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REVIEW

A comprehensive review on salt and health and current experience of worldwide salt reduction programmes

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Cardiovascular disease (CVD) is the leading cause of death and disability worldwide. Raised blood pressure (BP), cholesterol and smoking, are the major risk factors. Among these, raised BP is the most important cause, accounting for 62% of strokes and 49% of coronary heart disease. Importantly, the risk is throughout the range of BP, starting at systolic 115 mm Hg. There is strong evidence that our current consumption of salt is the major factor increasing BP and thereby CVD. Furthermore, a high salt diet may have direct harmful effects independent of its effect on BP, for example, increasing the risk of stroke, left ventricular hypertrophy and renal disease. Increasing evidence also suggests that salt intake is related to obesity through soft drink consumption, associated with renal stones and osteoporosis and is probably a major cause of stomach cancer. In most developed countries, a reduction in salt intake can be achieved by a gradual and sustained reduction in the amount of salt added to food by the food industry. In other countries where most of the salt consumed comes from salt added during cooking or from sauces, a public health campaign is needed to encourage consumers to use less salt. Several countries have already reduced salt intake, for example, Japan (1960–1970), Finland (1975 onwards) and now the United Kingdom. The challenge is to spread this out to all other countries. A modest reduction in population salt intake worldwide will result in a major improvement in public health.
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Introduction

For several million years the ancestors of humans, like all other mammals, ate a diet that contained less than 0.25 g of salt per day. About 5000 years ago, the Chinese discovered that salt could be used to preserve food. Salt then became of great economic importance as it was possible to preserve food during the winter and allowed the development of settled communities. Salt was the most taxed and traded commodity in the world, with intake reaching a peak around the 1870s. However, with the invention of the deep freezer and the refrigerator salt was no longer required as a preservative. Salt intake had been declining, but with the recent large increase in consumption of highly salted processed food, salt intake is now increasing towards levels similar to those of the 1870s, and is approximately 9-12 g/day (that is, 50 times more than our evolutionary salt intake) in most countries in the world.[1,2]

These changes in salt intake present a major challenge to the kidneys to excrete these large amounts of salt. The consequence is that the high salt intake causes a rise in blood pressure (BP),[1,3,4] thereby increasing the risk of cardiovascular disease (CVD — strokes, heart attacks and heart failure)[5,6] and renal disease.[7–9] Furthermore, a high salt intake may have direct harmful effects, for example, increasing the risk of stroke,[10,11] left ventricular hypertrophy,[12] progression of renal disease and proteinuria,[7] independent of but additive to the effect of salt on blood pressure. There is also increasing evidence that salt intake is indirectly related to obesity through soft drink consumption,[13,14] associated with an increased risk of renal stones and osteoporosis,[15] and is probably a major cause of stomach cancer.[16]

In this article, we review the evidence for the harmful effects of a high salt intake and the beneficial effects of reducing salt consumption. Additionally, we provide an update on the current experience of worldwide salt reduction programmes, which have been successfully carried

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out in several countries and a reduction in salt intake has been achieved in these countries.

Literature search

On the basis of the two search strategies developed earlier for meta-analyses on salt and BP in adults[17] and children,[18] we updated the search for electronic database—MEDLINE, EMBASE and the Cochrane Library. Furthermore, we reviewed the reference list of original and review articles to search for more studies.

Raised BP: the major cause of death in the world

In the late nineteenth century, life assurance and mortgage companies were the first to realize that the higher the BP, the greater the chances of dying at an earlier age. Extensive epidemiological work and treatment trials have subsequently confirmed this finding. A recent systematic analysis of population health data shows that raised BP is the biggest cause of death and the second biggest cause of disability coming after malnutrition in children worldwide.[19]

The damage that raised BP does, is mainly through its effect on CVD, which is the major cause of deaths worldwide. It has been shown that raised BP, raised cholesterol and smoking account for over 80% of CVD.[20] However, raised BP is the single most important cause, responsible for 62% of strokes and 49% of coronary heart disease (CHD).[21] Importantly, there is a continuous graded relationship between BP and CVD, beginning at 115/75 mm Hg.[22] Therefore, for most countries in the world, over 80% of all adults are at risk of CVD from their BP. In addition, although the risk of CVD increases progressively with increasing BP, the greatest number of CVD deaths attributable to BP occurs in the upper range of the usual BP (that is, BP around 130/80 mm Hg). This is because there are so many individuals having BP around this level in the population,[23] that is, a level which would not currently be treated with drugs. Therefore, a population-based approach through diet and lifestyle, for example, a reduction in salt intake, aimed at achieving a downward shift in the distribution of BP in the whole population, even by a small amount, will have a large impact on reducing the appalling burden of CVD.

Underlying factors that increase BP

Evidence suggests that obesity coupled with a lack of exercise is an important factor involved in the development of high BP. However, there is much stronger evidence that salt intake is related to the development of hypertension, and in particular the rise in BP with age,[1] and that fruit and vegetables through an increase in potassium intake have the opposite effect and may, in certain circumstances, partially offset the effects of a high salt intake.[24–26] Excess alcohol intake is related to BP, but the effect appears to be transient and there is debate as to whether excess alcohol consumption causes a more sustained increase in BP. Other dietary factors, for example, calcium, magnesium, fat and protein intake, have also been studied but so far the results are inconsistent.

Evidence that relates salt to BP

A large number of studies have been conducted, all of which support the concept that salt intake is the major factor increasing BP in the population. The diversity and strength of the evidence is much greater than other lifestyle factors, for example, overweight, low consumption of fruit and vegetables and lack of physical exercise.

Animal studies

Numerous studies in rat, dog, chicken, rabbit, baboon and chimpanzee have all shown that salt intake plays an important role in regulating BP.[27,28] Furthermore, in all forms of experimental hypertension, whatever the animal model, a high salt intake is essential for BP to rise. A study in chimpanzees (98.8% genetic homology with man) demonstrates that a gradual increase in salt intake from 0.5 g/day which is close to humans' evolutionary intake, to 10–15 g/day which is similar to our current salt intake, causes a progressive rise in BP (Figure 1).[27]

Human genetic studies

There are several very rare genetic causes of high BP. All of these result in a reduction in the kidney's ability to excrete salt, and thereby cause high BP.[29,30] The raised BP is considerably aggravated if salt is consumed. Rare genetic causes of low BP have also been described. These result in the kidney being unable to hold on to salt normally, thereby causing low BP. These forms of low BP are ameliorated by a high salt intake. Overall, these studies clearly indicate the importance of salt intake in regulating BP in humans.

Epidemiological studies

There are a number of studies in undeveloped societies that do not or did not have access to salt. These societies have lower BP compared with developed societies and there is no rise in BP with age. Although there may be other factors that also contribute to the lower BP, several studies have clearly demonstrated the profound importance of salt intake. For instance, a study in the Pacific Islands where one undeveloped community used seawater in their food and the other did not, showed that the community using seawater had higher BP.[31]

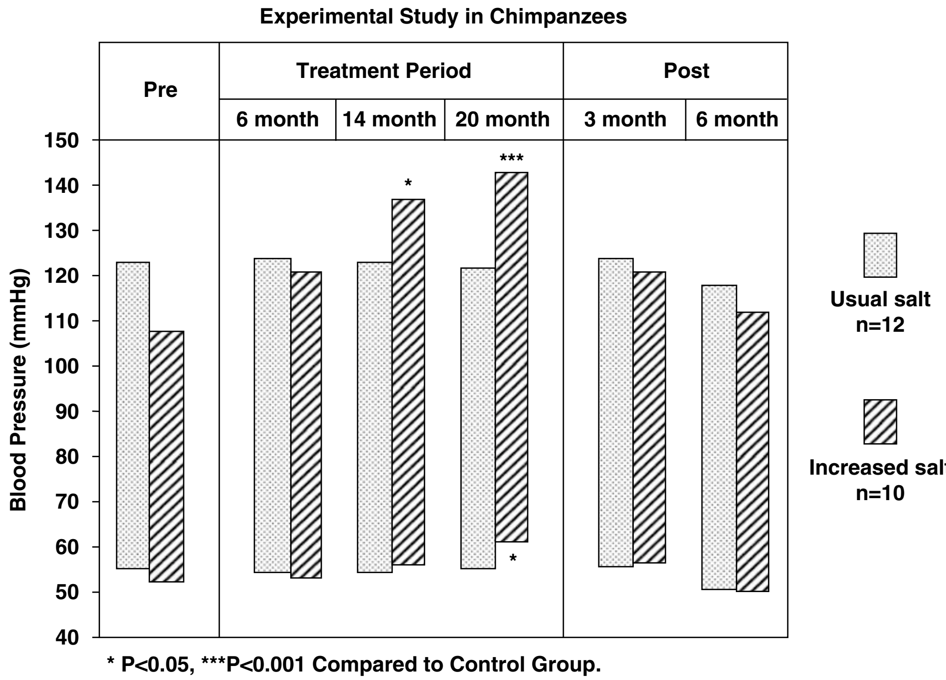

Figure 1 Blood pressure in chimpanzees who either continued on their usual diet (0.5 g/day of salt) or were given an increased salt intake (10-15 g/day). At the end of the 20-month study, the salt supplements were stopped and blood pressure declined to that of the control group. Adapted from Denton *et al.*[27]

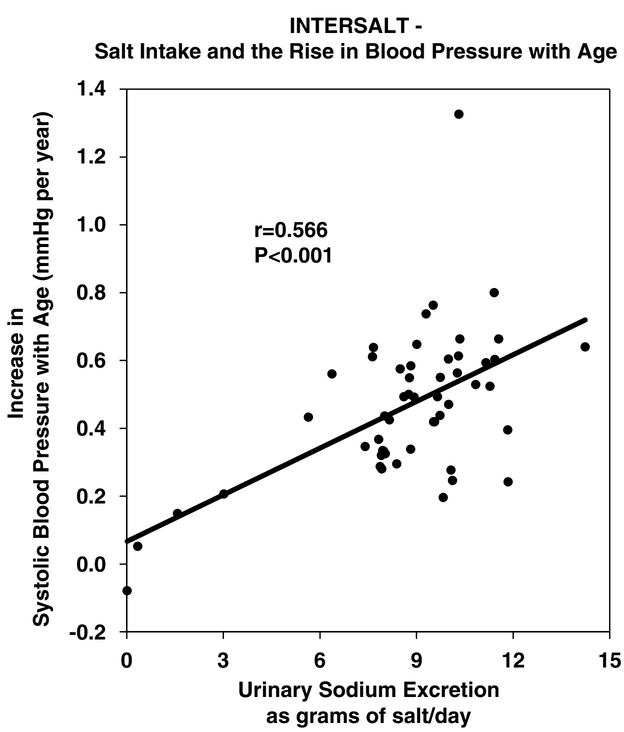

Figure 2 Relationship between salt intake and the slope of the rise in systolic blood pressure with age in 52 centres in the INTERSALT study. Adapted from Intersalt Cooperative Research group.[1]

Another study of two rural communities in Nigeria, one of which had access to salt from a salt lake and the other did not, showed differences in salt intake and differences in BP, and yet in all other aspects of lifestyle and diet the two communities were similar.[32] The Qash'qai, an undeveloped tribe living in Iran who had access to salt deposits on the ground, developed high BP and a rise in BP with age similar to that which occurred in western communities, but in all aspects lived a lifestyle similar to undeveloped communities who did not have access to salt.[33]

In spite of this evidence, it was felt necessary to set up a large international study on salt and BP (INTERSALT)[1] using a standardized method for measuring BP and 24-h urinary sodium. The intention was to study communities with a wide range of salt intake from 0.5 to 25 g/day. However, among the 52 communities recruited into the study, only four had a low salt intake (that is, 3 g/day or less) and the majority lay between 6 and 12 g/day and none had the high salt intake as originally envisaged. Nevertheless, the study demonstrated a significant positive relationship between salt intake (as judged by 24-h urinary sodium) and BP. There was also a highly significant positive relationship between salt intake and the increase in BP with age (Figure 2). It was estimated that an increase of 6 g/day in salt intake over 30 years would lead to an increase in systolic BP by 9 mm Hg.[1]

One criticism of the INTERSALT study made by the Salt Institute (a public relations company defending the interests of salt extractors and manufacturers worldwide) was that when the four communities consuming less salt were excluded, there was no overall relationship remaining between salt intake and BP in the 48 communities. Subsequently, the Salt Institute published a paper criticiz-

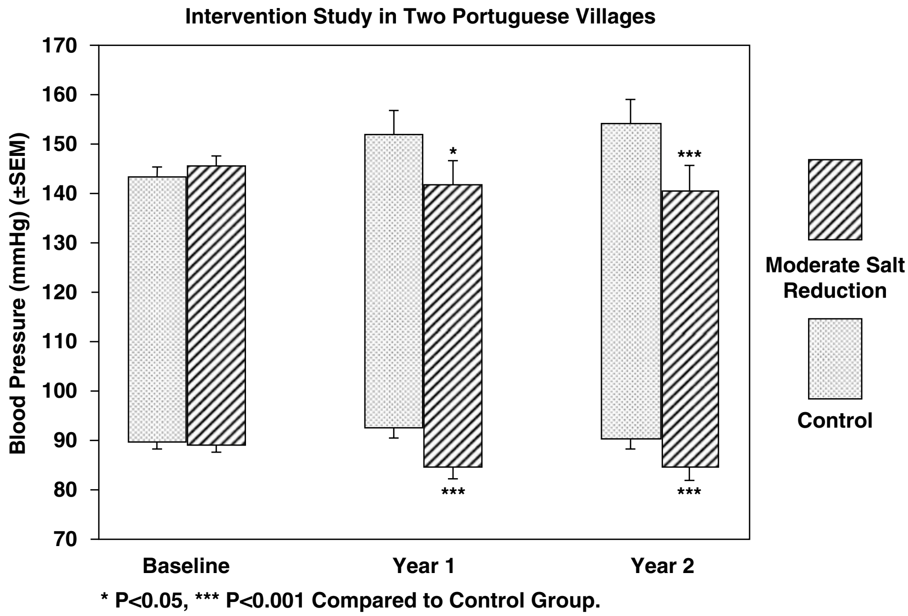

Figure 3 Blood pressure changes with time in two Portuguese villages, one of which had salt intake reduced, the other had similar measurements of blood pressure but no advice on diet. Note the significant differences in blood pressure at 1 year and continuing differences at 2 years. Adapted from Forte *et al.*[40]

ing the statistics of the study. The INTERSALT's investigators re-analysed their data and showed that the highly significant within-population association between salt intake and BP across all 52 centres was virtually unchanged when the four low-salt populations were excluded, and the association between salt intake and the rise in BP with age persisted across 48 centres.[1,34,35]

More recent epidemiological studies, for example, the INTERMAP study (International study of macro- and micro-nutrients and BP),[36] and the EPIC-Norfolk study (the Norfolk Cohort of the European Prospective Investigation into Cancer),[37] have lent further support for the important role of salt in determining the levels of BP in the population.

Migration studies

A number of studies have shown that migration from isolated low-salt societies to an urban environment with an increased salt intake is associated with a rise in BP.[38,39] For example, a well-controlled migration study of a rural tribe in Kenya showed that on migration to an urban environment, there was an increase in salt intake and a reduction in potassium intake, and BP rose compared with those in a similar control group who remained in the rural environment.[39]

Population-based intervention studies

Several population-based intervention studies have been carried out.[40–43] Some of the studies failed to achieve a reduction in salt intake, it is therefore not surprising that there was no change in BP in such studies.[42,43] However, a number of studies where salt intake was successfully decreased have demonstrated a reduction of BP in the population. The most successful intervention study is the one conducted in two similar villages in Portugal,[40] which achieved a difference of approximately 50% in salt intake between the two villages. After 2 years' intervention, there was a difference of 13/6 mm Hg in BP between the two villages (Figure 3). A recent randomized community-based intervention trial was carried out in 550 individuals in two rural villages in north-eastern Japan. The study demonstrated that dietary counselling for 1 year reduced salt intake by 2.3 g/day as measured by 24-h urinary sodium and this was associated with a decrease of 3.1 mm Hg in systolic BP.[44]

Treatment trials

Ambard and Beaujard, in 1904, were the first to show that a large reduction in salt intake lowered blood pressure. These results were confirmed over the next 30 years by several workers, but it was not until Kempner resuscitated the idea of severe salt restriction that it became widely used in the treatment of hypertension.[45] More recently, randomized trials have studied the effects of more modest reductions in salt intake, that is, from the current intake of approximately 9–12 g/day to around 5–6 g/day, and have shown that the fall in BP was equivalent to single drug therapy in hypertensive individuals[46] and there was also a significant fall in BP in those with normal BP.

Several meta-analyses of salt reduction trials have been performed.[47–52] In two meta-analyses,[48,50] it was claimed that salt reduction had very little effect on BP in individuals with normal BP and a reduction in population salt intake was not

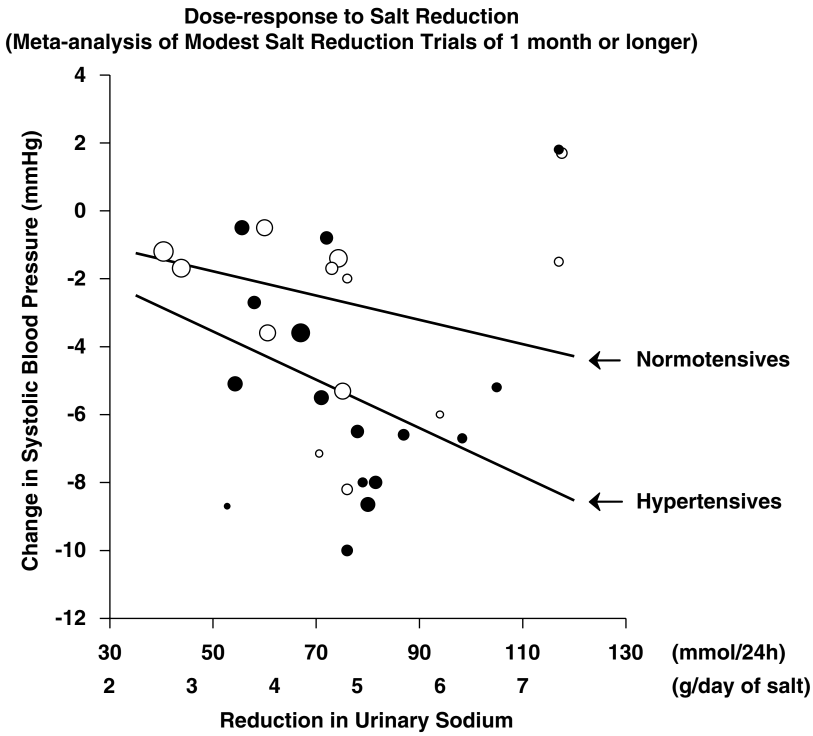

Figure 4 Relationship between the reduction in 24-h urinary sodium and the change in blood pressure in a meta-analysis of modest salt reduction trials.[17] The open circles represent normotensives and the solid circles represent hypertensives. The slope is weighted by the inverse of the variance of the net change in blood pressure. The size of the circle is in proportion to the weight of the trial.

warranted. However, these two meta-analyses are flawed. Both included trials of very short duration with many comparing the effects of acute salt loading to abrupt and severe salt restriction for only a few days. It is known that such acute changes in salt intake increases sympathetic activity, plasma renin activity and angiotensin II,[53] which would counteract the effects on BP. Furthermore, most BP-lowering drugs do not exert their maximal effect within a few days; this is particularly true with diuretics which are likely to work by a similar mechanism to that of salt reduction. It is, therefore, inappropriate to include the acute salt restriction trials in a meta-analysis that attempts to apply them to public health recommendations for a longer-term modest reduction in salt intake. A recent meta-analysis by Hooper *et al.*[52] is an important attempt to look at whether salt reduction ⩾6 months causes a fall in BP. However, most trials included in this meta-analysis only achieved a very small reduction in salt intake. It is, therefore, not surprising that there was only a small, but still significant fall in BP. A more recent meta-analysis of randomized trials of one month or longer, demonstrated that a modest reduction in salt intake caused significant and, from a population viewpoint, important falls in BP in both hypertensive and normotensive individuals.[17] Furthermore, there was a dose–response to salt reduction. A reduction of 6 g/day would lower BP by 7/4 mm Hg in hypertensives and 4/2 mm Hg in normotensives (Figure 4).[17]

Two well-controlled trials have studied three salt intakes (that is, 12, 6 and 3 g/day in one trial and 8, 6 and 4 g/day in the other), each for 4 weeks.[54,55] Both showed a clear dose–response, that is, the lower the salt intake achieved, the lower the BP.

From the dose–response relationship found in randomized trials, it is clear that the current recommendations to reduce salt from 9–12 to 5–6 g/day will have a major effect on BP, but are not ideal. A further reduction to 3 g/day will have a much greater effect.

A reduction in salt intake is additive to anti-hypertensive drug treatments[56] and also additive to other non-pharmacological treatments for BP.[55,57] For instance, the DASH (Dietary Approaches to Stop Hypertension)-Sodium trial,[55] a well-controlled feeding trial, studied three levels of salt intake (8, 6 and 4 g/day) on two different diets, that is, the normal American diet and the DASH diet, which is rich in fruits, vegetables and low-fat dairy products. The study demonstrated that a reduction in salt intake lowered BP both on the normal American diet and on the DASH diet. The combination of a low salt and the DASH diet had a greater effect on BP than either intervention alone, though the combined effects were not as great as the simple addition of each separate intervention (Figure 5).

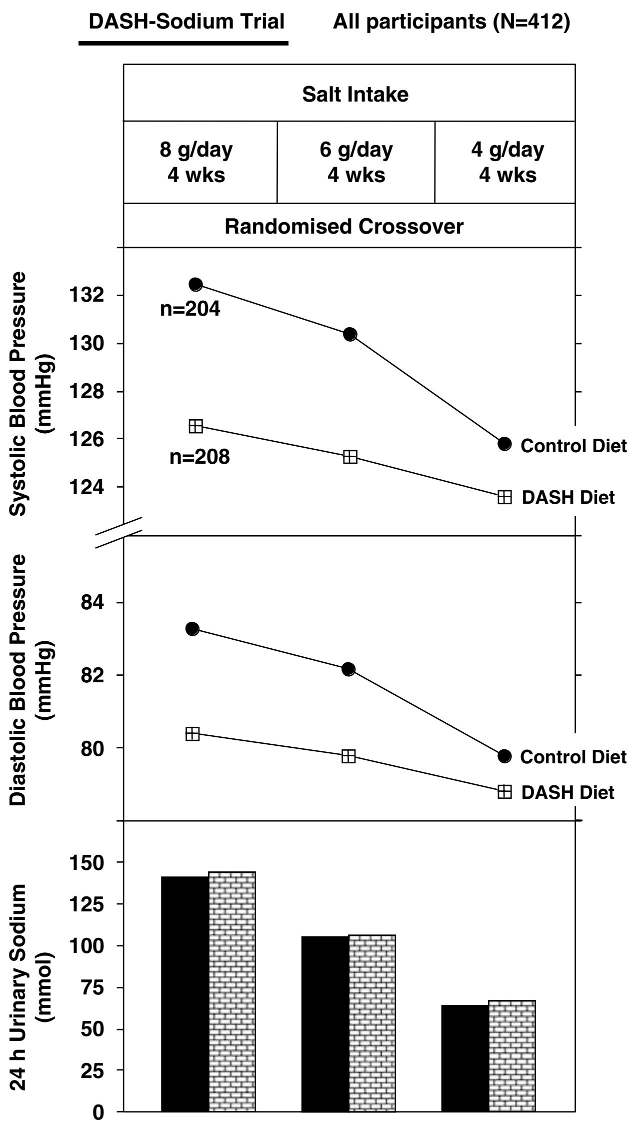

Figure 5 Changes in blood pressure and 24-h urinary sodium excretion with the reduction in salt intake in all participants (hypertensives: $n = 169$; normotensives: $n = 243$) on the normal American diet (that is, control diet) and on DASH diet. Redrawn from Sacks *et al.*[55]

It has been shown that there is a variation in BP response to a reduction in salt intake, that is, for a given reduction in salt intake, the falls in BP are larger in individuals of African origin,[55,58] in older participants,[51,59] and in those with raised BP.[17] These larger falls in BP are, at least in part, because of the lower levels of plasma renin activity and, thereby, angiotensin II, as well as the less responsiveness of the renin–angiotensin system in these individuals.[53,58,60]

Evidence that relates salt to cardiovascular disease

A reduction in salt intake lowers BP, and as raised BP throughout the range is a major cause of CVD, this would be predicted to reduce CVD. On the basis of the falls in BP from a meta-analysis of randomized salt reduction trials,[17] we estimated that a reduction of 6 g/day in salt intake would reduce strokes by 24% and CHD by 18%. This would prevent approximately 35 000 stroke and CHD deaths a year in the United Kingdom[61] and approximately 2.5 million deaths worldwide.

A reduction in salt intake may have other beneficial effects on the cardiovascular system,[62] which may be independent of and additive to its effect on BP, for example, a direct effect on stroke[10] and left ventricular hypertrophy.[12] Therefore, the total effect of salt reduction on cardiovascular outcomes may be larger than those estimated from BP falls alone.

Population studies

In the late 1950s deaths from stroke in Japan were among the highest in the world, and it became apparent that certain regions, particularly the north, had a high salt consumption. It was found that the numbers of strokes in different parts of Japan were directly related to the amount of salt consumed. The Japanese Government initiated a campaign to reduce salt intake. Over the following decade salt intake was reduced from an average of 13.5 to 12.1 g/day. However, in the north of Japan salt intake fell from 18 to 14 g/day. Paralleling this reduction in salt intake, there was a fall in BP both in adults and children, and an 80% reduction in stroke mortality[63] despite large increases in population fat intake, cigarette smoking, alcohol consumption and an increase in body mass index. It would appear that the Western influence which was rapidly overtaking Japan had little effect on BP, provided salt intake was reduced, and overall the reduction in salt intake appeared to be associated with large falls in deaths from stroke.

Since the 1970s, Finland has had the aim to reduce salt intake in the whole population.[64,65] This has been conducted through a collaboration with the food industry to develop reduced-salt food products and raise the general awareness among consumers of the harmful effects of salt on health. Over the following 30 years, salt intake has been reduced by one-third. This was accompanied by a fall of over 10 mm Hg in both systolic and diastolic BP, a pronounced decrease of 75–80% in both stroke and CHD mortality, and a remarkable increase of 5–6 years in life expectancy.[64] The reduction in salt intake was a major contributory factor for these results, particularly the fall in BP as both body mass index and alcohol consumption have increased during that period. An increase in potassium intake through the use of reduced-sodium, potassium- and magnesium-enriched salt, an increased consumption of fruit and vegetables, a reduction in fat intake and a decrease in smoking rate in men also played a part in the fall in CVD.

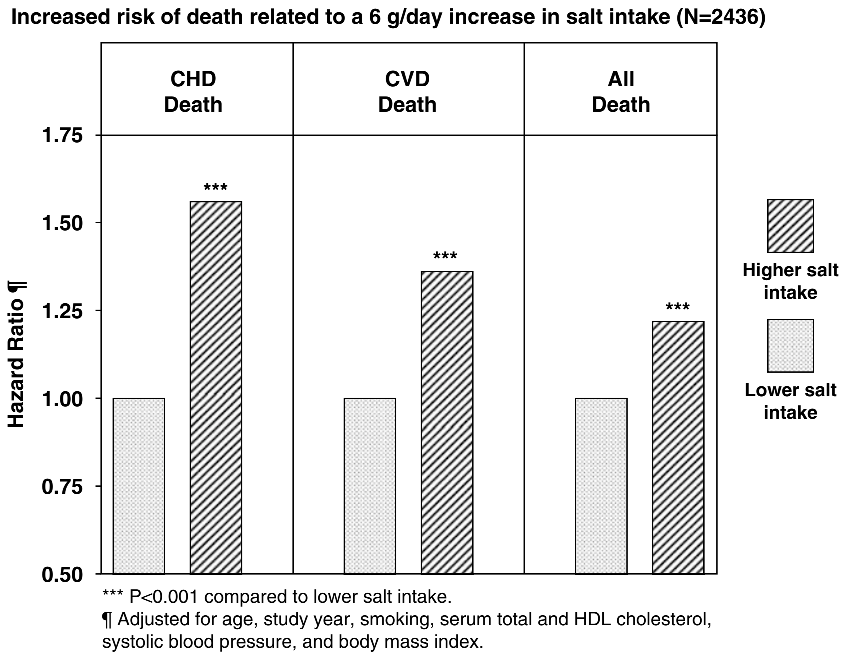

Figure 6 The hazard ratios for coronary heart disease (CHD), cardiovascular disease (CVD) and all-cause mortality associated with a 6 g/day increase in salt intake as judged by 24-h urinary sodium excretion. Adapted from Tuomilehto *et al.*[6]

Prospective cohort studies

Eleven prospective cohort studies have looked at the relationship between salt intake and cardiovascular outcomes.[6,11,66–75] Among these studies, seven used dietary assessment methods, one used overnight urinary sodium and three used 24-h urinary sodium to estimate dietary salt intake. The dietary methods, for example, 24-h dietary recall, have been shown to be unreliable in estimating a person's salt consumption, particularly as no account is taken of discretionary salt. Many of these prospective studies had baseline salt intake measured in the 1970s, a time when discretionary salt intake would have contributed substantially to salt intake. These dietary assessment methods have been severely criticized previously. For instance, Karppanen and Mervalaala[76] pointed out that, in NHANES-I follow-up study, many women in the lowest quartile of salt intake who had a calorie intake near starvation level, had survived for 20 years and they actually weighed 4 kg more than those in the highest quartile of salt intake who apparently also had a much higher calorie intake. Owing to the methodological flaws, the results from these studies should be interpreted with great caution.

Twenty-four-hour urinary sodium is the most accurate method to measure salt intake. Among the 11 prospective studies, three had 24-h urinary sodium measured. However, in the NY Worksite Study,[67] 24-h urinary sodium was measured after all hypertensive individuals had their salt intake restricted for 5 days and no measurement was made on the participants' usual diet. Furthermore, analysis of 24-h urinary data revealed severe methodological problems as individuals in the lowest quartile of salt intake had a much lower 24-h urinary creatinine[77] indicating incomplete collection of 24-h urine. The results from this study therefore cannot be used to look at the effects of salt reduction.

The Scottish Heart Health Study,[69] which enroled a random sample of 11 629 individuals aged 40–59 years, had 24-h urinary sodium measured while on individuals' usual diet. The follow-up data showed that a higher salt intake was associated with a higher risk of all coronary events in women, but the association was not significant in men. Another prospective cohort study[6] which measured 24-h urinary sodium on usual salt intake in a random sample of 2436 Finnish men and women aged 25–64 years, showed that a higher salt intake was significantly associated with a higher risk of death from CHD, CVD and all causes. An increase of 6 g/day in salt intake was related to an increase of 56% in CHD deaths, 36% in CVD deaths and 22% in all deaths (Figure 6).[6]

Outcome trials

Cook *et al.*[5] reported the long-term effects of salt reduction on CVD in individuals participating in two large randomized trials, the Trial of Hypertension Prevention (TOHP) I and II. Over 3000 participants with an average baseline blood pressure of 127/85 mm Hg were randomized to a reduced-salt group (for 18 months in TOHP I and 36–48 months in TOHP II) or to a control group. Compared with the control group, individuals in the intervention group reduced their salt intake by 25–30% from an average

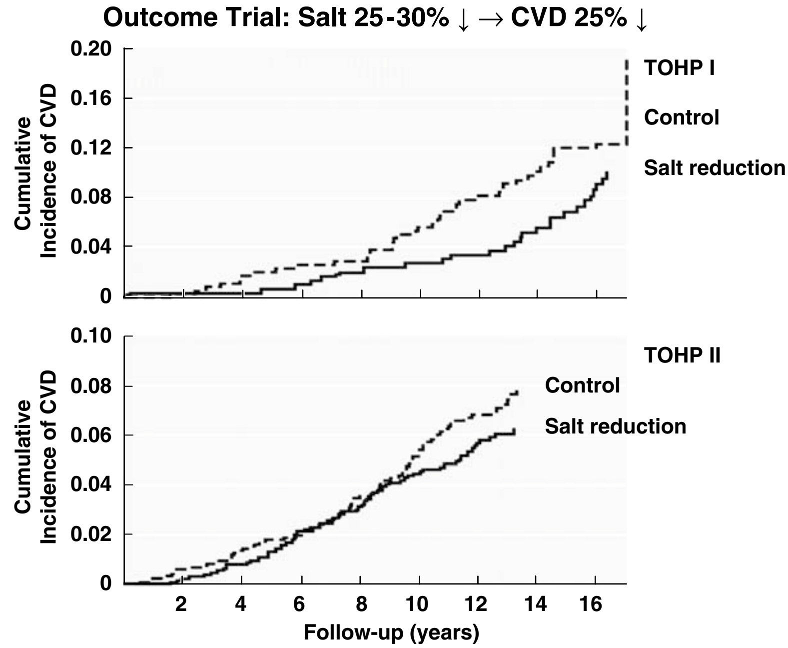

Figure 7 Cumulative incidence of cardiovascular disease (CVD) by salt intervention group in the Trial of Hypertension Prevention (TOHP) I and II, adjusted for age, sex and clinic. Adapted from Cook *et al.*[5]

of approximately 10 g/day in the original TOHP studies. These reductions in salt intake resulted in a fall in BP of 1.7/0.9 mm Hg at 18 months (TOHP I) and 1.2/0.7 mm Hg at 36 months (TOHP II). After the original trials completed, participants were not given further dietary advice. A follow-up study at 10–15 years post trial showed that individuals who were originally allocated to the reduced-salt group had a 25% lower incidence of cardiovascular events after adjusting for confounding factors (Figure 7).[5] Another outcome trial of over 2.5 years in elderly Taiwanese veterans ($N=1981$), demonstrated that switching from the usual salt to potassium-enriched salt (49% sodium chloride, 49% potassium chloride, 2% other additives) with a subsequent reduction of 17% in salt intake and an increase of 76% in potassium intake as measured by urinary sodium/creatinine and potassium/creatinine ratio, resulted in a 40% decrease in CVD mortality.[78]

Other adverse effects of salt

Much of the focus on salt has been its effect on BP. There is now increasing evidence that salt has other deleterious effects on health, independent of and sometimes additive to its effect on BP.

Salt and water retention

When humans go from a low to a high salt intake, there is retention of salt and thereby water, and this expands the extracellular volume. This increase in extracellular volume is a trigger for various compensatory mechanisms to allow an increase in urinary salt excretion but at the expense of continued retention of salt and water. Approximately 1.5 l of extracellular fluid is retained and this continues as long as a higher salt intake is consumed. This increase in extracellular fluid exacerbates all forms of salt and water retention, for example, heart failure[79] and is a major cause of oedema in women, aggravating both cyclical and idiopathic oedema.[80]

Direct effect on stroke

Experimental studies in animals[81] and epidemiological studies in humans[10,11,82] have shown that a high salt diet may have a direct effect on stroke, independent of and additive to its effect on BP. Perry and Beevers performed an ecological analysis of the relationship between urinary sodium excretion (data from INTERSALT study) and stroke mortality in Western Europe. They found a significant positive correlation between 24-h urinary sodium excretion and stroke mortality (Figure 8),[10] and this relationship was much stronger than that found when urinary sodium was plotted against BP.

Direct effect on left ventricular mass

Left ventricular hypertrophy is an important independent predictor of cardiovascular morbidity and mortality and is related to raised BP.[83,84] Several cross-sectional studies have shown a positive correlation between 24-h urinary sodium excretion and left ventricular mass in both hypertensives and normotensives, which is independent of BP[12,85,86] (Figure 9). A reduction in salt intake has been shown to decrease left ventricular mass in patients with essential hypertension.[87–89]

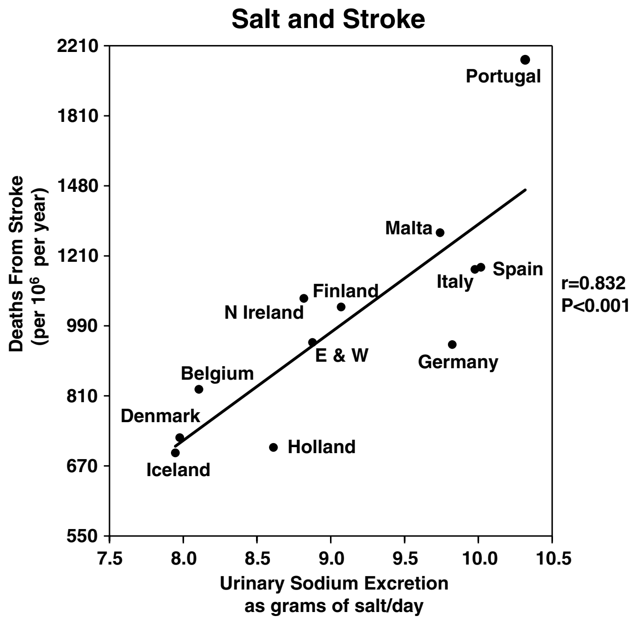

Figure 8 Relationship between salt intake and deaths from strokes in 12 European countries. Adapted from Perry and Beevers.[10]

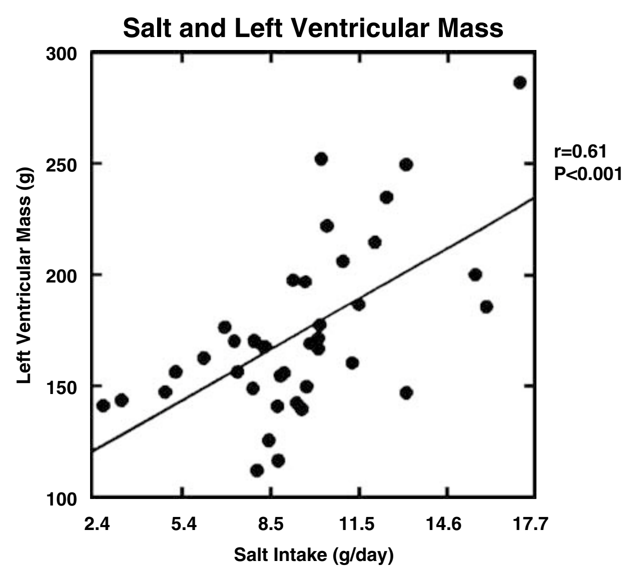

Figure 9 Relationship between salt intake and left ventricular mass in individuals with systolic blood pressure >121 mm Hg. Adapted from Kupari *et al.*[12]

Cancer of the stomach

An ecological analysis showed a significant direct association between salt intake (as judged by 24-h urinary sodium excretion) and deaths from stomach cancer among 39 populations from 24 countries[90] (Figure 10). A recent study from Japan confirms a close relationship between salt intake and stomach cancer within a single country.[16] A number of studies have shown that H-pylori infection, which underlies the cause of both duodenal and gastric ulcers and stomach cancer, is also closely associated with salt intake in different countries in both

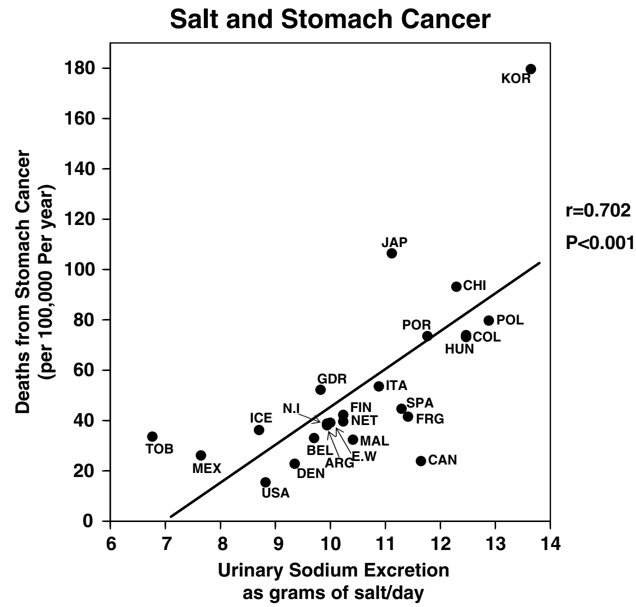

Figure 10 Relationship between salt intake and deaths from stomach cancer. Adapted from Joossens *et al.*[90]

women and men.[91–93] Foods that contain high concentrations of salt are irritating to the delicate lining of the stomach. It is possible that this makes H-pylori infection more likely or more severe and that the H-pylori infection then leads to stomach cancer. A modest reduction in salt intake may reduce H-pylori infection and therefore lead to stomach cancer prevention.

Proteinuria and renal disease

Increasing salt intake increases urinary protein excretion and markedly increases the rate of deterioration of renal function in experimental forms of renal disease. Studies in humans have shown that salt intake relates, on a population basis, to the amount of protein or albumin excretion[94,95] which is an important risk factor for the development of kidney disease and CVD.[96] A recent randomized double-blind trial in 40 hypertensive blacks demonstrates that a modest reduction in salt intake from approximately 10 to 5 g/day, as currently recommended, reduces urinary protein excretion significantly[9] (Figure 11). The effect of salt reduction on urinary protein is more marked when combined with an ACE inhibitor.[8] Therefore, individuals with kidney disease should restrict their salt intake because in nearly all forms of kidney disease the kidney retains sodium and water in the body. The increase in sodium retention causes an increase in BP and makes the proteinuria worse and causes a further deterioration in renal function.

Patients who are on dialysis need to restrict their salt intake as this reduces the amount of fluid that they drink between dialyses. This particularly applies to haemodialysis patients, where BP is a major problem and studies have clearly shown that if they restrict salt intake there is less gain in weight

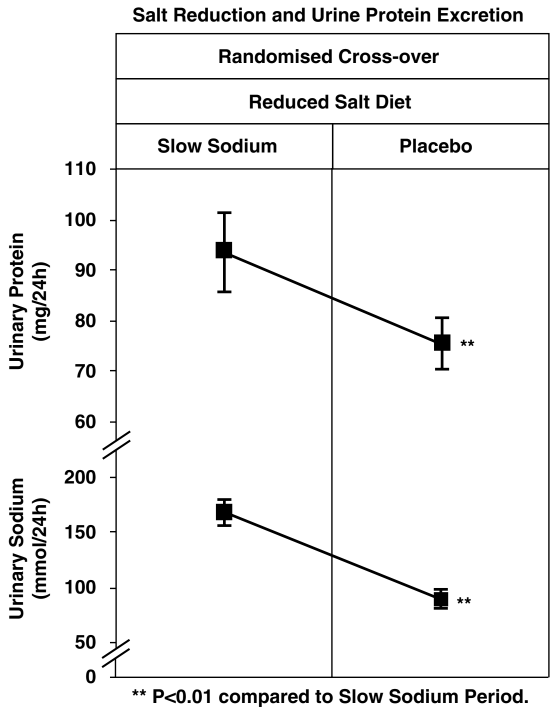

Figure 11 Change in urinary sodium and protein excretion with a modest reduction in salt intake from approximately 10 to 5 g/day in 40 hypertensive blacks.

between dialyses, less fluctuation in BP and BP is easier to control.

In patients with diabetes, a reduction in salt intake has been shown to increase the effectiveness of angiotensin receptor blocker (ARB) on reducing proteinuria.[97]

Renal stones and osteoporosis

Salt intake is one of the major dietary determinants of urinary calcium excretion. Both epidemiological studies and randomized trials show that a reduction in salt intake causes a decrease in urinary calcium excretion.[15,59,98,99] As calcium is the main component of most urinary stones, salt intake is therefore an important cause of renal stones. Until recently, it was assumed that when salt intake was increased, the increase in calcium excretion was compensated for by an increase in intestinal calcium absorption. There is now evidence to suggest that, when salt intake is increased, there is a negative calcium balance with stimulation of mechanisms not only to increase intestinal absorption of calcium, but also to mobilize calcium from bone. A study in post-menopausal women showed that the loss of hip bone density over 2 years was related to the 24-h urinary sodium excretion at entry to the study and was as strong as that relating to calcium intake.[100] Other studies have shown that reducing salt intake causes a positive calcium balance, and it is likely that reducing salt intake would slow down the loss of calcium from bone that occurs as we grow older.

Asthma

Although it is not thought that a high salt intake is a cause of asthma, epidemiological evidence suggests that the severity of asthma may relate to salt intake in different countries.[101] This is supported by trial data, for example, a double-blind study of modest salt restriction showed a reduction in the severity of asthma attacks and a reduction in the use of medication and an improvement in the measurement of airways resistance.[102] The changes seen were only significant in men. Another double-blind study illustrates the mechanism whereby a higher salt intake exacerbates asthma.[103]

A review of both epidemiological and clinical evidence has concluded that the adoption of a low salt diet for a period of 2–5 weeks may improve lung function and decrease bronchial reactivity in adults with asthma. Similarly, a low salt diet followed for 1–2 weeks also decreased symptoms in people who have exercise-induced asthma.[104] However, a recent double-blind trial showed that a lower salt diet as an adjunctive therapy to normal treatment had no additional therapeutic benefit in adults with asthma.[105] Nevertheless, a recent population-based study in children aged 6–7 years demonstrated that adding salt to food was strongly and independently associated with an increased risk of respiratory symptoms, that is, wheeze and asthma.[106]

Obesity

A high salt intake has been suggested as an indirect cause of obesity, through the effect it has on fluid intake. A carefully controlled metabolic study in adult humans showed that a reduction in salt intake caused a significant decrease in fluid consumption.[13] From this experimental study, it was estimated that a decrease in salt from the current intake of approximately 10 g/day to the WHO recommended level of 5 g/day would reduce total fluid consumption by about 350 ml/day. A study in 10 074 free living individuals across the world showed almost an identical relationship between usual salt and fluid intake.[13] It is known that a considerable proportion of fluid intake is in the form of soft drinks and that an increase in soft drink consumption is associated with an increase in body mass index (BMI),[107] therefore a reduction in salt intake could play a role in helping to reduce obesity.

Karppanen and Mervaala[64] analysed the data on the sales of salt and carbonated beverages in the USA between 1985 and 2005, and showed a very close link between the two. They were also in parallel with the trend of prevalence of obesity.

A recent analysis of the dataset of the National Diet and Nutrition Survey for young people in Great Britain showed that, in children aged 4–18 years, there was a significant association between salt intake and total fluid, as well as sugar-sweetened soft drink consumption after adjusting for potential confounding factors.[14] A difference of 1 g/day in salt intake was associated with a difference of 100 and 27 g/day ($P<0.001$) in total fluid and sugar-sweetened soft drink consumption respectively. These results, in conjunction with other evidence, particularly that from experimental studies where only salt intake was changed,[13] demonstrate that salt is an important determinant of fluid and sugar-sweetened soft drink consumption during childhood. If salt intake in children in the United Kingdom was reduced by half (mean decrease: 3 g/day), there would be an average reduction of 2.3 sugar-sweetened soft drinks per week per child. This amounts to a total reduction of approximately 1 billion sugar-sweetened soft drinks per year in the UK alone. Sugar-sweetened soft drink consumption has been shown to be related to childhood obesity by epidemiological studies[108] and randomized trials have also demonstrated that a reduction in soft drink consumption leads to a decrease in obesity.[109] A lower salt intake could therefore help to reduce childhood obesity through its effect on sugar-sweetened soft drink consumption. This would have beneficial effects on preventing CVD later in life, independent of and additive to the effect of salt reduction on BP.

Salt's effects on plasma renin activity, sympathetic nervous activity, lipids and insulin sensitivity

When salt intake is reduced, there is a physiological stimulation of the renin–angiotensin system and the sympathetic nervous system. These compensatory responses are bigger with sudden large changes in salt intake, and much smaller or minimal with a modest reduction in salt intake for a more prolonged period of time, which is the current public health recommendation on population salt intake. Randomized trials have demonstrated that, with a longer-term modest reduction in salt intake, there is only a small increase in plasma renin activity[17] and no detectable change in the sympathetic nervous activity.[110]

Salt reduction lowers BP in a similar mechanism to that of thiazide diuretics. Both stimulate the renin–angiotensin system and, in the short term, the sympathetic nervous system. But outcome trials have demonstrated that long-term treatment with thiazide diuretics significantly reduces cardiovascular morbidity and mortality in hypertensive individuals.[111]

An acute and large reduction in salt intake causes a reduction in plasma volume, and thereby a small increase in the concentration of plasma lipids. However, a modest reduction in salt intake does not have such effects. Randomized trials have shown that, with a longer-term modest reduction in salt intake, there is no significant change in total cholesterol, triglyceride, low or high-density lipoprotein cholesterol.[17]

There have been a number of randomized trials looking at the effects of changing salt intake on glucose tolerance and insulin sensitivity.[112,113] However, most of these trials involved a very large change in salt intake for only a few days, which are irrelevant to the current public health recommendations of modest salt reduction for a long period of time. Randomized trials have shown that a longer-term modest reduction in salt intake had no significant effect on glucose tolerance or insulin sensitivity in hypertensive individuals.[114] A prospective study in 932 Finnish men and 1003 women with an average follow-up of 18 years demonstrated that a higher salt intake (measured by 24-h urinary sodium) was associated with an increased risk of type 2 diabetes, independent of potential confounding factors including physical activity, obesity and hypertension.[115]

Long-term treatment with thiazide diuretics may increase the risk of diabetes.[116] This is likely to be because of low serum potassium levels induced by the diuretics.[116,117] Concomitant treatment with potassium supplementation or potassium-sparing diuretics could lessen the glucose intolerance and possibly prevent the development of thiazide-induced diabetes.[116] The advantage of modest salt reduction over thiazide diuretics is that salt reduction does not have a significant effect on serum potassium, but has a similar BP-lowering effect in hypertensive individuals as demonstrated by randomized trials.[118]

Salt in children

Infants

A well-controlled double-blind study in just under 500 newborn babies showed that when salt intake was reduced by about 30%, as judged by spot urinary sodium concentrations, there was a progressive difference in systolic BP between babies in the reduced salt and those in the usual salt group.[119] At the end of 6 months the babies on the lower salt intake had a 2.1 mm Hg lower systolic BP ($P<0.01$). The study was discontinued at 6 months. Thirty-five percent of these babies were followed up 15 years later.[120] There remained a significant difference in BP, when adjusted for potential confounding factors, between those babies who in the first 6 months of life had had a reduced salt intake compared with those who had not. These results suggest a programming effect of salt intake in early life, which fits with several studies in animals (Figure 12).

Children and adolescents

There have been over 20 observational epidemiological studies on salt and BP in children and adolescents.[121] Many of these studies did not show a significant association. This is not surprising given the large day-to-day intra-individual variations of

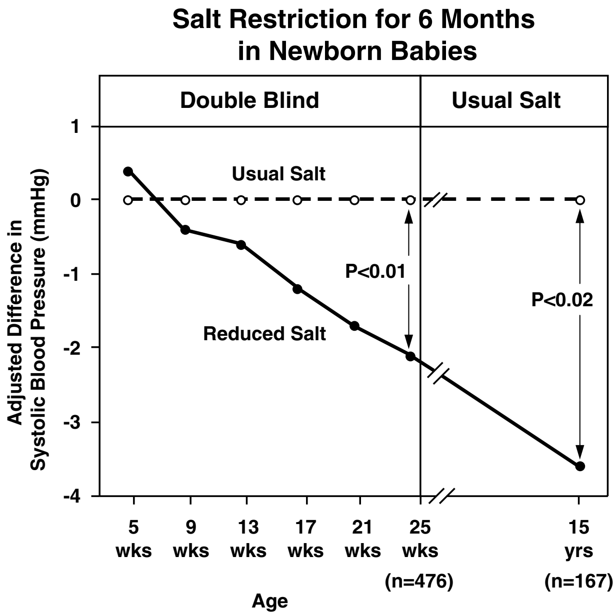

Figure 12 Difference in systolic blood pressure in newborn babies, randomized to either a usual salt intake or a reduced salt intake over the first 6 months of life. At 6 months, the study was discontinued, with all participants resuming their usual salt intake. Fifteen years later, a subgroup of those in the study had blood pressure re-measured. Adapted from Hofman *et al.*[119] and Geleijnse *et al.*[120]

salt intake. In addition, many studies had methodological problems, for example, the methods used to assess salt intake were unreliable. Among the observational studies that were methodologically stronger (for example, multiple measurements of salt intake were made, urinary sodium was measured and confounding factors were controlled for), the majority showed a significant positive association between salt intake and BP.[121,122] For instance, in a carefully conducted study where seven consecutive 24-h urines were collected by all participants, Cooper *et al.*[123] demonstrated a significant linear relationship between urinary sodium and systolic BP in 73 children aged 11–14 years, that is, the higher the salt intake, the higher the systolic BP. The relationship remained significant after controlling for age, sex, race, pulse rate, height and body weight.

A recent meta-analysis of 10 salt reduction trials with 966 participants, demonstrated that a modest reduction in salt intake had a significant effect on BP in children and adolescents.[18] With a 42% reduction in salt intake for an average duration of 4 weeks, systolic BP was reduced by 1.2 mm Hg ($P<0.001$) and diastolic by 1.3 mm Hg ($P<0.001$). These findings are important in view of the fact that BP tracks in children, that is, the higher the BP during childhood, the higher the BP in adulthood.[124] A lower salt diet, if continued, may well lessen the subsequent rise in BP with age, which would have major public health implications in terms of preventing the development of hypertension and CVD later in life.

Salt intake, because of the increased consumption of processed foods, is very high in many children. Even in 1984, a study in the United Kingdom where two consecutive 24-h urines were collected in 4- to 5-year-old primary school children showed that the average sodium excretion was 4 g of salt per day.[125] If this is expressed for adults on a weight basis, it is equivalent to approximately 15–20 g/day. This was at a time when consumption of processed foods by young children was not high. Since then, salt intake in children in developed countries will have increased because of the increasing consumption of processed foods which now account for approximately 80% of total salt intake. Surveys in the United States of America showed that the proportion of foods that children consumed from restaurants and fast food outlets increased by nearly 300% between 1977 and 1996,[126] and it is very likely to have increased even further in more recent years. Snack food consumption showed trends similar to those of fast food consumption. The restaurant foods, fast foods and snacks are generally very high in salt, fat and sugar. It is possible that children from the age of three to four onwards now consume a similar amount of salt as adults.

Cost saving of reducing population salt intake

Several cost-effective analyses have been carried out to assess the health effects and financial cost of reducing population salt intake.[127–130] All of these studies have demonstrated that a reduction in salt intake is very cost-effective. For example, Murray *et al.*[130] showed that non-personal health interventions, including government action to stimulate a reduction in the salt content of processed foods, were cost-effective ways to limit CVD and could avert over 21 million DALYs (disability-adjusted life years) per year worldwide. A study in the Norwegian population documented that a reduction of 6 g/day in population salt intake with a very conservative estimate of 2 mm Hg fall in systolic BP could save costs to individuals and society by US$4.7 million per year.[127] It is likely that this has considerably underestimated the true cost savings as randomized trials have shown that the fall in systolic BP with a 6 g/day decrease in salt intake is much greater than that projected in this Norwegian study.[61] A study in Canada estimated that a reduction of 4.6 g/day in salt intake would decrease hypertension prevalence by 30% and almost double the treatment and control rate of hypertension, and this would save approximately $430 million per year from drugs, physician visits and laboratory testing directly related to hypertension.[128]

In a more recent study, Asaria *et al.*[129] estimated the effects and cost of strategies to reduce salt intake and control tobacco use for 23 low- and middle-income countries that account for 80% of chronic

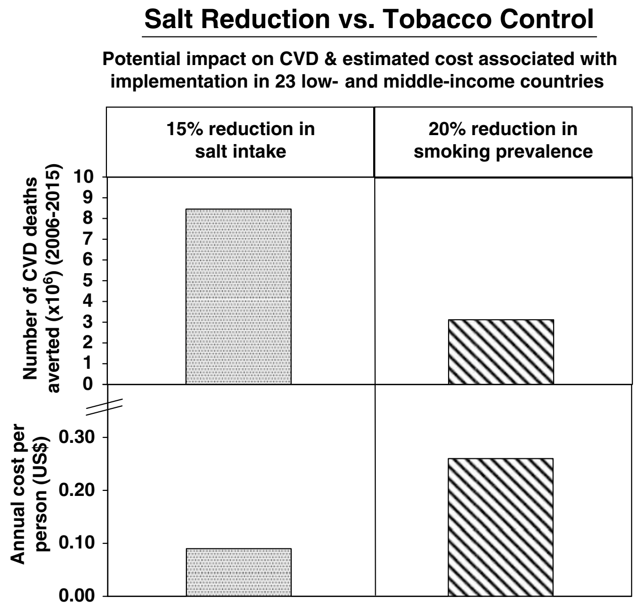

Figure 13 Number of cardiovascular disease (CVD) deaths averted and the financial costs associated with implementation of salt reduction and tobacco control in 23 low- and middle-income countries. Adapted from Asaria *et al.*[129]

disease burden in the developing world. They demonstrated that, over 10 years (from 2006 to 2015), a 15% reduction in mean population salt intake could avert 8.5 million cardiovascular deaths and a 20% reduction in smoking prevalence could avert 3.1 million cardiovascular deaths. The modest reduction in salt intake could be achieved by a voluntary reduction in the salt content of processed foods and condiments by manufacturers, plus a sustained mass media campaign aimed to encourage dietary change within households and communities. The cost for implementing such salt reduction programmes was estimated to be US$0.09 per person per year. The cost for tobacco control including both price and non-price measures, was US$0.26 per person per year[129] (Figure 13). These figures clearly suggest that a reduction in salt intake is more, or at the very least just as cost-effective as tobacco control in terms of reducing cardiovascular disease on its own, the leading cause of death and disability worldwide.

Worldwide actions occurring on salt

Currently there is considerable variation in the amount of action being taken to reduce salt intake in populations around the world. Many, but not all countries have produced their own recommendations about how far salt intake should be reduced. The WHO, after an extensive review of the evidence, has set a worldwide target of a maximum intake for adults of 5 g/day.[131] Through its regional directorates, the WHO is starting salt reduction strategies.[132] The European Union is also following and 11 countries have signed up to make a 16% reduction in salt intake over the next 4 years.[133] Several countries, for example, Finland, and the United Kingdom, have already successfully carried out salt reduction programmes. However, many other countries, particularly developing countries where approximately 80% of global BP-related disease burden occurs,[134] have not even developed a salt reduction strategy. It is important that each country in the world determines what its salt intake is and where are the major sources of salt in the diet, and then implements a strategic approach to lowering salt intake in the population to the target level.

United Kingdom

The United Kingdom (UK) is one of the countries leading the way and setting an example for other countries in salt reduction strategies. In 1994, an independent advisory panel, COMA (the Committee on Medical Aspects of Food and Nutrition Policy), appointed by the Government reviewed all of the evidence and recommended that salt intake in adults should be reduced to 6 g/day or less.[135] However, the recommendations on salt were rejected as some food companies had threatened to withdraw funding from the political party in power. As a result of the rejection of the salt reduction recommendations by the Chief Medical Officer with no reasons given,[136] 22 scientific experts on salt and BP in the United Kingdom set up an action group, Consensus Action on Salt and Health, known as CASH[137,138] to reverse this policy decision and to persuade food processors and suppliers to gradually reduce the salt content in food and to educate the public in realizing the dangers of eating too much salt and to avoid highly salted foods.

Since CASH was set up in 1996, it has been very successful in raising the awareness of the importance of salt and, within a few years, persuaded the UK Department of Health to change its stance on salt, finally resulting in the new Chief Medical Officer endorsing the original recommendations of the COMA report to reduce salt intake to less than 6 g/day in adults. Before this endorsement, CASH had already persuaded a major supermarket and several food companies to reduce the amount of salt they added to their foods by 10–15%, an amount that cannot be detected by the human salt taste receptors.[139] Two years later, CASH ensured that the newly set up UK Food Standards Agency took on the task of reducing salt intake in the UK, and their independent Scientific Advisory Committee on Nutrition (SACN) again confirmed that there was a very strong scientific case to reduce salt intake in the whole population.[140]

The UK strategy - a model for other countries

The first step for all countries who want to carry out a salt reduction policy is to measure or estimate salt intake, for example, in the UK, a random sample of the adult population collected 24-h urines and this showed that the average 24-h urinary sodium excretion was 9.5 g/day of salt in 2001. From a knowledge of the dietary intake in the UK, it was then possible to roughly calculate what proportion of this salt intake is added by the consumer, that is, in the form of added salt, stock cubes, sauces, pickles, and so on, and how much is contributed by the food industry as a whole, that is, where the consumer has no control over the amount of salt, for example, in supermarkets, fast food, restaurants and takeaways.

In the UK, it was roughly estimated that 15% of the total 9.5 g of salt consumed (that is, 1.4 g) was added either at the table or in the cooking. Approximately 5% was naturally present in the food (that is, 0.6 g) and the rest, 80% (that is, 7.5 g), was not in the hands of the consumer and was added by the food industry either in processed, canteen, restaurant food, and so on. From these figures it can then be worked out (Figure 14) that if the target in a particular country is 6 g, which is the target in the UK, and therefore the reduction in salt intake that is needed is from 9.5 to 6 g (that is, 3.5 g), which is an approximate 40% reduction. This means that the public would have to reduce the amount of salt they add to foods themselves by 40% and the food industry would need to reduce the amount of salt added to all foods by 40%. It was also estimated in the UK that only 15% of food was eaten outside the home, that is restaurant, canteen, and so on, and therefore the main target in the initial phase of salt reduction should be on foods that were bought in supermarkets. These foods, where salt was added, were split into more than 80 different categories. Targets were set for each food category that the food industry needed to achieve within a certain time period. The aim was to reduce the salt added to food by small amounts, that is 10 to 20% which cannot be detected by human salt taste receptors and, furthermore, cause no technical or safety issues to the food in question. After a 1- to 2-year gap, a further 10 to 20% reduction could be made and this could be followed by a further reduction after a further 1–2 years.

This strategy has worked successfully in the United Kingdom on a voluntary basis with most processed foods bought in supermarkets having now been reduced by 20 to 30% in the last 3 years. The salt targets for the 80 categories have recently been revised so that they will be lower than the previous ones, to ensure that the 6 g target for all adults will be reached by 2012. Having successfully shown that the amount of salt can be reduced in foods bought in supermarkets, this message is now being spread out to restaurants, takeaways, caterers, canteens, prisons, hospitals and fast food outlets, and so forth.

At the same time, this has been backed by a major public health campaign, both by the Food Standards Agency and CASH. As a result, the number of people aware they should be eating no more than 6 g of salt/day had risen from 3% to 34% in just 1 year and over 20 million, that is, approximately one-third of the adult population were saying they were trying to cut down on the amount of salt they ate.[141]

Clear labelling of the salt content of food is essential, so that consumers can see at a glance how much salt is in any food they purchase. A front of pack signpost labelling system[142] has been developed which is being implemented by many supermarkets where there is a colour-coding of Green, Amber and Red for low, medium and high amounts of salt, fat, sugar and calories, as well as the amount of salt per portion and per 100 g and the recommended intake for an adult for the whole day. This type of label is much preferred by consumers to others as they can see at a glance whether a product has a little or a lot of salt. It has already been shown to have a dramatic effect on the purchase of foods, particularly when they are in the Red category.

UK Strategy for Reducing Salt

Salt intake		Reduction needed	Target intake g/day
Source	**g/day**		
Table/Cooking (15%)	**1.4 g**	**40% reduction**	**0.9 g**
Natural (5%)	**0.6 g**	**No reduction**	**0.6 g**
Food industry (80%)	**7.5 g**	**40% reduction**	**4.5 g**
	Total 9.5 g		**Target 6.0 g**

Therefore the food industry needs to reduce salt content of all foods where salt has been added by 40% over the next 5 years

Figure 14 UK strategy for reducing salt.

The UK salt reduction strategy started in 2003/2004 and the adult daily salt intake has already fallen, as documented by a random sample of the population where 24-h urines were collected, from an average of 9.5 g/day to 8.6 g/day by May 2008.[143] This may seem a small change, but it was on the back of an earlier increasing salt intake and it marks the beginning of a reversal of an increasing trend that is occurring in most other countries with the greater consumption of processed food.

Salt intake will fall further as increasing reductions in salt added to food are made by the food industry, particularly as new targets are currently being set for over 80 categories of food and it is anticipated, with these new targets, that salt intake will reach the target of an average of 6 g/day by 2012. An important aspect of this policy is that it particularly targets the most disadvantaged in the community as the biggest reductions in salt added to food have been made in the cheapest foods as part of the policy. The amount of salt added to children's food is also being reduced. This means that the salt added to food is being reduced across the board and, therefore, the public does not necessarily need to change the foods they eat but, nevertheless, their salt intake will fall without them necessarily being aware of it. At the same time, consumers, who want to, can avoid the most highly salted products and reduce their salt intake even further.

Finland

Finland in the late 1970s was one of the first countries to initiate a systematic approach to decrease salt intake in the population through mass media campaigns, co-operation with the food industry and implementing salt labelling legislation.[64,144] Since the 1980s many food companies have reduced the sodium content of their food products by replacing conventional table salt with a sodium-reduced, potassium- and magnesium-enriched mineral salt known as Pansalt. Furthermore, in the early 1990s, the Ministry of Trade and Industry and the Ministry of Social Affairs and Health, set new salt labelling legislation for all the food categories which made a substantial contribution to the salt intake of the Finnish population. Foods that are high in salt are required to carry a ‘high salt content’ warning and if a food product contains a low level of salt the product is allowed to display a low salt label. These different measures have resulted in a significant reduction in salt intake of the Finnish population, from an average of approximately 12 g/day in 1979 to less than 9 g/day in 2002 as measured by 24-h urinary sodium.[65]

Other countries

Following the success of the UK campaign group—CASH, a World Action group (WASH) was established in 2005 to encourage action on salt reduction worldwide.[145] The aim of the group is to improve the health of populations throughout the world by achieving a gradual reduction in salt intake. WASH, like CASH, works to reduce salt in the diet worldwide by exerting pressure on multi-national food companies to make small but repeated reductions in the amount of salt added to their products. WASH is supported by over 300 international members, who are mainly experts in hypertension. WASH members in each country are being encouraged to set up their own country division of WASH, to work together on a localized level to lower salt intake specifically in their own population. For example, in 2007 an Australian Division of World Action on Salt and Health (AWASH) was established. They have launched a national campaign to lower the salt intake of the Australian population to 6 g/day by 2012. The main objectives of the campaign known as Drop the Salt! are to lower salt in food by 25%, increase consumer awareness about the benefits of a low salt diet and promote clear labelling of foods that makes the salt content immediately apparent to the consumers.

In Ireland a nutrition committee of the Food Safety Authority of Ireland (FSAI) concluded, in 2005, that the scientific evidence supports a link between salt intake and raised blood pressure.[146] Subsequently the FSAI set the goal to reduce salt intake in the population from 10 to 6 g/day. The strategic approach includes consumer awareness efforts, as well as action by the food industry to lower the salt content of their food products, where to-date substantial reductions have been made in the salt content of food.

In Canada the first Chair in Hypertension Prevention and Control was appointed in 2006. The Chair is supported by a number of health-related organizations as well as scientists. Together they will lobby the government and public food sector for policies to reduce the addition of salt to food.[147] Already the food industry is lowering salt in foods. For example a number of whole grain bread products have had their salt levels reduced by 25%.

Many other countries are stepping up their activity. In the Netherlands the dietary guidelines were revised in 2006 stating that salt intake should be reduced to 6 g/day.[148] The Dutch Consumer Organisation (Consumentenbond) has also initiated a number of activities to raise awareness about the harmful effect of too much salt on health. In addition, both the French Food Standards Agency (AFFSA) and the Swedish Food Standards Agency have now considered the evidence and have a programme in place for reducing the salt content of food in both France and Sweden in a similar way as in the UK.

In the USA there has been consistent advice to reduce salt intake to 6 g/day since the 1980s. For example, in January 2000, a large meeting was organized by the National Heart, Lung and Blood Institute in Washington where all of the evidence on

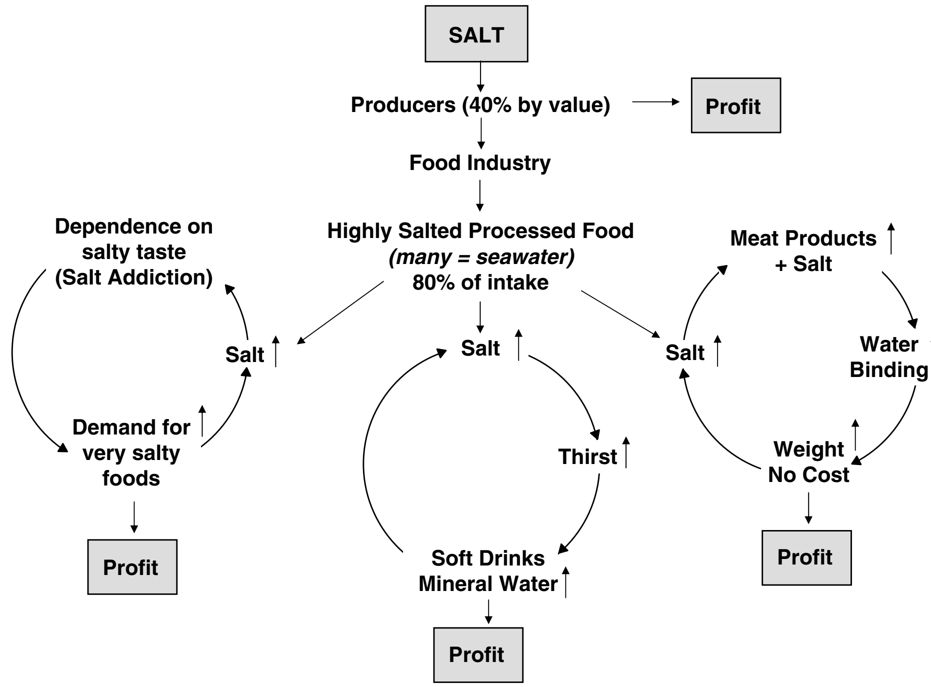

Figure 15 The commercial importance of salt in processed food.

salt was reconsidered. There was representation both from the food industry and salt institute. The conclusion of this meeting was that 'Americans consume more sodium than they need and a population wide strategy of reducing salt in the food supply is an important public health strategy that can lower BP among populations'.[149] More recently in 2007, The American Medical Association (AMA) published a report calling for a major reduction in the salt content of processed and restaurant foods.[150] The AMA also pressed the FDA (Food and Drug Administration) to cease the rule that allows salt and its component sodium to be treated as 'generally recognized as safe'. In a petition to the FDA in 2005, the Center for Science in the Public Interest (CSPI) called for tougher regulations on salt.[151] However, despite this, little action has been taken.

Food industry's resistance to reducing the salt content of processed foods

The reasons that the food industry adds large amounts of salt to processed foods is mainly because it makes cheap, unpalatable food edible at no cost. If high salt foods are consistently consumed, the salt taste receptors are suppressed and habituation to highly salted foods occurs, with greater demand for profitable highly salted processed foods. Food manufacturers often argue that the reason for the high salt content of their products is because of consumer taste preferences, that is, individuals prefer these saltier products and if the salt content was lowered it would lead to consumer rejection. However, one very important factor to be considered is that as salt intake falls, the specific salt taste receptors in the mouth become much more sensitive to lower concentrations of salt and this adjustment takes only one or two months.[152] This means that lower concentrations of salt then taste as salty as the earlier higher concentrations. It is therefore very unlikely that the lowering of salt concentrations in foods will lead to rejection of the foods. Indeed, all of the evidence suggests that once salt intake is reduced, individuals much prefer food with less salt[153] and reject the highly salted foods they ate earlier. Consumer experience in the UK has confirmed this, that is, where salt has been reduced in major brand products, there has been no reduction in sales and no complaints about taste.

Salt has two other important properties—one is in meat products where increasing the salt concentration in conjunction with other water binding chemicals increases the amount of water that can be bound as a gel into the meat product and the weight of the product can be increased by up to 20% with water at no cost. The other important property is that salt is a major determinant of thirst and any reduction in salt intake will reduce fluid consumption with a subsequent reduction in soft drink and mineral water sales (Figure 15).[13,14] Some of the largest snack companies in the world are part of companies selling soft drinks. Salt manufacturers and extractors also have a major interest in the salt used in processed foods as approximately 40% by value of their sales of salt go to the processed food industry. However, in those countries where processed foods are a major source of salt intake, reducing the salt content of processed foods to the lowest possible level is essential. Initially Governments should set voluntary salt reduction targets for each category of food in order to achieve the required reduction in salt intake. However, if these are ignored then statutory regulation to lower salt in food products should be considered. In addition, if a multi-national company lowers the salt content of a product in one country, this should be reflected in all countries where that product is sold. At the moment, there is a very large variation in the amount of salt added to the same branded products in different countries or regions of the world. This variation is entirely random.[155] This illustrates once again how easy it would be for the food industry to reduce the amount of salt they add to food, particularly as they could do this straightaway to their branded products with the lowest level in the world.

Conclusion

The evidence that relates dietary nutrients, such as salt, saturated fat, fruit and vegetables, to BP and CVD has to rely on weighing all of the findings from various types of research studies—epidemiology, migration, intervention, treatment trials as well as genetic and animal studies. When all of the evidence is considered, the evidence for salt, particularly when judged against other nutrients, is robust and strong. A reduction in salt from the current intake of 9–12 g/day to the recommended level of 5–6 g/day will have a major effect on BP and CVD, and may have other beneficial effects on health as outlined in this article.

It is vital that all countries adopt a coherent and workable strategy to reduce salt intake in the whole population. In most developed countries approximately 80% of salt comes from processed food,[154] and the amount of salt added to food by the food industry must be reduced. In these countries, reducing salt intake is one of the easiest changes in the diet to implement, as it does not require consumers to change their dietary practices, but it requires the food industry to make gradual and sustained reductions in the amount of salt they add to food. In other countries where most of the salt consumed comes from salt either added during cooking or from sauces, a public health campaign is needed to encourage consumers to use less salt, perhaps a combination of both, as in developing countries more and more processed food is being consumed. In several countries salt reduction programmes have already been carried out successfully and salt intake has fallen.[64,143] Other countries should follow these examples and start taking action now. A modest reduction in population salt intake worldwide would result in a major improvement in public health—similar to the provision of clean water and drains in the late nineteenth century in Europe.

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