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RESEARCH

The effect of consumption of soy foods on metabolic syndrome in women: a case study from peri-urban Qwa-Qwa, South Africa

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Objectives: The objective was to determine the long-term effect (18 months) of 40 g daily consumption of whole soy bean on metabolic syndrome (MetS) in apparently healthy women.
Design: Single-system experimental design.
Subjects and setting: Ninety women were randomly recruited from three communities in Qwa-Qwa, Free State province.
Outcome measures: Dietary intake (24-h recall questionnaire), waist circumference (WC), blood pressure, fasting venous blood samples for total serum cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), triglycerides (TRGs) and glucose analyses.
Results: The prevalence of MetS was significantly ($p < 0.001$) reduced from 53.3% to 34.4% after the intervention. The most prominent risk factors were low serum HDL-C and high serum TRG levels followed by obesity (WC). After the intervention, the MetS group had significantly improved mean serum glucose ($p = 0.013$), systolic ($p < 0.001$) and diastolic ($p < 0.001$) blood pressure. No significant improvements were observed in the non-MetS group.
Conclusions: The prevalence of MetS is high in black women residing in Qwa-Qwa. Despite the beneficial metabolic effects observed in this study, a relationship between soy protein consumption and MetS risk factors could not statistically be confirmed. However, soy is a source of good-quality protein and is often used in low-income households as a replacement for other more expensive protein sources and the use of soy should not be discontinued as it may have a beneficial effect on MetS and may play a role in preventing MetS. More research is needed in large-scale case-control studies to determine the effect of soy consumption on MetS risk factors.
Social media message: Research has shown that soy may be beneficial for ameliorating some of the metabolic syndrome risk factors.

Keywords: metabolic syndrome, South Africa, soy consumption, women

Introduction

In 2017, it was estimated that 48% of all deaths in South Africa (SA) were due to non-communicable diseases (NCDs), many of which were associated with nutrition and lifestyle.[1] Metabolic syndrome (MetS) is a cluster of interconnected metabolic risk factors that increase the risk for developing atherosclerotic cardiovascular disease (CVD), type 2 diabetes[2,3] and all-cause mortality.[4] These factors include atherogenic dyslipidaemia (high triglyceride and low high-density lipoprotein cholesterol (HDL-C), high blood pressure, abdominal obesity and insulin resistance (elevated serum glucose levels). When these risk factors are prevalent simultaneously in individuals, they are in a prothrombotic and pro-inflammatory state.[2,3] Although the cause for MetS is multifactorial with genetic, environmental and metabolic causes,[2,3] the predominant underlying risk factor for MetS is abdominal obesity and insulin resistance.[5]

Dietary intakes play an important role in the prevention and treatment of MetS. The general recommendations include an improvement in lifestyle such as promoting physical activity and obesity control, a balanced low-energy diet with decreased intakes of saturated fats and cholesterol, simple sugars and increased intakes of vegetables and fruit.[2,3] The role of soy has received international recognition for its preventative and therapeutic role in CVD and specifically the normalising roles soy has on lipid profile through decreased synthesis of low-density lipoprotein cholesterol (LDL-C), also in MetS subjects.[2,6] Soy also has a hypotensive effect due to the low energy value and satiety properties.[7] Furthermore, the isoflavones in soy have a regulating effect on glucose metabolism.[8,9] It has also been found that soy consumption significantly lowers systolic and diastolic blood pressure in both hyper- and normotensive women.[10,11] The effect on MetS could be because of its beneficial components, namely complex carbohydrates, unsaturated fatty acids, soluble fibre, oligosaccharides, vegetable protein, vitamins, minerals and phytoestrogens.[12]

The objective of this study was to compare the effect of long-term (18 months) consumption of at least 40 g daily of whole soy bean, consisting of 15 g of soy protein, on the metabolic factors contributing to MetS in apparently healthy women resident in peri-urban Qwa-Qwa in the Free State province. This is one of the first studies in SA where a soy consumption intervention was evaluated; however, the mechanisms of the effects of soy protein intake, namely whether the changes would be attributable to the soy protein or to other soy-derived factors such as isoflavones, were not part of the aims of the study.

Methods

The study protocol was approved by the University of the Witwatersrand's Medical Ethics Committee for Research on Human Beings (M080931). Due to the high illiteracy of the community, the letter of information and informed consent was verbally explained to the respondents and translated to Sotho by a trained fieldworker. Confidentiality was confirmed by allocating a study number to each of the respondents. Participation was voluntary and informed consent was obtained prior to implementation.

Study design and sampling

This study formed part of the larger Qwa-Qwa Integrated Nutrition Programme (QQINP). A single-system design was used for this study due to the researchers having studied the same community on a repetitive basis since 2008.[13–15] A baseline survey was conducted to determine the main challenges to be addressed in the community.[15] A household soy gardening programme was implemented[13] and soy recipes, containing 40 g of whole soy beans (15 g soy protein) per portion, were developed and tested for sensory acceptability. Skills training included teaching the women to prepare the soy recipes and how to include the recipes in the household menu planning. The soy consumption intervention was undertaken over 18 months. Ninety women (n = 90) were randomly recruited for the intervention study to measure the impact of soy consumption on lipid profile and MetS. Sampling was described elsewhere.[14] During the 18-month intervention study, the respondents were instructed to follow their usual diet, but to replace one of the recipes with a soy-based recipe each day to ensure the intake of at least 40 g of whole soy beans per person per day. The researchers visited the women every month to measure compliance, checking on the availability of soy beans and discussing problems regarding soy recipe preparation and side effects. All measurements were recorded, and blood was drawn one week before and one week after the 18-month period.

Measurements

Age was recorded at baseline. The 24-h recall questionnaire data were collected for a period of three non-consecutive days (one weekend and two weekdays). Trained fieldworkers used a four-stage, multiple-pass interviewing procedure[16] and food models to assist with estimation of portion sizes. Dietary intake data were analysed by a registered dietitian using Foodfinder® version 3. The mean intake of the three days was calculated for macronutrients.

Waist circumference (WC) was measured at the area halfway between lower rib and iliac crest with a non-stretchable measuring tape in a horizontal position around the body.[16] The women were seated and the right arm supported at heart level and a cuff bladder was used for blood pressure measurements using a Tensoval Hartmann® duo control monitor by a registered nursing practitioner. Two measurements were taken and the average of the two readings used.

Fasting (> 8 h) venous blood samples were drawn between 07h00 and 10h00, after subjects had been seated for 15 min, by two nursing practitioners and a haematologist using a Vacutainer needle with minimal use of tourniquets. The blood was placed on ice until separation within two hours of blood collection. Serum was harvested by low-speed centrifugation at 3000 rpm for 30 s at 4°C and aliquoted into individual tubes. Serum and plasma were stored at 80°C until analyses were performed according to standard laboratory protocol by a registered haematologist. The Konelab 20i random access automated clinical chemistry system (Thermo Fisher Scientific, Waltham, MA, USA) was used for the analyses of total serum cholesterol, HDL-C, triglycerides (TRGs) and glucose with a coefficient of variation (percent CV) between runs of 1.2–2.8% for all serum variables. A Chemiluminescence Immunoassay (CLIA) system (Maglumi 1000 immuno analyser; Diamond Diagnostics, Holliston, MA, USA) was used to determine serum insulin. The Friedewald formula was used to calculate LDL-C.[17]

Statistical analyses

All analyses were done using IBM SPSS®, version 23 (IBM Corp, Armonk, NY, USA) and $p < 0.05$ was considered significant for all statistical analyses. Linearity regression was used to test all continuous variables for normality. Most variables were normally distributed. Age was analysed for mean and standard deviation (SD). Correlation coefficients were used to examine the association between the study variables ($p < 0.05$). Daily nutrient intakes were reported as means and standard deviations and compared with the estimated average requirement (EAR) values for women aged 31–50 years.[18]

The women were stratified into two groups based on MetS classification at baseline. The MetS group consisted of respondents with a presence of three or more of the following MetS criteria:

- WC ≥ 88 cm;
- TRG ≥ 1.7 mmol/l (150 mg/dl);
- HDL-C < 1.3 mmol/l (50 mg/dl);
- Systolic blood pressure ≥ 130 mmHg and diastolic blood pressure ≥ 85 mmHg or on antihypertensive drug treatment;
- Fasting glucose ≥ 5.5 mmol/l (100 mg/dl).[19]

The non-MetS group comprised respondents with two or less of the metabolic risk factors.

To assess the difference between the MetS and non-MetS groups, chi-square was used for analysis of the categorical data and adjustments made according to Bonferroni. Student's t-test was used to determine the mean difference between continuous variables such as age, WC, blood pressure and biochemical values. Thus, Levene's test for equality of variance was used at a p-value of < 0.05. Independent samples t-tests were done to determine significant differences between the two groups before and after the intervention. Pearson correlations were calculated for nominal data. Only significant correlation results are reported. To understand the predictors of MetS, linear regression was carried out with those dependent variables that had a significant correlation with MetS (age, systolic and diastolic blood pressure, WC, serum LDL-C, TRG, glucose).

Due to the significant age difference between the MetS and non-MetS groups, analysis of covariance (ANCOVA) was used to adjust for possible differences between the groups. Generalised eta squared (η^2_G) is reported to provide an estimate of standardised effect size at significance level of $p < 0.05$.

Results

The participants (n = 90) had a mean ± SD age of 46.5 ± 12.9 years. The results showed a prevalence of 53.3% (n = 48) MetS. The mean ± SD age of the MetS group was statistically significantly (p = 0.002) higher (50.7 ± 12.6 years) than the non-MetS group (42.1 ± 12.4 years).

The prevalence of MetS was significantly ($p < 0.001$) reduced from 53.3% to 34.4% after the intervention (Figure 1). The most prominent risk factors were low serum HDL-C and high serum TRG levels followed by obesity (WC). Furthermore, the prevalence

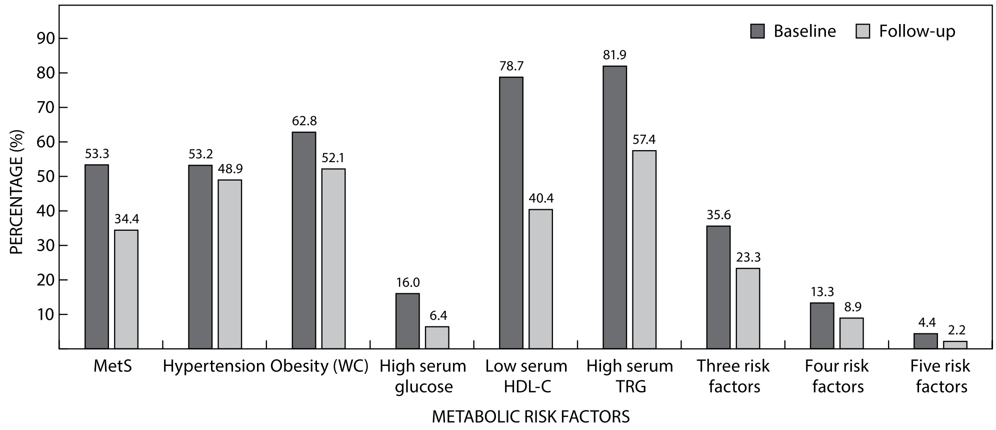

Figure 1: MetS classification of the women before and after the intervention.

Table 1: Descriptive statistics: anthropometric and biochemical parameters measured

Variable	**Unit of measure**	**Normal range**	**MetS group(n = 48, 53.3%)**		**Non-MetS group(n = 42, 46.7%)**		**ANCOVA**
			BaselineMean±SD	**Follow-upMean±SD**	**BaselineMean±SD**	**Follow-upMean±SD**	η^2_G(***p***)
WC	cm	< 88	$0.97\pm0.09^{a,b}$	0.97 ± 0.10^{c}	$0.82\pm0.12^{a,d}$	$0.89\pm0.12^{b,d}$	0.019 (0.201)
Serum glucose	mmol/l	< 5.5	$7.14\pm5.59^{a,b}$	4.38 ± 4.15^{b}	4.68 ± 1.37^{a}	3.42±1.32	0.013 (0.320)
HDL-C	mmol/l	> 1.3	0.95±0.66	1.42±0.49	0.87±0.53	1.47±0.64	0.000 (0.871)
LDL-C	mmol/l	< 4.1	4.39 ± 2.03^{a}	6.35 ± 2.53^{b}	$3.49\pm1.70^{a,c}$	$5.18\pm2.32^{b,c}$	0.001 (0.777)
Serum triglycerides	mmol/l	< 1.7	2.75 ± 0.85^{a}	2.38±1.21	2.07 ± 0.79^{a}	1.9±1.00	0. 004 (0.572)
Systolic blood pressure	mm Hg	< 130	$130.67\pm20.51^{a,b}$	137.19 ± 25.58^{b}	119.19 ± 14.60^{a}	128.07±18.16	0.096(0.003)
Diastolic blood pressure	mm Hg	< 85	$87.80\pm11.79^{a,b}$	89.54 ± 16.97^{b}	82.31 ± 13.01^{a}	87.05±19.21	0.008 (0.413)

Notes: ^{a,b,c} in the same row refer to statistically significant differences between the variables $p \leq 0.05$ (independent [between groups] and paired [within groups] t-test for equality of variances).

of respondents with three, four and five metabolic risk factors also progressively declined after the intervention.

Statistically significant differences in all the biochemical parameters between the two groups were observed at baseline, except for HDL-C (Table 1). At follow-up, the MetS group had significantly improved mean serum glucose (p = 0.013), systolic (p < 0.001) and diastolic (p < 0.001) blood pressure; however, clinical improvements in the mean serum HDL-C and TRG levels were also observed but were not statistically significant. In the non-MetS group, no significant improvements were observed after the intervention, but a clinical improvement in the mean serum glucose, HDL-C and TRG was observed. No significant difference in visceral adiposity was observed in the MetS group after the intervention. In the non-MetS group, a significant (p < 0.001) increase in mean WC was observed. Analysis of covariance showed no significant age effect size for WC, biochemical parameters and diastolic blood pressure between the MetS and non-MetS groups; however, a significant (p = 0.003), but small age effect size (η^2_G = 0.096) for systolic blood pressure was observed.

Both groups had low macronutrient intakes, except for carbohydrates, at baseline and follow-up when compared with the EAR.[18] No significant differences in macronutrient intakes were observed between the groups. The total fat intake showed low intakes (< 30% of total energy intake) in both groups at baseline and after the intervention. In both groups, significantly higher dietary intakes were observed for all the macronutrients except for dietary fibre where a significant decrease was observed in the non-MetS group after the intervention. Analysis of covariance showed no significant age effect size between the MetS and non-MetS groups for the dietary intake parameters; however, a significant (p = 0.043), but small age effect size (η^2_G = 0.047) for plant protein intake was observed (Table 2).

The Pearson correlation analyses revealed that at baseline MetS was significantly and positively correlated with age (r = 0.335, p = 0.001), systolic (r = 0.309, p = 0.003) and diastolic (r = 0.219, p = 0.038) blood pressure, serum TC (r = 0.277, p = 0.008), LDL-C (r = 0.236, p = 0.025), TRG (r = 0.383, p < 0.001) and glucose (r = 0.287, p = 0.011) levels and negatively correlated to WC (r = –0.566, p < 0.001). Furthermore, significant inverse relationships existed between total protein intake with systolic blood pressure (r = –0.241, p = 0.023) and glucose (r = –0.250, p = 0.027). Plant protein intake was significantly negatively associated with systolic blood pressure (r = –0.226, p = 0.033) whereas animal protein intake was significantly positively associated with serum glucose levels (r = 0.304, p = 0.008). Carbohydrate intake showed a significant negative association with diastolic blood pressure (r = –0.217, p = 0.041). Age was significantly associated with LDL-C levels (r = 0.319, p = 0.002), WC (r = 0.452, p < 0.001), systolic (r =

Table 2: Analysis of 24-h recall: daily mean intakes of the women (*n* = 90)

Dietary intake variable	Unit of measure	MetS group (*n* = 48, 53.3%)		Non-MetS group (*n* = 42, 46.7%)		ANCOVA	DRI[18] / WHO guidelines[20]
		Baseline Mean±SD	Follow-up Mean±SD	Baseline Mean±SD	Follow-up Mean±SD	η^2_G (*p*)	
Total energy (TE)	kJ	3758±1716[a]	4504±2177[a]	3678±2231[b]	4489±2758[b]	0.024 (0.146)	7999 EER
Total protein	g	38±18[a]	39±16[a]	37±22[b]	40±24[b]	0.001 (0.388)	46
Plant protein	g	14±8[a]	17±10[a]	15±13[b]	16±10[b]	0.043 (0.047)	
Total animal protein	g	25±19[a]	23±14[a]	23±19[b]	24±18[b]	0.000 (0.867)	
Total dietary fat	g	28±22[a](28.2%)	35±28[a] (29.4%)	23±16[b](23.6%)	33±33[b](27.8%)	0.002 (0.703)	30–35% total E
Dietary cholesterol	mg	110.7±130.0[a]	171.0±216.3[a]	83.4±94.8	114.5±191.8	0.000 (0.957)	< 300 mg
Carbohydrate	g	113±56[a]	141±63[a]	120±91[b]	143±81[b]	0.031 (0.103)	100
Dietary fibre	g	9±6[a]	10±6[a]	11±10[b]	10±5[b]	0.032 (0.096)	25

Notes: Estimated energy requirements (EER) based on mean ± SD age for the total group was 46 ± 13 years, with mean ± SD height, weight and BMI of 1.6 ± 0.1 m, 76.5 ± 16.5 kg and 30.0 ± 6.4 kg/m^2 respectively with moderate activity levels.[18]
[a,b,c] in the same row refer to statistically significant differences between the variables $p \leq 0.05$ (independent [between groups] and paired [within groups] *t*-test for equality of variances).
DRI = dietary reference intakes as represented by the estimated average requirement for females aged 31-50 years old, and adequate intake (AI)# where no EAR is available.[18]

0.263, *p* = 0.015) and diastolic (r = 0.263, *p* = 0.012) blood pressure. Serum glucose levels showed significant associations with systolic blood pressure (r = 0.342, *p* = 0.002) and TRG levels (r = 0.382, *p* = 0.012).

At follow-up, significant associations were observed between age and systolic (r = 0.209, *p* = 0.048) blood pressure, WC (r = 0.338, *p* = 0.001) and plant protein intake (r = 0.215, *p* = 0.043). Systolic blood pressure showed further associations with diastolic blood pressure (r = 0.707, *p* < 0.001), WC (r = 0.380, *p* < 0.001) and serum glucose levels (r = 0.390, *p* < 0.001) whereas diastolic blood pressure was also associated with WC (r = 0.261, *p* = 0.013). WC also showed a negative significant relationship with HDL-C (r = –0.379, *p* < 0.001). Serum TRG showed a significant positive relationship with serum glucose (r = 0.354, *p* < 0.001).

The linear regression analysis carried out on the MetS variables and age showed that WC was the only predictor for MetS (R^2 = 0.125, *p* = 0.034, SEE = 0.623) in this community.

Discussion

MetS has received much attention recently due to its association with cardiovascular morbidity and mortality[21] and the increasing prevalence globally and also in Africa. SA has a high prevalence of MetS compared with other African countries such as Nigeria, Ethiopia and Tunisia.[22] The decrease in metabolic risk factors for MetS through dietary changes, novel functional foods and nutraceuticals has been widely addressed in the literature recently. The effects of soy on lipid parameters have also been widely described in the literature[23] and this has led to the Food and Drug Administration of the United States of America recommending a daily consumption of 25 g of soy protein for a cholesterol-lowering effect.[24] A study undertaken in the same study community has found that in both hypercholesterolaemic and normocholesterolaemic women, the HDL-C and LDL-C levels improved significantly after the same intervention.[11] This study is the first to report on a comparison of the long-term effect of daily consumption of 15 g of whole soy bean protein on MetS lipid markers in black African women with and without MetS in SA.

According to the American Heart Association (AHA) definition of MetS, the prevalence of MetS among the women in this study was 53.3%, which was higher than the 44.9% and 46.3% found among black urban women[25] and coloured women respectively in the Western Cape.[22] The most prominent MetS risk factors among the women in this study were low HDL-C and high serum TRG levels, followed by visceral obesity, which were consistent with another study conducted among black women,[25] but inconsistent with the results of the study among coloured women.[22] Reduced HDL-C and hypertriglyceridemia, the two main types of dyslipidaemia associated with MetS,[21] were also found in this study. The prevalence of abnormally low HDL-C levels nationally at 47.9%[26] was much lower than the 78.7% found in this study at baseline. However, hypertriglyceridemia (81.9%) was more common than reduced HDL-C (78.7%) in this study, but in other African countries such as Botswana, Nigeria, Cameroon and Cotonou, reduced HDL-C contributed more frequently to dyslipidaemia than hypertriglyceridemia.[21]

Diabetes mellitus is no longer a rare condition in Africa and type 2 diabetes accounts for almost 90% of all cases of diabetes.[21] A review of MetS in Africa has found that dysglycemia ranks low in terms of the contributing factors to MetS.[21] Similarly in our study, high blood glucose levels were prevalent in only 16.0% of the women and showed the lowest prevalence of all the risk factors at baseline. Hypertension is one of the common CVD and MetS disorders in Africa.[21] In this study, 53.2% of the women had hypertension—much higher than the 10.4% and 10.2% prevalence of pre-hypertension and hypertension nationally.[26]

The prevalence of central obesity was 62.8% at baseline in the total group of women. This was higher than the national prevalence of 47.1% for women.[26] Visceral adiposity was observed in the MetS group and no changes were observed after the intervention. In the non-MetS group, a significant (*p* < 0.001) increase in mean WC (0.89 ± 0.12) was observed after the intervention. WC was, however, the only predictor of MetS in these women.

A reduction in all the MetS risk factors was observed in the respondents after the 18-month soy consumption intervention. At baseline, 35.6%, 13.3% and 4.4% had three, four and five MetS risk factors respectively. This improved to 23.3% with three, 8.9% with four and 2.2% with five MetS risk factors after the intervention. Although the prevalence of low serum HDL-C and high serum TRG were reduced in the total group, no significant differences between serum HDL-C and serum TRG were observed after the intervention. This was consistent with the findings of a meta-analysis of 11 clinical trials.[27] However, clinical improvements in the mean serum HDL-C and TRG levels were observed for both the MetS and non-MetS groups. The MetS group showed significantly improved mean serum glucose (p = 0.013), systolic ($p < 0.001$) and diastolic ($p < 0.001$) blood pressure compared with the non-MetS group in whom no significant improvements were observed after the intervention. Although some studies have not shown an effect of soy-protein consumption on blood pressure,[28,29] a meta-analysis of 10 clinical trials reported a significant difference in diastolic blood pressure with soy protein supplementation.[27] The same meta-analysis also reported that soy protein consumption improved glycaemic control,[27] which is consistent with our findings for the MetS group. Furthermore, soy protein supplementation or consumption for a short-term period of eight weeks[28] and a longer period of > 6 months reduced blood glucose levels significantly,[27] however, a meta-analysis showed inconsistent effects of soy intake on glycaemic control in various subgroups.[30]

The dietary intake of the women in this study showed very low intakes of all macronutrients as well as dietary cholesterol, except for carbohydrates, when compared with the EAR. Dietary carbohydrate is a major precursor of serum glucose and strongly related to lipid metabolism. A high carbohydrate intake, as observed in our study, will increase serum triglycerides and possibly decrease HDL-C levels.[31] Although no significant relationship between carbohydrate intake and serum lipid levels was observed, the high carbohydrate intakes may have contributed to the dyslipidaemia observed in the women of this study. The detrimental effects of a high carbohydrate diet are mainly observed when high glycaemic index (GI) foods are consumed and the consumption of fibre-rich, low GI foods,[31] such as soy,[32] may reduce this effect.[31] In this study, dietary fibre intakes were very low at less than 50% of EAR. Significantly higher intakes were observed for all the measured dietary intakes at follow-up in the MetS group. The effect of dietary fibre, especially whole grain fibre, on cardiometabolic health has been established and it has been proved that dietary fibre can lower serum TRGs and LDL-C.[33] Despite significantly improved dietary fibre intakes, dietary fibre intakes were still low after the intervention. Total protein, specifically plant protein intakes, significantly increased in both groups whereas total animal protein intakes significantly decreased and increased in the MetS and non-MetS groups respectively. Plant protein intake was significantly negatively associated with systolic blood pressure (r = –0.226, p = 0.033). No significant relationship was observed between plant protein intake and diastolic blood pressure in our study. A recent systematic review has found an inverse relationship between plant protein intake and both systolic and diastolic blood pressure, but no relationship between animal protein intake and blood pressure.[34] In our study, no relationship between animal protein intake and blood pressure was observed, but animal protein intake was significantly positively associated with serum glucose levels (r = 0.304, p = 0.008). Carbohydrate intakes showed a significant negative association with diastolic blood pressure (r = –0.217, p = 0.041). No significant relationships between dietary intake and MetS risk factors have been observed at follow-up, however. These results are contradictory to a meta-analysis that showed statistically beneficial relationships between soy protein intake with hypertension, lowering serum cholesterol and glucose levels.[34] Despite the beneficial metabolic effects observed in this study, a relationship between soy protein consumption and MetS risk factors could not statistically be confirmed.

Despite the MetS group being significantly older than the non-MetS group, age has not had an effect on the results except for plant protein intake and systolic blood pressure. At baseline, age was significantly associated with LDL-C levels (r = 0.319, p = 0.002), WC (r = 0.452, $p < 0.001$), systolic (r = 0.263, p = 0.015) and diastolic (r = 0.263, p = 0.012) blood pressure. These results confirm previous research that showed the prevalence of MetS increases with age.[21] Serum glucose levels showed significant associations with systolic blood pressure (r = 0.342, p = 0.002) and TRG levels (r = 0.382, p = 0.012). At follow-up, significant associations were observed between age and systolic (r = 0.209, p = 0.048) blood pressure, WC (r = 0.338, p = 0.001) and plant protein intake (r = 0.215, p = 0.043). Systolic blood pressure showed further associations with diastolic blood pressure (r = 0.707, $p < 0.001$), WC (r = 0.380, $p < 0.001$) and serum glucose levels (r = 0.390, $p < 0.001$) whereas diastolic blood pressure was also associated with WC (r = 0.261, p = 0.013). WC also showed a negative significant relationship with HDL-C (r = –0.379, $p <$ 0.001). Serum TRG showed a significant positive relationship with serum glucose (r = 0.354, $p < 0.001$). These relationships proved the interrelationship between the risk factors for MetS.

This study contributes to the paucity of research on the effect of soy protein consumption on MetS of black African women in Qwa-Qwa, but had a number of limitations, the first being that urinary/blood samples were not analysed for isoflavones during the intervention to measure compliance. Unfortunately, due to low literacy the women could not keep a log book to record the recipes prepared every day, though they verbally confirmed that they consumed one soy recipe per day, but the quantities could not be verified. Second, no control group was included. A third limitation was that these results are not generalisable due to a relatively small sample size. However, as an exploratory study, the results revealed issues and actions needed for the successful implementation of dietary interventions and for future research. A strength of the study was the high retention rate with no dropouts. Although the use of different MetS criteria used when comparing results of different studies can be a limitation,[21] the information generated is still informative regarding the burden of MetS among women in Qwa-Qwa.

Conclusions and recommendations

This study has showed that the prevalence of MetS is high in black women residing in Qwa-Qwa. Overweight and obesity are health problems that increase the risk of MetS,[27] and WC was found to be the only predictor of MetS, but we failed to show that soy protein consumption could significantly reduce the prevalence of obesity. The prevalence of MetS was significantly reduced after the soy consumption intervention, mainly through the significantly improved glycaemic control and blood pressure. Although the most prominent MetS risk factors were low HDL-C and high TRG levels, no significant improvements were observed in HDL-C and TRG levels despite metabolic improvements.

Despite the beneficial metabolic effects observed in this study, a relationship between soy protein consumption and MetS risk factors could not statistically be confirmed. However, soy is a source of good-quality protein and is often used in low-income households as a replacement for other more expensive protein sources. The use of soy should not be discontinued as it may have a beneficial effect on MetS and may play a role in preventing MetS. More research is needed in large-scale case-control studies to determine the effect of soy consumption on MetS risk factors and to study the effect of the different components, such as soy phytoestrogens, isoflavones and equol, on the MetS risk factors. Research should also aim to determine the optimal soy protein dosage for the most favourable effect on the MetS risk factors.

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