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Meta-analysis

Effect of soya protein on blood pressure: a meta-analysis of randomised controlled trials

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Abstract

Observational studies have indicated that soya food consumption is inversely associated with blood pressure (BP). Evidence from randomised controlled trials (RCT) on the BP-lowering effects of soya protein intake is inconclusive. We aimed to evaluate the effectiveness of soya protein intake in lowering BP. The PubMed database was searched for published RCT in the English language through to April 2010, which compared a soya protein diet with a control diet. We conducted a random-effects meta-analysis to examine the effects of soya protein on BP. Subgroup and meta-regression analyses were performed to explore possible explanations for heterogeneity among trials. Meta-analyses of twenty-seven RCT showed a mean decrease of 2·21 mmHg (95 % CI −4·10, −0·33; $P=0·021$) for systolic BP (SBP) and 1·44 mmHg (95 % CI −2·56, −0·31; $P=0·012$) for diastolic BP (DBP), comparing the participants in the soya protein group with those in the control group. Soya protein consumption significantly reduced SBP and DBP in both hypertensive and normotensive subjects, and the reductions were markedly greater in hypertensive subjects. Significant and greater BP reductions were also observed in trials using carbohydrate, but not milk products, as the control diet. Meta-regression analyses further revealed a significantly inverse association between pre-treatment BP and the level of BP reductions. In conclusion, soya protein intake, compared with a control diet, significantly reduces both SBP and DBP, but the BP reductions are related to pre-treatment BP levels of subjects and the type of control diet used as comparison.

Key words: Soya protein: Isoflavones: Blood pressure: Hypertension

High blood pressure (BP), or hypertension, with a high prevalence in developed countries, is increasing dramatically in developing countries, in parallel with economic development. It has become a serious burden of global public health, influencing approximately 42 % of the population in England and one billion individuals worldwide[1,2]. Furthermore, hypertension has been identified as a large but modifiable risk factor for cardiovascular mortality, which is the leading cause of death in Europe and North America. Considerable attention therefore should be paid to the prevention and control of hypertension.

Soya has received an increasing scientific interest for its beneficial effects on cardiovascular health since the US Food and Drug Administration (Silver Spring, MD, USA) approved a health claim in 1999 that a daily intake of 25 g of soya protein may reduce heart disease. Isoflavones in soya protein, a class of phyto-oestrogens acting as oestrogen mimics, are suggested to have potential hypotensive effects[3–5]. However, a recent meta-analysis by Hooper *et al.*[6] has shown that isoflavone extracts did not affect BP, though the result for systolic BP was close to significance. Also, three trials[7–9] published subsequently to that meta-analysis did not yield significant results either. Moreover, two trials[7,8] showed that isoflavone extract intervention resulted in an increase in BP compared with control. On the basis of the current evidence, we believe with some confidence that isoflavone extracts have no

Abbreviations: BP, blood pressure; DBP, diastolic blood pressure; RCT, randomised controlled trial; SBP, systolic blood pressure.

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significant effects on BP. On the other hand, numerous epidemiological studies have been carried out to evaluate the effects of soya protein or soya foods on cardiovascular health as well as BP reductions. Observational studies[10–12] have indicated that soya protein intake or soya food consumption might be inversely associated with BP. Several randomised controlled trials (RCT) have documented a BP-lowering role of soya[3,5,13,14], whereas others have suggested no effect. A previous meta-analysis[6] reported that soya protein isolate, but not other soya products or components, significantly reduced diastolic BP (DBP). However, that study was not primarily designed to assess the effects of soya protein or isoflavones on BP, and sources of heterogeneity were not explained.

With newly emerging evidence supporting a BP-lowering role of soya protein rather than isolated isoflavones, we aimed to conduct an updated and comprehensive meta-analysis of RCT to evaluate the effects of soya protein on BP reductions, and to explore the potential sources of heterogeneity across studies for a better understanding of the present literature.

Materials and methods

Search strategy

We searched the PubMed database (National Library of Medicine, Bethesda, MD, USA) through to April 2010 for published studies in the English language using search terms 'soya OR soya protein OR soybeans OR phytoestrogens OR isoflavones' and 'hypertension OR blood pressure'. In addition, we carried out a manual search using reference lists of original articles and recent reviews. Each published paper was independently reviewed and relevant information was extracted by three authors (J.-Y. D., X. T. and Z.-W. W.).

Study selection

To be included in our analysis, a study was restricted to RCT conducted in human subjects and reported a net change in systolic BP (SBP) and DBP during the intervention with their corresponding standard deviations, or appropriate data to calculate these values. In one study, two independent strata (normotension *v.* hypertension) were included; thus, it was treated as two trials.

Major reasons for exclusion were as follows: (1) using isoflavone extracts as treatment; (2) non-randomised treatment allocation; (3) lack of BP data; (4) a systematic difference between the intervention and control groups other than soya protein; (5) absence of a concurrent control group; (6) recurrent publication of data already represented in the present analysis.

Data extraction

We recorded the study characteristics as follows: (1) first author's name, publication year and country of origin; (2) number of participants; (3) mean age, age range, sex distributions and health status of participants; (4) design details, including whether parallel or cross-over and open, single blind or double blind; (5) study duration; (6) dosage of soya protein and isoflavones, placebo and other treatment interventions; (7) type of soya protein; (8) mean BP at baseline. The Jadad score, a scale that ranges from 0 to 5 according to the descriptions of randomisation, blinding and reporting of participant withdrawals, was used to measure the quality of each trial[15].

Statistical analysis

Net changes in SBP and DBP at the end of the intervention were calculated, if not reported. For studies reporting only the mean difference between the treatment and control groups, we set the control group's mean change as zero and the treatment group's mean change as the reported mean difference. Standard errors, CI and P values were converted to standard deviations for the analyses. When the standard deviation for paired differences was not reported, we calculated it from the standard deviation at baseline and at the end of the follow-up on the basis of the method of Follmann *et al.*[16], assuming a correlation coefficient of 0·5 between initial and final BP. We assumed equal variances during the trial and between the treatment and control groups.

With each trial weighted by the reciprocal of the variance for BP change, we calculated a weighted mean difference and its corresponding 95 % CI. Both fixed- and random-effects models were used. The homogeneity of effect size across trials was tested by Q statistics ($P<0{\cdot}10$ was considered heterogeneous). If there was significant heterogeneity among the studies, the random-effects model was used; otherwise, the fixed-effects model was acceptable. We also examined the I^2 statistic, which measures the percentage of the total variation across studies that is due to heterogeneity, rather than chance[17]. A sensitivity analysis was conducted to examine the influence of various exclusion criteria on the overall effect sizes.

To explore the influence of covariates on the net change in BP, we carried out a series of subgroup analyses. Subgroups were selected based on biological plausibility, study design and participant characteristics. Furthermore, we conducted a meta-regression analysis to estimate the effects of various study characteristics on the effect size. Covariates for meta-regression analysis were selected based on the results of the subgroup analysis and biological knowledge. For each trial, the covariates were calculated as average values of the treatment and control groups at baseline. Mean aortic pressure was used as pre-treatment BP. When information on mean values was absent, for example dosage of soya protein, we estimated it as the median of the remaining trials.

To assess the publication bias, we performed both Egger's and Begg's tests[18,19], and inspected the funnel plots as well. All analyses were performed using STATA version 10.0 (StataCorp, College Station, TX, USA). A P value $<0{\cdot}05$ was considered to be statistically significant, unless otherwise specified.

British Journal of Nutrition

Table 1. Characteristics of all trials included in the present meta-analysis

First author and year	Design	Sample size	Mean age (years)	Type of soya protein	Control	Soya protein (g/d)	Isoflavones (mg/d)	Duration (weeks)	Baseline BP (mmHg)	Jadad score
Kurowska (1997)[20]	Open, X	32	55	Soyabean products	Milk	31	NR	4	131·0/77·0	2
Washburn (1999)[21]	DB, X	51	51	SPI	Carbohydrate	20	34	6	132·0/82·0	5
Burke (2001)[22]	Open, P	18	55	SPI	Maltodextrin	66	23	8	134·8/76·9	2
Hermansen (2001)[23]	DB, X	20	63·6	SPI	Casein	50	160	6	130·0/78·0	4
Teede (2001)[13]	DB, P	179	NR	SPI	Casein	40	116	12	129·0/76·0	5
Jayagopal (2002)[24]	DB, X	32	62·5	SPI	Cellulose	30	132	12	147·1/82·1	5
Jenkins (2002)[25]	Open, X	41	62·2	Soya foods	Low-fat dairy	50	73	4	124·0/78·0	2
Rivas (2002)[3]	DB, P	40	50	Soya milk	Cow skimmed milk	18	143	12	153·4/99·8	4
Allison (2003)[26]	Open, P	74	50	Soya-based meal	Placebo	NR	NR	12	117·7/76·9	2
Cuevas (2003)[27]	DB, X	18	59	SPI	Caseinate	40	80	4	132·0/73·0	4
Meyer (2004)[28]	Open, X	23	54	Soya foods	Dairy	30	80	5	132·0/77·0	1
Puska (2004)[29]	DB, P	143	58	SPI	Milk	41·4	153	8	131·2/80·8	5
Sagara (2004)[30]	DB, P	50	52·2	SPI	Placebo	20	80	5	138·0/84·0	4
Anderson (2005)[31]	Open, P	52	50	Soya-based meal	Milk-based meal	NR	NR	12	125·6/69·3	2
He 1 (2005)[14]	DB, P	174	51	SPI	Carbohydrate	40	76·4	12	135·0/85·0	5
He 2 (2005)[14]	DB, P	102	51	SPI	Carbohydrate	40	76·4	12	144·0/92·0	5
Hermansen (2005)[32]	DB, P	89	59	SPI	Casein	30	100	24	133·0/80·8	5
Kreijkamp (2005)[33]	DB, P	175	66·7	SPI	Milk	25·6	99	52	140·8/75·2	5
Lukaczer (2006)[34]	Open, P	42	54·6	SPI	Standard diet	30	34	12	126·5/83·5	3
Teede (2006)[4]	DB, X	38	60	SPI	Gluten	40	118	12	142·9/84·2	5
Anderson (2007)[35]	SB, P	43	45	Soya-based shakes	Casein	40	150	21	124·1/81·0	2
Azadbakht (2007)[36]	Open, X	42	NR	Texture soya protein	DASH diet	15	84	8	136·0/87·0	3
Matthan (2007)[37]	Open, X	28	65	Soyabean	Animal protein	37·5	132	6	120·0/73·5	2
Welty 1 (2007)[5]	Open, X	12	58·3	Soya nuts	Non-soya protein	25	101	8	116·0/69·0	1
Welty 2 (2007)[5]	Open, X	48	53·5	Soya nuts	Non-soya protein	25	101	8	152·0/88·0	1
Santo (2008)[38]	DB, P	19	24	SPI	Milk	25	97	4	110·8/69·5	5
Wong (2010)[39]	Open, X	23	58·1	Soya foods	Low-fat dairy	30	61	4	122·8/76·7	3

BP, blood pressure; X, cross-over; NR, not reported; DB, double blind; SPI, soya protein isolate; P, parallel; SB, single blind; DASH, Dietary Approaches to Stop Hypertension.

Results

Characteristics of the studies

After our complete review, twenty-five studies[3–5,13,14,20–39] including twenty-seven trials met the inclusion criteria. Characteristics of the trials included in the present meta-analysis are presented in Table 1. The trials published between 1997 and 2010 varied from 12 to 276 participants, with a median of 42 and a total number of 1608. Of the twenty-seven trials, nine were conducted in the USA, eight in Europe and ten in other countries. All trials were conducted in adults, with ages ranging from 18 to 75 years. The subjects' initial mean BP ranged from 110 to 153 mmHg for SBP, and from 69 to 100 mmHg for DBP. Of the twenty-six trials that reported the sex distribution, eight consisted entirely of women, of which six were conducted among post-menopausal women, and two trials consisted entirely of men. There were five trials[3–5,14,22] conducted only in hypertensive subjects (210 participants) with a mean baseline BP of 145·2/90·5 mmHg, among which two trials reported antihypertensive therapy use and the other three did not. There were eleven trials that included only normotensive subjects (714 participants) with a mean baseline BP of 126·8/77·9 mmHg. The remaining eleven trials included both hypertensive and normotensive subjects. There were two studies[23,24] conducted in patients with type 2 diabetes. Of the twenty-seven trials, fourteen were parallel-designed, and the rest had a cross-over design. The duration of the intervention lasted from 4 to 52 weeks, with a median of 8 weeks. Treatment was double blind in fourteen trials, single blind in one trial and open in twelve trials. There were fifteen trials that used soya protein isolate containing isoflavones and twelve that used other soya foods. Most of the control groups received casein or milk. Dosage of soya protein varied from 18 to 66 g/d, with a median of 30 g/d. Dosage of isoflavones contained in soya protein varied from 23 to 160 mg/d, with a median of 100 mg/d.

Net changes in blood pressure

Tests for heterogeneity indicated that the treatment effect was significantly different across studies ($P<0·001$ for SBP and $P<0·001$ for DBP). I^2 values were 65·7 % for SBP and 61·5 % for DBP. Compared with control, intervention was associated with an average net change in BP ranging from −17·0 to 5·0 mmHg for SBP and −12·2 to 4·0 mmHg for DBP. For SBP, a trend towards intervention-related reduction in BP was observed in seventeen trials, with five trials showing a significant reduction. For DBP, a trend towards intervention-related reduction in BP was observed in nineteen trials, with a significant reduction in five trials. Overall pooled estimates of the effect of soya protein were −2·21 mmHg (95 % CI

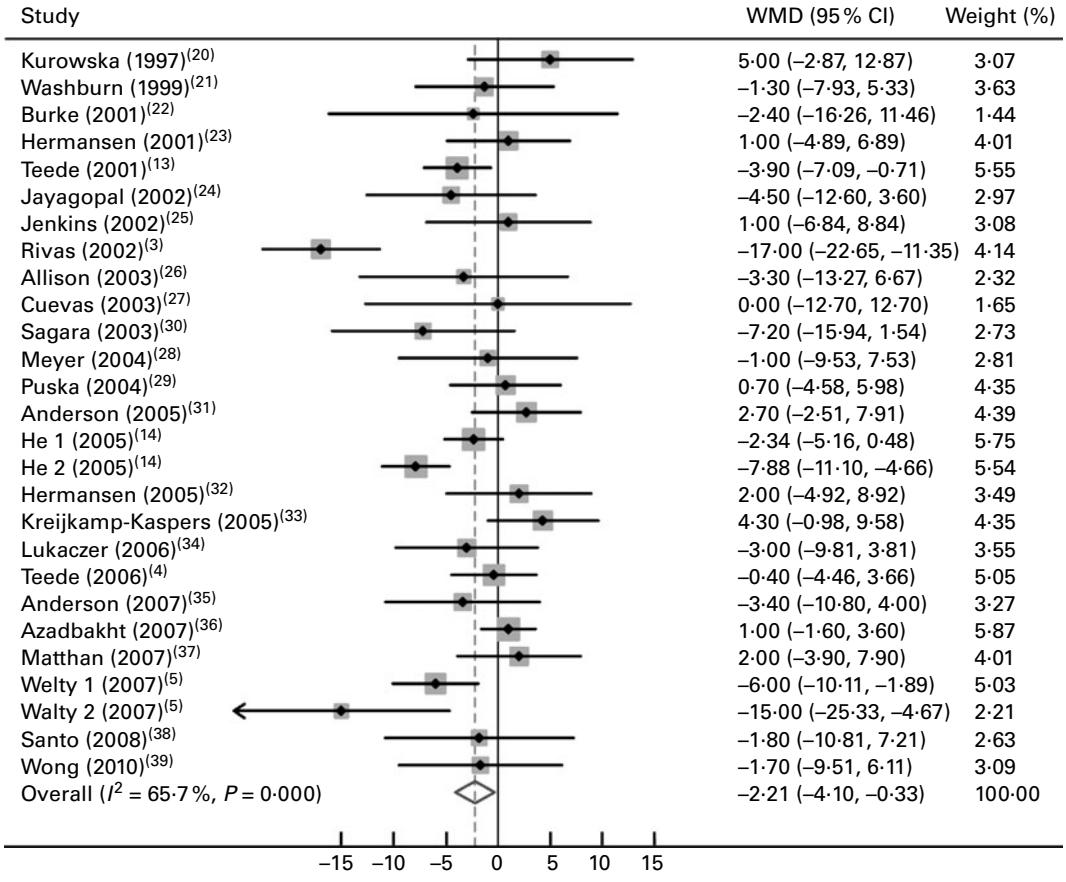

Fig. 1. Pooled effect size of soya protein with isoflavones on systolic blood pressure. WMD, weighted mean difference.

−4·10, −0·33; P=0·021) for SBP (Fig. 1) and −1·44 mmHg (95 % CI −2·56, −0·31; P=0·012) for DBP (Fig. 2).

Sensitivity analysis

Table 2 presents the results of sensitivity analysis that excluded trials based on different criteria. Overall pooled estimates for treatment effects in BP changed little in the sensitivity analysis.

Stratified analysis

Table 3 shows the results from stratified analyses. SBP and DBP were significantly reduced in both the hypertensive and normotensive groups. Furthermore, the mean decrease in the hypertensive group was 8·58 mmHg (95 % CI −15·10, −2·06; P=0·010) for SBP and 5·24 mmHg (95 % CI −9·40, −1·08; P=0·014) for DBP, markedly greater than that in the normotensive group. Significant BP reductions in response to the intake of soya protein were also observed in trials using carbohydrate as the control diet, with a longer duration, using soya protein isolate as treatment, and in trials employing a parallel design. Moreover, the reductions tended to be greater among trials using carbohydrate than those using milk or casein as the control diet, among trials with a parallel design than those with a cross-over design and among trials with the intervention duration of at least 12 weeks than those with less than 12 weeks.

Meta-regression analysis

We first conducted univariate meta-regression analyses for each of the following variables: pre-treatment BP; duration of intervention; sample size; BMI; dosage of soya protein; dosage of soya isoflavones. There was a significant inverse association of effect size with pre-treatment BP for both SBP (Fig. 3) and DBP (Fig. 4), but not with other covariates (all P>0·3; e.g. P values are 0·791 and 0·492 for isoflavone dosage *v.* net changes in SBP and DBP, respectively). In our multivariate meta-regression, pre-treatment BP remained significant after adjustment for the other covariates (P=0·011 for SBP and P=0·039 for DBP). Pre-treatment BP was therefore proved to be a significant and independent predictor for heterogeneity, strengthening the results of the present subgroup meta-analyses.

Publication bias

There was no sign of publication bias when examining the funnel plots (plot not shown). Results from Begg's and Egger's tests also did not indicate the evidence of publication bias (SBP: Begg P=0·297, Egger P=0·988; DBP: Begg P=0·381, Egger P=0·243).

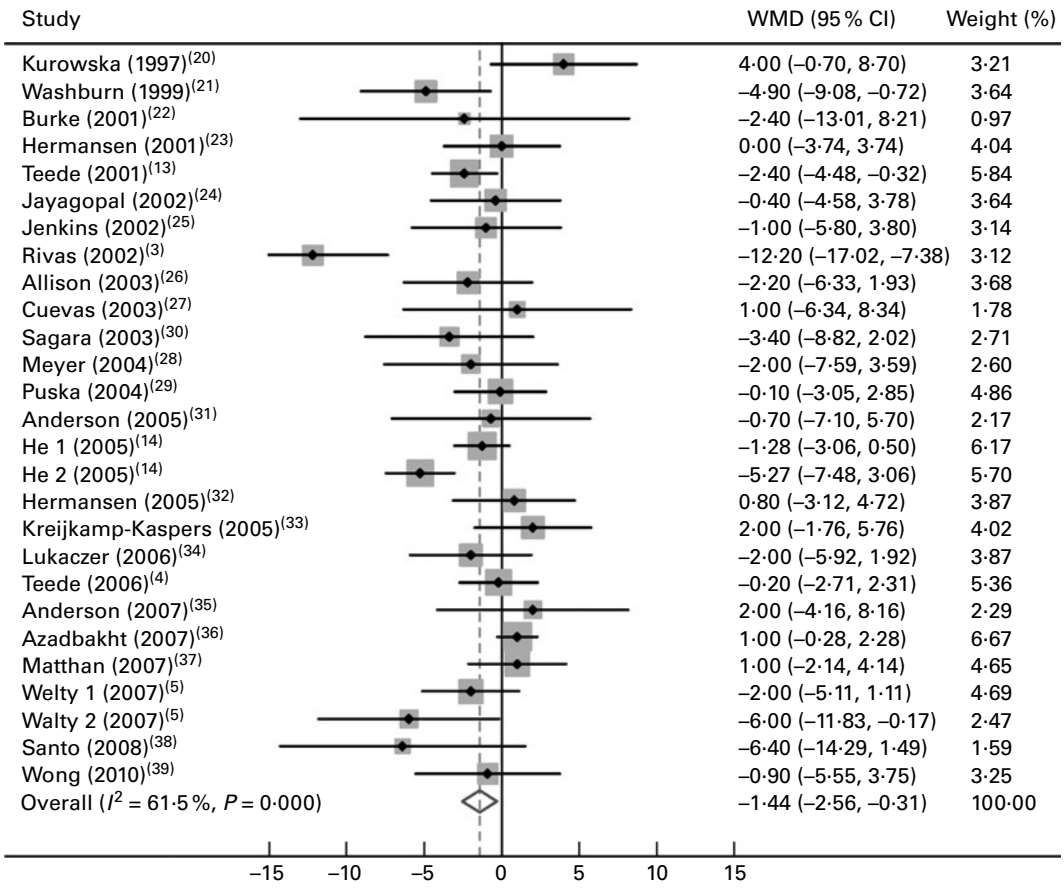

Fig. 2. Pooled effect size of soya protein with isoflavones on diastolic blood pressure. WMD, weighted mean difference.

Table 2. Pooled estimates of treatment effects on blood pressure through sensitivity analyses
(Number of trials, I^2 and 95 % confidence intervals)

	Systolic blood pressure (mmHg)						Diastolic blood pressure (mmHg)					
	Trials (*n*)	Net change	95 % CI	*P* for trend	*P* for heterogeneity	I^2 (%)	Trials (*n*)	Net change	95 % CI	*P* for trend	*P* for heterogeneity	I^2 (%)
All trials	27	−2·21	−4·10, −0·33	0·021	<0·001	65·70	27	−1·44	−2·56, −0·31	0·012	<0·001	61·50
All trials except outliers	26	−1·59	−3·17, −0·00	0·05	0·003	48·90	26	−1·08	−2·04, −0·11	0·029	0·005	46·40
Blinded trials	15	−2·90	−5·49, −0·31	0·028	<0·001	71·40	15	−1·93	−3·53, −0·34	0·017	<0·001	67·80
Trials using soya protein isolate	16	−1·99	−3·91, −0·07	0·042	0·036	43·80	16	−1·57	−2·76, −0·38	0·01	0·044	42·00
Trials with Jadad score ≥3	16	−2·82	−5·29, −0·36	0·025	<0·001	69·40	16	−2·02	−3·49, −0·56	0·007	<0·001	64·30
Trials excluding diabetics	25	−2·28	−4·27, −0·29	0·025	<0·001	67·70	25	−1·55	−2·75, −0·35	0·012	<0·001	64·20

Table 3. Pooled estimates of treatment effects on blood pressure in subgroups of trials
(Number of trials, I^2 and 95 % confidence intervals)

	Systolic blood pressure (mmHg)						Diastolic blood pressure (mmHg)					
Groups	Trials (*n*)	Net change	95 % CI	*P* for trend	*P* for heterogeneity	I^2 (%)	Trials (*n*)	Net change	95 % CI	*P* for trend	*P* for heterogeneity	I^2 (%)
Hypertension												
Yes	5	−8·58	−15·09, −2·06	0·01	<0·001	84·1	5	−5·24	−9·40, −1·08	0·014	<0·001	81·6
No	11	−2·27	−3·77, −0·76	<0·001	0·175	24	11	−1·21	−2·19, −0·23	0·016	0·339	11·1
Study design												
Parallel	14	−3·08	−5·95, −0·21	0·035	<0·001	73·6	14	−2·25	−3·95, −0·55	0·009	<0·001	65·1
Cross-over	13	−1·07	−3·24, 1·10	0·332	0·073	39·1	13	−0·41	−1·62, 0·79	0·5	0·136	30·9
Sample size												
≤ 42	15	−2·28	−5·37, 0·81	0·149	<0·001	69	15	−1·30	−3·04, 0·44	0·143	<0·001	0·638
> 42	12	−2·28	−4·60, 0·03	0·053	0·003	61·2	12	−1·74	−3·07, −0·42	0·01	0·034	0·475
Type of soya protein												
Soya protein isolate	15	−1·99	−3·91, −0·07	0·042	0·036	43·8	15	−1·57	−2·76, −0·38	0·01	0·044	42
Soya foods	12	−2·78	−6·53, 0·96	0·145	<0·001	78·3	12	−1·41	−3·52, 0·69	0·188	<0·001	71
Type of control diet												
Milk or casein	16	−2·00	−5·00, 0·96	0·184	<0·001	72	16	−1·33	−3·04, 0·37	0·126	0·001	59·1
Carbohydrate	6	−4·52	−6·42, −2·63	0·002	0·166	36·1	6	−3·01	−5·05, −0·97	0·004	0·079	49·3
Duration (weeks)												
≤ 8	15	−1·15	−3·27, 0·97	0·287	0·094	34·3	15	−0·78	−2·08, 0·52	0·237	0·09	34·8
> 8	12	−3·09	−6·08, −0·10	0·043	<0·001	77·2	12	−1·89	−3·63, −0·14	0·034	<0·001	70·3

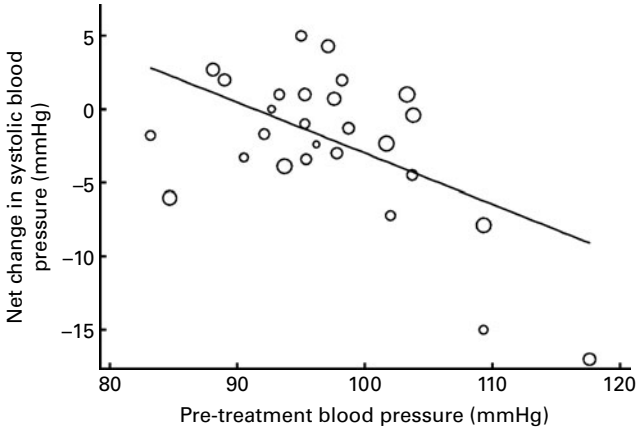

Fig. 3. Net change in systolic blood pressure according to pre-treatment blood pressure (r −0·54, P=0·006). Diameters of circles depend on the weights in the random-effects model.

Discussion

The present study identified significant reductions in the overall estimates in both SBP and DBP during soya protein interventions. Soya protein consumption significantly reduced SBP and DBP in both hypertensive and normotensive subjects, and the reductions were markedly greater in hypertensive subjects than those in normotensive subjects. Meta-regression analyses further revealed a significantly inverse association between pre-treatment BP and the level of BP reductions. In addition to pre-treatment BP, the type of control diet used as a comparison also has an impact on the BP reductions.

Our findings have potential public health implications. Although the BP reductions reported here are moderate at the individual level, a reduction of 4–5 mmHg in SBP and 2–3 mmHg in DBP would be expected to substantially reduce the risk of stroke (by about 20 %), CHD (by 10 %) and all-cause mortality (by 8 %) at the population level[40]. Given the high prevalence of hypertension[1,2], even a slight reduction in BP may contribute to a considerable public health benefit from soya protein consumption. Moreover, when used for other purposes, such as improving lipid profiles[41,42], the moderate hypotensive effects of soya protein doubtlessly provide extra benefits.

The observed substantial heterogeneity is most probably explained by pre-treatment BP and the type of control diet. It is probable that subjects with higher BP have more room for improvement. In fact, the study by Rivas *et al.*[3] that enrolled mild-to-moderate hypertensive patients and reported substantial BP reductions has been partly responsible for the observed heterogeneity, as exclusion of this outlier resulted in I^2 values <50 % for both SBP and DBP. Furthermore, trials[5,13,14,20,26,31,34,35,37–39] conducted in normotensive subjects yielded consistent and significant, although small, BP reductions, with little evidence of heterogeneity (P=0·175 for SBP and P=0·339 for DBP). This is probably because normotensive subjects are evidently healthy and are unlikely to take antihypertensive drugs that may potentially mask the effects of soya protein on BP.

Of note, the type of control diet appeared to play an important role in the effects of soya protein on BP. Growing evidence shows that milk product consumption has potential benefits on BP regulations[43]. When compared with milk or casein, soya protein showed small but not significant reductions in BP, which indicated soya protein may not be superior to milk products in improving BP. When compared with carbohydrate, soya protein consumption produced greater and significant BP reductions. These findings are consistent with the current evidence that partial substitution of refined carbohydrate with dietary protein can lower BP[44,45]. Thus, further studies of soya protein on BP should take the type of control diet into consideration.

In addition to pre-treatment BP and type of control diet, other characteristics of trials are worth considering, including duration of intervention and study design. Although the association of intervention duration with BP reductions was not found in the meta-regression analyses, results from subgroup analyses indicated that duration of at least 12 weeks would be necessary for intervention. Parallel-designed trials showed a greater reduction in BP than cross-over-designed trials. This is possibly because parallel-designed trials usually have longer duration that was associated with significant BP reductions as observed earlier. It is also possible that carry-over effects have residual impacts on BP reductions, as wash-out periods were short in most cross-over trials.

The present study has several strengths. First, it provides a comprehensive report of the effects of soya protein consumption on BP, based on the pooled evidence from twenty-seven RCT conducted in a wide range of geographical locations. The participant characteristics such as patient background, baseline BP status and ethnicity varied across trials, indicating that our findings might have a certain degree of external validity to be generalised to a broader population. Second, compared with the previous meta-analysis[6], the present analysis identified and included thirteen more RCT through an updated search. The enlarged sample size enhanced the power to detect a significant difference and provide more precise estimates of effects, and allowed us to perform a meta-regression

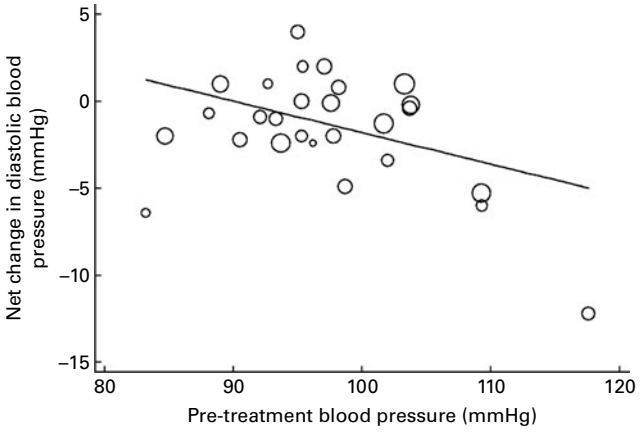

Fig. 4. Net change in diastolic blood pressure according to pre-treatment blood pressure (r −0·45, P=0·024). Diameters of circles depend on the weights in the random-effects model.

analysis to explore sources of heterogeneity. We also excluded studies in which other dietary factors were substantially different other than soya protein; therefore, soya protein with isoflavones was more likely to be the major contributor to the BP-lowering effects. Third, we investigated the potential sources of substantial heterogeneity across studies by a series of subgroup and meta-regression analyses, thereby increasing the clinical relevance of our conclusions and the scientific understanding of the relevant studies[46]. In addition, sensitivity analyses supported the robustness of our findings, and there was little evidence of publication bias in the present study.

Limitations in the present study should also be acknowledged. Substantial heterogeneity across trials that makes our findings complicated to interpret is the primary one. However, we have identified the major sources of inconsistency through a series of subgroup and meta-regression analyses. Since some trials were not primarily designed to test the hypotensive effects of soya protein, a rigorous methodology for measuring BP and the use of antihypertensive medications among participants were seldom reported. Likewise, unmeasured dietary factors that potentially influenced BP outcomes, such as dietary Na and K intake during the intervention, may not be controlled and balanced. In addition, there were only five trials[3–5,14,22] conducted in hypertensive participants, and the pooled results in this target group showed an even higher degree of heterogeneity. For all of these reasons, the findings of the present meta-analysis should be considered with caution, and further high-quality large-scale RCT are warranted, especially in the hypertensive population.

The underlying mechanisms by which soya protein with isoflavones may influence BP remain unclear. Isoflavones in soya are widely considered as the major contributors to the hypotensive effects of soya[3–5]. It is plausible that isoflavones, as oestrogen mimics, may exhibit antihypertensive activities by stimulating the production of the potent vasodilator NO[47]. Isolated isoflavones, however, appear to have little effect on BP as observed previously, suggesting the necessity for isoflavones to be ingested in combination with soya protein. Alternatively, hypotensive effects of soya may be mediated not only by oestrogenic mechanisms, but also by other soya components. Arginine, for example, which is a precursor of NO and with a high content in soya protein, might also exert BP-lowering effects[48]. Additionally, pinitol isolated from soyabeans has been documented to significantly decrease BP in patients with type 2 diabetes[49].

Equol, a metabolite of the soya isoflavone daidzein produced by gut bacteria, has recently received considerable interest due to its higher bioactivity compared with other isoflavones[50]. Because only approximately 30–50 % of the population is able to metabolise daidzein to equol, conflicting results from previous studies have led to the 'equol hypothesis' that equol producers are more likely to benefit from consuming soya foods than non-equol producers[50]. However, several clinical studies[28,33,51] investigating the effects of soya isoflavones on BP have observed no significant difference between equol producers and non-equol producers. Limitations of these studies including small sample sizes may result in insufficient statistical power to detect the difference. Thus, the equol hypothesis is not supported by the current evidence and deserves further study.

Conclusions

In summary, current evidence demonstrates that soya protein intake, compared with a control diet, significantly reduces both SBP and DBP, but the BP reductions are related to pretreatment BP levels of subjects and the type of control diet used as a comparison.

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