al. (2016)
Khaw and Barrett-Connor (1987)	USA	x	x	x	x	x
Lee et al. (1988)	Japan	–	–	–	–	x
Ascherio et al. (1998)	USA	x	x	x	x	–[(e)]
Iso et al. (1999)	USA	x	x	x	x	–[(f)]
Bazzano et al. (2001)	USA	x	x	x	x	x
Green et al. (2002)	USA	x	x	x	x	x
Geleijnse et al. (2007)[(a)]	Netherlands	x	x	x	x	x
Larsson et al. (2008)	Finland	x	x	x	x	x
Umesawa et al. (2008)	Japan	x	x	x	x	x
Weng et al. (2008)	Taiwan	x	x	x	x	x
Larsson et al. (2011b)	Sweden	x	–	x	x	x
O'Donnell et al. (2011)[(a)]	40 countries[(b)]	–	x	x	–	x
Sluijs et al. (2014)	Netherlands	–	–	x	x	x
Adebamowo et al. (2015a)	USA	–	–	–	x	x
Adebamowo et al. (2015b)	USA	–	–	–	–	x
Seth et al. (2014)	USA	–	–	–	–	x
O'Donnell et al. (2014)[(a)]	40 countries[(b)]	–	–	–	–	x
Kieneker et al. (2016)[(a)]	Netherlands	–	–	–	–	x
Number of studies included		10	10	12	12	16
Pooled RR (95% CI)[(c)]		0.89 (0.83–0.96) by 1,000 mg increase of potassium intake (I^2 = 50.8%[(d)])	0.76 (0.66–0.88) for higher potassium intake compared to lower potassium intake (I^2 = 62%)	0.80 (0.72–0.90) for higher potassium intake compared to lower potassium intake (I^2 = 47%); 0.90 (0.84–0.96) by 1,000 mg increase of potassium intake (I^2 = 47%)	0.91 (0.88–0.94) by 1,000 mg increase of potassium intake (I^2 not reported)	0.87 (0.80–0.94) for higher potassium intake compared to lower potassium intake (I^2 = 45.5%)

CI: confidence interval; I^2: heterogeneity index; RR: relative risk.
(a): Potassium intake estimated on the basis of urinary potassium excretion.
(b): Argentina, Australia, Austria, Belgium, Canada, China, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hong King, Hungary, Ireland, Italy, Malaysia, Mexico, the Netherland, New Zealand, Norway, the Philippines, Poland, Portugal, Russia, Singapore, Slovakia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, Ukraine, United Arab Emirates, the United Kingdom, the USA.
(c): Calculated from study-specific RRs adjusted for the most number of covariates.
(d): In a sensitivity analysis, Khaw and Barrett-Connor (1987) was found to account for the observed heterogeneity. When that study was omitted, the pooled RR was 0.91 (95% CI = 0.86–0.96) and between-study heterogeneity was I^2 = 20.7%.
(e): Not included as more recent results for the same cohort were available (Adebamowo et al., 2015a).
(f): Not included as more recent results for the same cohort were available (Adebamowo et al., 2015b).