

BMJ Open Cost-effectiveness of milk powder fortified with potassium to decrease blood pressure and prevent cardiovascular events among the adult population in China: a Markov model

Livia Dainelli,¹ Tingting Xu,^{2,3} Min Li,⁴ Diane Zimmermann,¹ Hai Fang,² Yangfeng Wu,^{4,5,6} Patrick Detzel¹

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¹Nestlé Research Center, Lausanne, Switzerland

²China Center for Health Development Studies, Peking University, Beijing, China

³Department of Health Policy and Administration, Peking University School of Public Health, Beijing, China

⁴Department of Epidemiology and Biostatistics, Peking University School of Public Health, Beijing, China

⁵The George Institute for Global Health, Peking University Health Science Centre, Beijing, China

⁶Peking University Clinical Research Institute, Beijing, China

Correspondence to

Dr Patrick Detzel;
patrick.detzel@rdls.nestle.com

ABSTRACT

Objective To model the long-term cost-effectiveness of consuming milk powder fortified with potassium to decrease systolic blood pressure (SBP) and prevent cardiovascular events.

Design A best case scenario analysis using a Markov model was conducted.

Participants 8.67% of 50–79 year olds who regularly consume milk in China, including individuals with and without a prior diagnosis of hypertension.

Intervention The model simulated the potential impact of a daily intake of two servings of milk powder fortified with potassium (+700 mg/day) vs the consumption of a milk powder without potassium fortification, assuming a market price equal to 0.99 international dollars (int\$); the consumption of a milk powder without potassium fortification, assuming a market price equal to int\$0.99 for the latter and to int\$1.12 for the first (+13.13%). Both deterministic and probabilistic sensitivity analyses were conducted to test the robustness of the results.

Main outcome measures Estimates of the incidence of cardiovascular events and subsequent mortality in China were derived from the literature as well as the effect of increasing potassium intake on blood pressure. The incremental cost-effectiveness ratio (ICER) was used to determine the cost-effectiveness of a milk powder fortified with potassium taking into consideration the direct medical costs associated with the cardiovascular events, loss of working days and health utilities impact.

Results With an ICER equal to int\$4711.56 per QALY (quality-adjusted life year) in the best case scenario and assuming 100% compliance, the daily consumption of a milk powder fortified with potassium shown to be a cost-effective approach to decrease SBP and reduce cardiovascular events in China. Healthcare savings due to prevention would amount to int\$8.41 billion. Sensitivity analyses showed the robustness of the results.

Conclusion Together with other preventive interventions, the consumption of a milk powder fortified with potassium could represent a cost-effective strategy to attenuate the rapid rise in cardiovascular burden among the 50–79 year olds who regularly consume milk in China.

Strengths and limitations of this study

- This is the first study to evaluate the cost-effectiveness of a food fortified with potassium to prevent cardiovascular diseases in China.
- A conservative approach was adopted, including only stroke and myocardial infarction among the possible cardiovascular events.
- This analysis was based on data reported in the literature rather than data from real cases.
- In order to extend our results to a national level, we assumed that the incidence and costs related to cardiovascular events were the same across China.

INTRODUCTION

Cardiovascular diseases (CVD) are the leading cause of premature death and disability worldwide: more people die annually from CVD than from any other cause.^{1 2}

China is not unique in that respect and has a very high burden from CVD.^{3 4} Among the individual modifiable risk factors, the most important in China is high blood pressure.⁵ Hypertension is a serious health issue which has significantly increased over the past few decades. In 2010, the prevalence of hypertension was estimated at 34% of the adult population (35% in men and 32% in women)⁴ with no signs of decline.⁶ The excessive dietary salt consumption (eg, in rural China, salt intake can be as high as 12–15 g/day)⁷ is one of the major causes of hypertension and could partly explain why, among other reasons (eg, obesity, smoking and air pollution), the Chinese population has a higher overall stroke incidence compared with Caucasians.^{8–10} In China, 20%–41% of deaths are due to cardiovascular episodes^{2 11} and this percentage is likely to increase resulting in 21.3 million additional cardiovascular events

and 7.7 million deaths from 2010 to 2030, based on population ageing and growth alone.^{12 13}

The financial burden from CVD is substantial to both patients and the healthcare system. In 2011 alone, almost 13 million patients in China were hospitalised for CVD, with total hospitalisation expenditures equaling ¥40 billion (international dollar (intl\$) 11.36 billion at a conversion rate of intl\$1.00=3.52¥),¹⁴ which corresponded to 1.64% of the national health expenditures.¹¹ The total amount of the annual direct costs are estimated to be more than US\$40 billion, the equivalent of 4% of China's gross national income, with indirect costs more than doubling the direct costs.¹⁵

In order to decrease systolic blood pressure (SBP), the WHO guidelines recommend to decrease sodium intake to less than 2000 mg/day and increase potassium intake to at least 90 mmol or 3510 mg/day.¹⁶ Many studies have shown that reducing sodium intake in China would be an effective strategy,¹⁷ and recent studies have shown that increased potassium intake can benefit endothelial function,¹⁸ which is correlated with future cardiovascular events.¹⁹

This study aims to specifically evaluate the cost-effectiveness of increasing potassium intake (+700 mg/day) to lower SBP, and, consequently, the risk of CVD among the 50–79 year olds who regularly consume milk in China via the consumption of a milk powder product fortified with potassium.

METHODS

The cost-effectiveness of a milk powder product fortified with potassium was estimated using TreeAge Pro 2015. We hypothesised that an additional potassium intake of 700 mg/day would reduce the burden of disease related to CVD events due to the lowering effect of potassium intake on SBP.

Baseline potassium intake

Data from the 2009 China Health and Nutrition Survey (CHNS)²⁰ were used to assess the baseline distribution of potassium intake among adults in nine provinces. Since individual-level data are distributed free of charge via the web, no agreement was required. Crème Nutrition,²¹ a scientific, cloud-based software service designed to analyse dietary intakes of foods and nutrients, was used to estimate the baseline potassium dietary intake. In their unpublished report, final outcome of a consultancy for Nestlé, the baseline potassium intake of the Chinese population aged over 45 years was 1781 (±9.95) mg/day (figure 1). No permission to publish was needed.

Potassium effect on the SBP

We relied on the literature to estimate the effect of increasing potassium intake on SBP. Potassium supplementation is associated with a reduction of blood pressure and the effect size may vary depending on different factors.^{22–26} For our model, we relied on one human

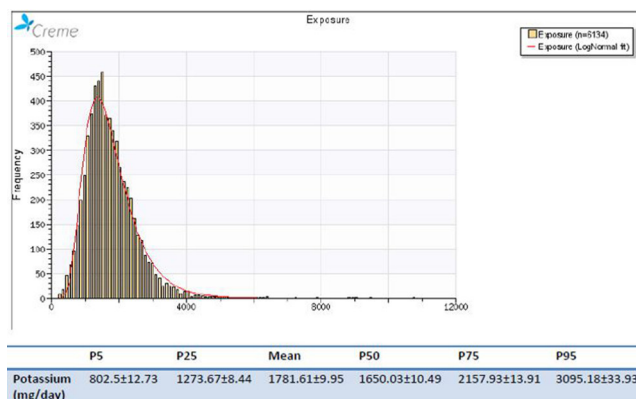


Figure 1 Baseline daily potassium intakes (mg/day) from the total diet in the Chinese population aged over 45 years. Mean is the average of intake values for all individuals within the target population; P25, P50, P75 and P95 are percentiles and represent the values of intake below which the 25%, 50%, 75% and 95% of the analysed population, respectively, falls. WHO guidelines recommend a potassium intake to at least 90 mmol or 3510 mg/day for adults. Source: Crème Global.

intervention study conducted in China on a heterogeneous population (normotensive, prehypertensive and hypertensive), where the subjects were given 60 mmol/day via potassium chloride tablets.²⁷ Compliance among subjects, measured using 24 hours urine samples and assuming 80% recovery, indicated a dietary intake of about 26 mmol/day, corresponding to about 1 g of potassium. The reduction of SBP after 6 and 12 weeks was –6.38 and –3.68 mmHg, respectively. To be conservative, we used the value of SBP reduction at the end of the intervention (–3.68 mmHg) to represent the average decrease in SBP for individuals in China. To account for the different potassium amounts (1 g in the Gu study vs 700 mg in our model), and the non-linear relationship between potassium intake and blood pressure,²³ we evaluated the impact at different levels (% effectiveness) by downgrading 3.68 mmHg to 2.76 mmHg (75%), 1.84 mmHg (50%) and 0.92 mmHg (25%).

Markov model

Finally, we built a Markov model (figure 2), based on the structure of Li *et al*,²⁸ in TreeAge Pro 2015 to compare the long-term cost-effectiveness, from a societal perspective, of an additional potassium intake (+700 mg/day), given through a milk powder product, against consumption of the same product without potassium fortification. The cost of the potassium fortification in the milk powder was modelled as a 13.13% increase (intl\$0.99 vs intl\$1.12). Both arms (milk powder with potassium fortification and milk powder without fortification) have the same structure, but different probabilities of CVD events.

In order to populate the model, we relied on several data sources including published literature, expert opinion, national statistics and tariff lists. The stroke and MI incidence and mortality for the milk powder without potassium fortification arm (control group), and the risk reduction applied to estimate the probabilities for the

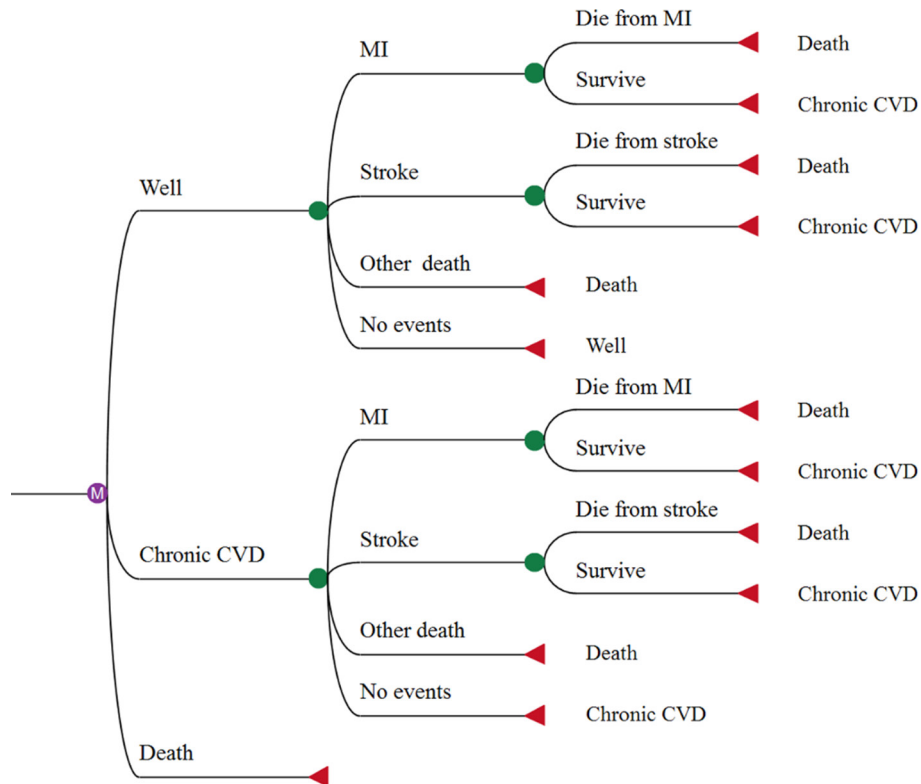


Figure 2 Decision tree representation of the Markov model structure for each arm.⁶³ Circles indicate chance events and triangles indicate terminal nodes. The ‘well’ and ‘chronic CVD’ state represent people without or with prior AMI or stroke, respectively. For the initial population, we assigned 3.83% to start in ‘chronic CVD’ state, consistent with the prevalence of CVD in China among 50–79 years old. The remaining 96.17% start from the ‘well’ state. People in the ‘well’ state can remain in their state or passing to ‘chronic CVD’ in case of first AMI or stroke. In each cycle, people in Well and the chronic CVD states may experience a MI or stroke and have the same chances to survive as the other people in their state, regardless of their personal story. ‘Other death’ accounts for all people who die for causes different from CVD. AMI, acute myocardial infarction; CVD, cardiovascular disease; MI, myocardial infarction.

other arm (intervention group) are reported in [table 1](#). Given the linear relationship between SBP and CVD risk reduction, we extrapolated the impact of a 3.68 mmHg reduction in SBP on CVD risk by dividing the referenced impact of a 10 mmHg reduction by 2.71.^{29–32}

Costs and utilities associated with a cardiovascular event are reported in [table 2](#). The cost of inpatient care due to a stroke was calculated as a weighted average of 25% cerebral haemorrhage and 75% cerebral infarction. The early outpatient drug cost for treating hypertension was obtained from a Chinese publication, where only two geographical areas (Beijing City and Jiangsu Province) were surveyed.³³ In order to calculate a national cost, we first calculated the average of these two provinces. Given that the outpatient drug costs were collected only in Tier 1 hospitals, we then calculated the costs in the Tier 2 and Tier 3 hospitals (which are more expensive). We obtained the total number of outpatient visits for Tier 1, Tier 2 and Tier 3 hospitals in China and average outpatient drug costs (ie, general costs, not only for hypertensive) at each tier from the China Health and Family Planning Statistical Yearbook 2015.³⁴ We used these data to estimate the amounts Tier 1 and Tier 2 hospitals spend as compared with Tier 1. In this way, we obtained the average outpatient

drug cost per capita for hypertensive patients in all Tier hospitals in 2014. When necessary, the appropriate inflation rate was applied to convert the costs from previous years to 2014 prices. In order to estimate the societal loss due to CVD among the population of 50–79 year olds, we multiplied the average daily salary for the number of days of work lost after a stroke or a MI. This was valid even for retired people, on the assumption that their time still has a value (eg, they may be involved in socially useful activities such as looking after grandchildren). All costs are expressed in international dollars.¹⁴

Utilities were obtained from the literature and were expressed in quality-adjusted life years (QALY). The utilities for MI and stroke referred to acute states (moment of the event).

Taking into account the minimum age of the population of interest (50 years old) and the average life expectancy in the Chinese population (76 years),³⁵ we considered a time horizon of 30 years. A discount rate of 3% per annum was applied for both costs and utilities.^{36 37} The findings were presented as incremental cost-effectiveness ratio (ICER), which measures the incremental cost per QALY. We performed both deterministic and probabilistic sensitivity analyses to assess the impact of the

Table 1 Stroke and MI incidence, mortality and risk reduction*Incidence per annum and mortality*

Age group	Stroke incidence ^{34 64}	28 day mortality risk of stroke (%) ⁶⁴⁻⁶⁷	MI incidence ^{34 64-68}	28 day mortality risk of MI (%) ⁶⁸	Non-CVD mortality ³⁴	
Well						
50-59	474.07/100 000	13.6	151.42/100 000	38	290.92/100 000	
60-69	1087.85/100 000	13.3	419.42/100 000	41	768.88/100 000	
70-79	3257.71/100 000	18.3	1241.38/100 000	47	2099.18/100 000	
Chronic CVD						
Age group	Stroke incidence ^{69 70}	28 day mortality risk of stroke (%) ⁶⁷	MI incidence ⁷¹	28 day mortality risk of MI (%) ⁷²	Stroke: non-CVD mortality ^{69 70}	MI: non-CVD mortality ⁷¹
50-59	15 490.00/100 000	19.5	7960.00/100 000	55.5	4980.00/100 000	970.00/100,000
60-69	20 820.00/100 000	19	11 000.00/100 000	59.9	6690.00/100 000	970.00/100,000
70-79	27 980.00/100 000	26.2	15 320.00/100 000	68.6	8990.00/100 000	3280.00/100,000
<i>RR reduction for lower SBP (%)</i>						
Age group	RR reduction (10 mmHg)	RR reduction (3.68 mmHg)				
Stroke ⁷³						
50-59	47.8	17.59				
60-69	37.4	13.76				
70-79	28.5	10.49				
MI ⁷⁴						
50-59	40.9	15.05				
60-69	29.1	10.71				
70-79	24.7	9.09				

CVD, cardiovascular disease; MI, myocardial infarction; RR, relative risk; SBP, systolic blood pressure.

Table 2 Costs and utilities

	Value	Reference
Milk powders price		
Fortified powdered milk per serving	1.12	Market price per serving
Not fortified powdered milk per serving	0.99	Market price per serving
Outpatient drug costs		
Beijing's total outpatient drug costs per capita for hypertensive patients in 2009 Tier 1 hospital	2186.75	33
Jiangsu's total outpatient drug costs per capita for hypertensive patients in 2009 Tier 1 hospital	983.99	33
Average total outpatient drug costs per capita for hypertensive patients in 2009 Tier 1 hospital	1585.37	
Inflation factor from 2009 to 2014 (%)	17	55
Average total outpatient drug costs per capita for hypertensive patients in 2014 Tier 1 hospital	1853.27	
Average drug costs in Tier 1 hospital in 2014	18.86	34
Average drug costs in Tier 2 hospital in 2014	23.52	34
Average drug costs in Tier 3 hospital in 2014	38.64	34
Average drug costs in Tier 2 hospital/average drug costs in Tier 1 hospital	1.25	
Average drug costs in Tier 3 hospital/average drug costs in Tier 1 hospital	2.05	
Outpatient visit numbers in Tier 1 hospital in 2014	4 790 887 798	34
Outpatient visit numbers in Tier 2 hospital in 2014	1 147 086 000	34
Outpatient visit numbers in Tier 3 hospital in 2014	1 398 044 000	34
Share of outpatient visit numbers in Tier 1 hospital	0.65	
Share of outpatient visit numbers in Tier 2 hospital	0.16	
Share of outpatient visit numbers in Tier 3 hospital	0.19	
Average total outpatient drug costs per capita for hypertensive patients in 2014 All Tier hospital	2295.04	
Hypertension screening cost and frequency		
Assumed hypertension screening yearly frequency (no of visits)	1	
Hypertension screening visit cost	16.50 (14.50–17.20)	36
Inpatient costs and days		
Inpatient MI	7018.75	34
Inpatient stroke	3015.191761	34
MI inpatient days	11 (7–15)	75
Stroke inpatient days	28 (23 not insured–32 insured)	76
Chronic costs		
Chronic cost for the rest of year 1 MI	1060	36
Chronic cost for the rest of year 1 stroke	650	36
Annual chronic cost after year 1 MI	740	36
Annual chronic cost after year 1 stroke	420	36
Indirect costs		
GDP per capita 2014	13 246.87	55
Working days per year	250	365-weekends-11 national holidays
Daily salary int\$ (RMB)	53	GDP per capita/working days

Continued

Table 2 Continued

	Value	Reference
Discount (%)		
Annual discount rate for costs and QALYs (%)	3	(37, 36)
Utilities (QALY)		
MI	0.58	36
Stroke	0.7	36
Chronic CVD	0.872	39
Death		
Well	1	36

CVD, cardiovascular disease; GDP, gross domestic product; intl\$, international dollar; MI, myocardial infarction; QALY, quality-adjusted life year; RMB, Renminbi.

uncertainty of the key variables in the model on the base case estimates. This study did not involve human subjects and thereby was exempt from institutional review board approval.

RESULTS

Cost-Effectiveness

With an ICER equal to intl\$4711.56 per QALY gained, the intervention can be classified as very cost-effective according to the conventional WHO threshold which accounts for a country's annual gross domestic product (GDP) per capita (very cost-effective if <1 GDP per capita; cost-effective if equal to 1–3 GDP per capita; no cost-effective is >3 GDP per capita).³⁸ Moreover, we evaluated the impact on the base case estimates of an increase in potassium intake (+700 mg/day) at different level of effectiveness (75%, 50% and 25%) on SBP. The consumption of milk powder fortified with potassium was the preferred strategy compared with the milk powder without fortification, *ceteris paribus*, up to an effectiveness of potassium on SBP equal to the 50% (table 3).

Sensitivity analyses

We performed both deterministic and probabilistic sensitivity analysis evaluating the impact on the base case estimates of an increase in potassium intake (+700 mg/day)

at different level of effectiveness (75%, 50% and 25%) on SBP.

In the deterministic sensitivity analysis (Tornado diagrams, figure 3), we applied $\pm 20\%$ variations to all costs and the appropriate ranges (table 2) to the inpatient days of MI and stroke. Hospitalisation after a stroke had the largest impact whereas a hypertension visit had the least impact on final costs.

In the probabilistic sensitivity analysis (Monte Carlo simulations, figure 4), all costs and resources used were modelled using a gamma distribution, while probabilities and utilities using a beta distribution.³⁹ The consumption of milk powder fortified with potassium was the preferred strategy compared with the milk powder without fortification, *ceteris paribus*, up to an effectiveness of potassium on SBP equal to -1.83 mmHg (49.72%). The results were overall robust.

DISCUSSION

Principal findings

To the best of our knowledge, this study is the first to show the cost-effectiveness of increasing potassium intake, via a milk powder product fortified with potassium (+700 mg/day), to reduce blood pressure and prevent cardiovascular diseases in China. This model capitalises on the

Table 3 Base case results

Effectiveness on SBP	Strategy	Cost	Incremental cost	QALY	Incremental QALY	ICER
100% (3.68 mmHg)	Milk not fortified	18518.43	1234.07	16.27	0.26	4711.56
	Milk fortified	19752.5		16.53		
75% (2.76 mmHg)	Milk not fortified	18518.43	1321.2	16.27	0.2	6734.10
	Milk fortified	19839.63		16.47		
50% (1.84 mmHg)	Milk not fortified	18518.43	1406.43	16.27	0.13	10767.12
	Milk fortified	19924.86		16.40		
25% (0.92 mmHg)	Milk not fortified	18518.43	1489.8	16.27	0.07	22842.90
	Milk fortified	20008.23		16.33		

ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life year; SBP, systolic blood pressure.

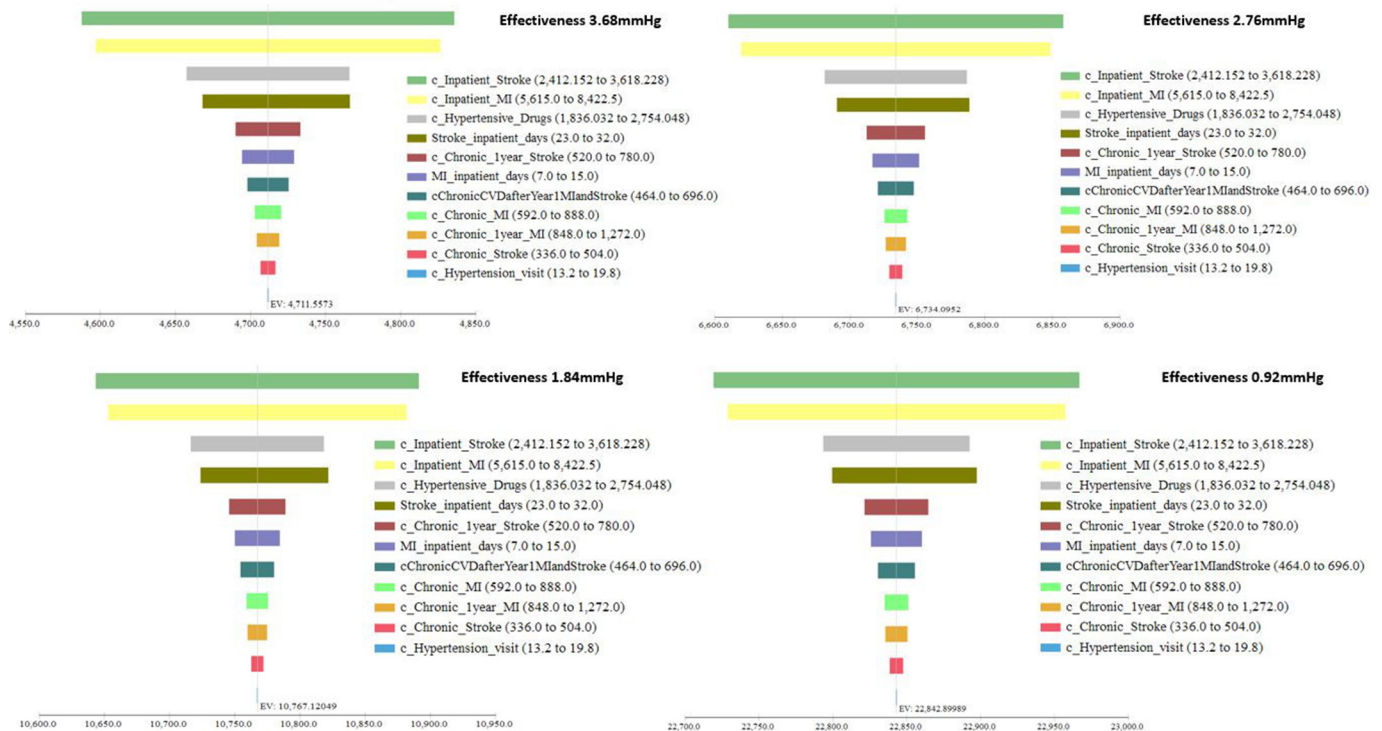


Figure 3 Deterministic sensitivity analysis—Tornado diagrams. The bars represent the relative importance of the variables on the expected value (EV), the incremental cost-effectiveness ratio: the larger the bar, the higher the impact of that cost choice. In this case the cost of the hypertensive drugs is the one affecting the final cost the most, the hypertension visit the less. CVD, cardiovascular disease; MI, myocardial infarction.

substantial evidence already existing on the association between increased potassium intake and the reduction of blood pressure.^{23 40} The daily potassium intake we used as baseline, 1.785 g/day, is consistent with the values reported in the literature: 1.7 g/day and 1.8 g/day.^{41 42} It is worth to mention that, in their subgroup analyses, Aburto *et al* showed that, regardless of baseline potassium intake, there is a comparable reduction in blood pressure when potassium intake is increased.²³

We estimated that an increase in potassium intake (+700 mg/day), would result in an average reduction in SBP of 3.68 mmHg in the Chinese adult population. This value was based on an intervention study conducted in Chinese adults (mean age: 56.9±7.4 in the intervention group)²⁷ with an overall low risk of bias,⁴³ which has been included in several recent systematic reviews and meta-analyses.^{23 40} The baseline SBP was 130–159 mmHg, which is consistent with other reported figures from the literature for a similar age range.⁴⁴ In that specific study, the difference in 24 hours urinary excretion of potassium between intervention and control group was 20.6 mmol, hence corresponding to an estimated intake of 1.0 g of potassium (close to our own case), assuming a recovery of 80% of dietary potassium in the urine. This value is in agreement with the reduction in SBP reported in the Aburto meta-analysis of 3.49 mmHg (95% CI: 1.82 to 5.15) on average for the overall population.²³ Moreover, when the difference in achieved potassium intake between the intervention and the control group was less than

30 mmol/day (1.17 g/day), a reduction of 4.89 mmHg in SBP (95% CI: 2.20 to 7.59) was observed.²³ It is well acknowledged that BP status at baseline as well as age influence the reduction in the blood pressure triggered by potassium intake, with much larger effects observed in hypertensive compared with non-hypertensive individuals,²³ and in older compared with younger individuals.²⁶ Also, blood pressure may be significantly lowered in normotensive subjects with a low dietary intake of potassium,⁴⁵ or with sodium sensitivity, an independent risk factor for cardiovascular disease.⁴⁶ We are therefore confident that both normotensive and hypertensive would equally benefit from a potassium supplementation.

Unfortunately, no other study has been conducted with such a small amount of potassium like ours (+700 g/day), therefore we could not model the provincial level variation impact. Acknowledging these limitations, we took uncertainty into consideration through an extended sensitivity analysis, to model which would be the effect at different level of effectiveness on SBP (100%, 75%, 50%, 25% and 10%).

Strengths and weaknesses of the study

The main strength of this study was the conservative approach adopted. The cost-effectiveness model only included stroke and MI among the possible cardiovascular events, focused only on medical costs and partially on indirect costs (days of work lost), and did not include other cost types such as travelling costs, mortality costs

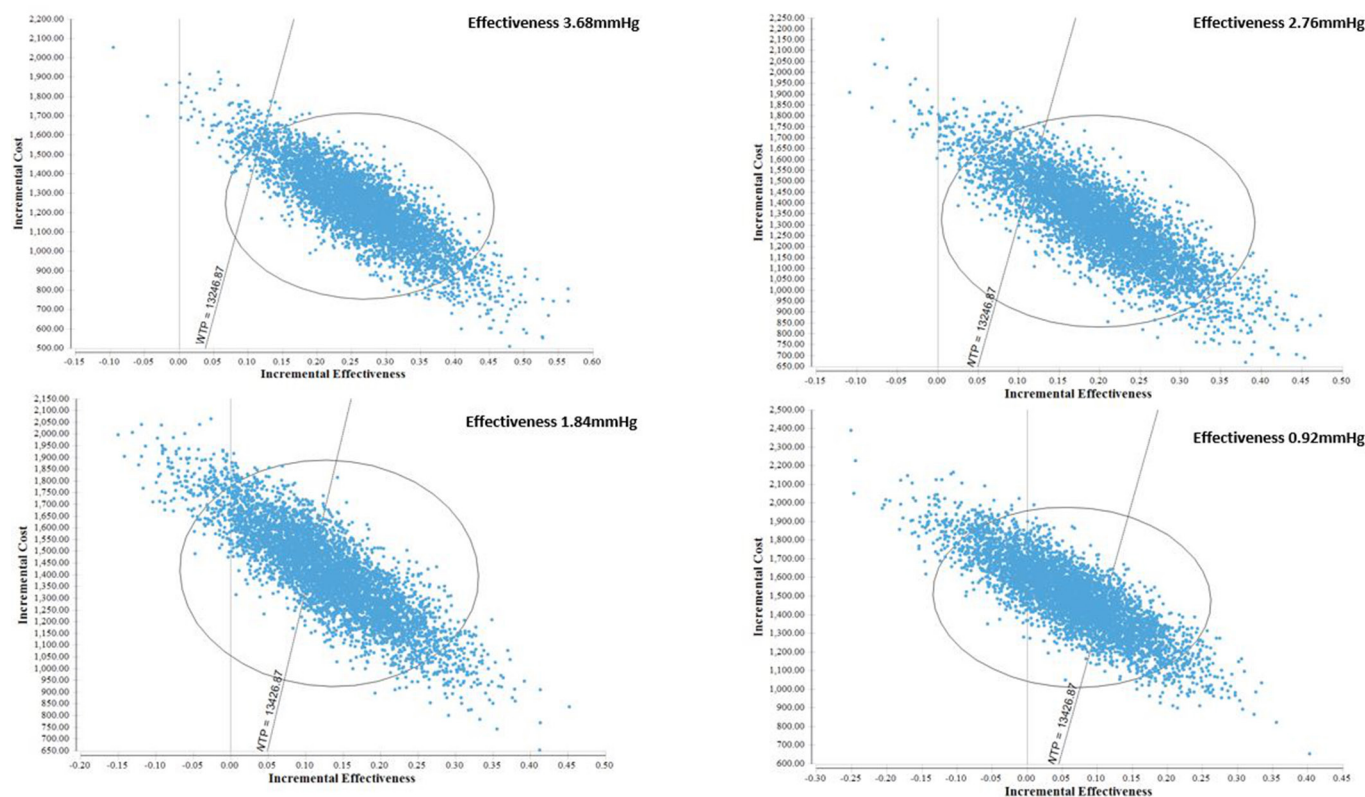


Figure 4 Probabilistic sensitivity analysis—Monte Carlo simulations. The x and y axes, respectively, represent the incremental effectiveness and cost. The dots represent the incremental cost-effectiveness ratio values outcome of 5000 simulations carried out to take into consideration the uncertainty around both cost and effectiveness. The ellipse represents 95% of all data points. The line from the origin is the willingness to pay (WTP), corresponding to the gross domestic product per capita. Points below right of the WTP line recommend the fortified milk powder as preferred strategy and are 96.32% for 3.68 mmHg (100% effectiveness), 86.24% for 2.76 mmHg (75% effectiveness), 61.34% for 1.84 mmHg (50% effectiveness) and 30.72% for 0.92 mmHg (25% effectiveness).

or intangible costs. An additional strength was the extensive sensitivity analysis conducted on the effectiveness of a potassium supplementation to decrease SBP which evaluated several scenarios given that limited clinical evidence is available in this population. To the best of our knowledge, interventions have not been conducted using relatively small amounts (700 mg/day) of potassium, but given that potassium fortification may also make foods bitter, this is the maximum amount consumers showed to tolerate during consumers tastes. An additional amount would mean to risk to have a negative impact on the compliance and, as a consequence, on the effectiveness, of such an intervention.

The first limitation of this study was the use of multiple sources of data for the model parameter values.

Unfortunately, no data exist about CVD risk or burden of the Chinese 50–79 year olds who regularly drink milk compared with those who do not. Moreover, given the lack of detailed information about some provinces and ethnic groups, we assumed that incidences, costs and baseline BP and potassium intakes were the same across China in order to extend our results to a national level. For the same reason, we assumed people who never had a CVD event to be fully healthy and do not face any cost to treat hypertension. Finally, we did not consider the

current sodium intake nor any effect of fortified milk consumption on sodium consumption. The sodium to potassium ratio regulates blood pressure and Chinese population consume excessive amounts of sodium and not enough potassium. Therefore, increasing potassium intake would be indeed more effective in preventing cardiovascular diseases if combined with a reduction in the salt consumption.

Comparison with other studies

Multiple cardiovascular risk factors are common among the Chinese population, including smoking or overweight, and often both are present in the same individual.^{3 47} A large body of literature exists on interventions aiming to reduce blood pressure,^{48 49} the most important individual risk factor for CVD, with some studies assessing the effectiveness and cost-effectiveness of the interventions.^{50 51} One study from He *et al*, targeted to families of the Chinese schoolchildren in the Changzhi urban area, evaluated an education programme to lower-salt intake,¹⁷ while a study from Wang *et al* simulated which would be the effect of promoting the replacement of the cooking salt with a substitute, currently available, containing 25% potassium and 10% magnesium in the Chinese diet.⁴⁴ Both studies analyse the impact of a culturally tailored intervention:

differently from North American and European population, who take the most of their salt intake from packaged processed food, Chinese population primary salt intake is food consumed at home, therefore home-cooked foods is what public policies should target.⁴⁴ Another study from Gu *et al* simulated the effect of a hypertension treatment of essential medicines in Chinese adults and evaluated different healthcare scenarios.³⁶ Similar to the He *et al* study,¹⁷ the present analysis evaluated the effectiveness of a SBP reduction through food, and similar to Gu and Wang study,^{36 44} it was based on a simulation model and not a real intervention. Simulations allow generalising the results to the whole country, but are less precise than a real intervention. All studies, however, had a positive outcome and showed the effectiveness and/or cost-effectiveness of the interventions. Together with our findings, these results suggest that in China different interventions (less sodium, more potassium and appropriate medicines) could be implemented to decrease blood pressure and lower the risk of CVD.

While consistent evidence exists in China, studies evaluating the effect of fortifying food to decrease the risk of CVD have had mixed findings in Europe. In a study from Germany, an enriched margarine with plant sterols has been shown to be a cost-effective method to decrease the risk of coronary heart disease (CHD) in a representative sample of the 30–79 year olds population; assuming a health insurer's perspective and calculating the transition probabilities for CHD and CHD-related death on the basis of the Framingham risk equations.⁵² In a study from the Netherlands, they evaluated the cost-effectiveness of functional foods containing phytosterols/phytosteranols, in addition to statins, to prevent cardiovascular diseases among the population of 35–75 year old eligible for use according to their 10-year absolute risk of fatal cardiovascular disease (SCORE risk).⁵³ The results, differently from the German study,⁵² showed that this strategy was not cost-effective.

A lack of consistency in the findings between China and Europe could be due to differences in the type of intervention (margarine and functional food containing phytosterols/phytosteranols vs potassium/sodium), the health outcomes (cholesterol vs SBP), the healthcare systems and the health status of the populations.

Public health implications

In China, and like many other developing countries, the rapid rise of non-communicable diseases imposes major challenges to the healthcare system and targeting high blood pressure is a public policy priority.⁵⁴ Adults in China consume excessive amounts of sodium and not enough potassium. Both are key minerals involved in the regulation of blood pressure; therefore, increasing potassium intake, in combination with other public health interventions, may help in decreasing blood pressure and preventing cardiovascular diseases.^{23 42}

According to our findings, the consumption of milk powder fortified with potassium was cost-effective, if

compared with the milk powder without fortification, for the 8.67% of 50–79 year olds who regularly consume milk,^{20 21} and could have a beneficial impact without increasing the total caloric intake. Healthcare savings due to CVD prevention would amount to int\$267.54 per consumer. Given a total population of 362.74 million in that age range,⁵⁵ the consumption of milk powder fortified with potassium could allow medical cost savings equal to int\$8.41 billion. In addition, out-of-pocket expenditures are well known to be a substantial portion of the healthcare costs and a large portion of the population in China is not covered by insurance. In 2003, approximately 56% of CVD patients did not have health insurance and on average, 76% of outpatient costs per visit and 65% of inpatient costs were paid out-of-pocket.⁵⁶ Indeed, individuals experiencing severe CVD are likely to face catastrophic health spending (CHS), defined as health expenditures higher than 30%–40% of the total household budget.^{57 58} In a 2009 survey involving 62 hospitals in China, more than the 71% of poststroke patients reported CHS, which results in impoverishment for individuals and their families.⁵⁹ Recent healthcare reforms are aimed towards improving this situation and reducing inequalities, but further strategies are still needed for patients with cardiovascular disease; especially for those living in rural areas or belonging to lower income groups.^{60–62}

Unanswered questions and future research

Further research is needed to assess the cost-effectiveness of reducing CVD risk with other types of foods and new clinical trials are encouraged to evaluate the effectiveness of small increases in potassium intake on the SBP.

CONCLUSION

Together with other preventive interventions, the consumption of a milk powder fortified with potassium could represent a cost-effective strategy to attenuate the rapid rise in cardiovascular burden among the 50–79 year olds in China. This strategy could be especially easy to implement in those already having regular dairy consumption, and even encouraged in those with low dairy product intake.

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Contributors PD conceived the study. LD built the model and drafted the paper. HF and TX updated the economic model with demographic, cost and utilities and helped in running the model; YW and ML contributed with epidemiological data

and estimates; both HF and YW oversaw and supervised the empirical work. DZ supervised and contributed to everything (data, effectiveness, writing) related to the potassium effectiveness on systolic blood pressure and consequent risk reduction. All authors contributed with their comments to the manuscript and revised the final version of the paper.

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Data sharing statement Requests for access to data should be made to the corresponding author at patrick.detzel@rdls.nestle.com.

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