Review Article

Dietary patterns and metabolic syndrome - a review of epidemiologic evidence

Amanda J Baxter BAppSc (Hons)[1], Terry Coyne PhD[2,3] and Christine McClintock PhD[3]

[1] *Queensland Institute of Medical Research, Brisbane, Australia*
[2] *School of Population Health, The University of Queensland, Brisbane, Australia*
[3] *Epidemiology Services Unit, Queensland Health, Brisbane, Australia*

Metabolic syndrome is associated with increased risk of coronary heart disease and type 2 diabetes, and appears to be widely prevalent in both developed and developing countries. While lifestyle modification is recommended for management of the syndrome, the dietary pattern most beneficial for patients is yet to be ascertained. Original research papers from the Medline database were examined for dietary patterns that may be associated with the syndrome. Three large-scale epidemiological studies were found fitting our criteria. Dietary patterns high in fruit and vegetable content were generally found to be associated with lower prevalence of metabolic syndrome. Diet patterns with high meat intake were frequently associated with components of metabolic syndrome, particularly impaired glucose tolerance. High dairy intake was generally associated with reduced risk for components of metabolic syndrome with some inconsistency in the literature regarding risk of obesity. Minimally processed cereals appeared to be associated with decreased risk of metabolic syndrome, while highly processed cereals with high glycaemic index are associated with higher risk. Fried foods were noticeably absent from any dietary pattern associated with decreased prevalence of metabolic syndrome. The conclusion of this review is that no individual dietary component could be considered wholly responsible for the association of diet with metabolic syndrome. Rather it is the overall quality of the diet that appears to offer protection against lifestyle disease such as metabolic syndrome. Further research is required into conditions, such as overweight and obesity, which may influence the effect of diet on the development of metabolic syndrome.

Key Words: metabolic syndrome, X syndrome, literature, review, diet, diet quality, dietary patterns

Introduction

The metabolic syndrome describes a cluster of abnormalities which are associated with increased risk of developing coronary heart disease (CHD). Core components of the metabolic syndrome include: insulin resistance, type 2 diabetes or impaired glucose tolerance, hypertension, dyslipidaemia and central obesity. Coronary heart disease is the leading cause of death in Australia, accounting for 19.5% of all deaths in 2002.[1] The major physiological and behavioural risk factors for CHD include high blood pressure, high blood cholesterol, diabetes, overweight and obesity, tobacco smoking, poor nutrition and physical inactivity.[2] CHD risk factors are widespread in the Australian population as highlighted in a report from the Australian Diabetes, Obesity and Lifestyle Study (AUSDIAB).[3] This study found that nearly one in four Australian adults suffer from diabetes or impaired glucose tolerance. Chronic high blood pressure, known to increase the risk of CHD by two to four times, affects 28% of the Australian population over the age of 25. An estimated 50% of the adult population have high blood cholesterol and approximately 60% of the adult population is classified as being overweight or obese. All of these risk factors were found to increase with age,[3] and as the number of risk factors increases, so too does the risk of CHD.[1] Although there is now comprehensive data regarding the prevalence of core components of metabolic syndrome, there has been little research published in Australia on prevalence of the syndrome. In the United States, the NHANES III study estimated that almost 24% of American adults have metabolic syndrome.[4] This figure increased to 43.5% among those aged 60 to 69 years. These statistics have serious implications for Australian health professionals. The number of Australians with metabolic syndrome is likely to be of a similar magnitude, and given our similar risk profile and ageing population, individuals at risk of CHD will increase significantly within the next decade.

The rate of death attributed to CHD in Australia has decreased by around 70% since the 1960's.[1] Improvement in lifestyle risk-factors are at least partly responsible for this reduction.[1] In support of this conclusion, dietary and exercise therapies have been shown to significantly reduce the progression of chronic diseases such as CHD[5] and type 2 diabetes.[6]

Correspondence address: Amanda Baxter, B.App.Sc(Hons), Queensland Institute of Medical Research, 300 Herston Road, Herston QLD 4029, Australia.
Tel: 07 3845 3573 ; Fax: 07 3362 0101
Email: amandaB@qimr.edu.au
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There are no clear recommendations regarding dietary guidelines for the prevention of metabolic syndrome in persons at risk. The aim of this paper is to review current research related to dietary factors that may be associated with the metabolic syndrome.

Materials and methods

This paper reviewed large cross-sectional studies and intervention trials which found associations between dietary factors and the metabolic syndrome. Both prospective and cross-sectional studies were included to account for the often extensive timeframe involved in the development of this syndrome. This review focused on recent publications in peer-reviewed sources including journals, clinical textbooks and professional websites. The methodology involved a search of the available databases including Cochrane Reviews, Medline, and the Australasian Medical Index (AMI) for topical keywords, including:

1. (metabolic syndrome) or (insulin resist syndrome) – 1496 entries found
2. (diet pattern) or (food pattern) – 1046 entries found

Altogether, five articles were found on dietary patterns and the metabolic syndrome, three of which were robust epidemiologic studies based on large populations, the other two (excluded) looked at specific populations of small sample size (N <1000).

Description of studies

Two studies, the Isle of Ely[7] and the Malmö Diet and Cancer Project[8], examined the relationship between dietary patterns and prevalence of metabolic syndrome components in a population-based cross-sectional study. The CARDIA study[9] looked at food groups and nutrients associated with incidence of the syndrome in a 10-year prospective study.

The Isle of Ely Study, Williams et al.[7]

The Isle of Ely study[7] was a population-based study of type 2 diabetes and metabolic disorders in men and women from the Isle of Ely in the United Kingdom. Researchers drew on this cohort to investigate the relationship between dietary patterns and components of the metabolic syndrome in 802 adults aged 40 to 65 years.[7] The study used principal component analysis (PCA) to isolate four dietary patterns from food frequency questionnaire data, and related these patterns to features of the metabolic syndrome. Four diet patterns were derived through calculation of factor loadings for variance of frequency for each food item in comparison to the remaining items. Table 1 shows the foods consumed, commonly and regularly as part of the four dietary patterns.

Both diets 1 and 2 demonstrated an inverse association with separate components of the metabolic syndrome. After adjustment for age, those with a higher score for diet 1 had a lower risk for increased waist-hip ratio (WHR), impaired glucose tolerance, increased plasma triglycerides and type 2 diabetes, and lower risk for decreased HDL-cholesterol. A tertile increase in loading for diet 1 was associated with a 28% reduction in the risk of type 2 diabetes, a relationship which persisted after controlling for age, sex, BMI and smoking. Diet 2 had an inverse association with impaired glucose tolerance and increased plasma non-esterified fatty acids. Diets 3 and 4 showed no significant associations with metabolic syndrome. Overall, the Isle of Ely Study suggest that eating patterns characterised by high intake of fruit, vegetables and whole cereals, and low intake of fried foods appeared to be associated with lower risk of metabolic syndrome components. Bread and milk were not specifically mentioned as part of a dietary pattern.

Table 1. The four dietary patterns identified in the Isle of Ely study[7]

	Diet 1	Diet 2	Diet 3	Diet 4
Commonly consumed foods	Fruit Salad Fish (not fried) Other veges Poultry Green vegetables Pasta/rice Ice cream	Cakes Sweets Root vegetables Biscuits Puddings/ pies Pulses Green vegetables Chocolate Cheese	Chocolate Sweets Crisps Cheese Soft drinks Fruit	Eggs Fried food Sausages Cheese Fried fish Nuts Other vegetables
Irregularly consumed foods	Fried food Sausages Fried fish Potatoes Cakes Crisps	Nil	Root vegetables Green vegetables Potatoes Red meat Other vegetables	Biscuits Cakes Ice cream

The Malmö Diet and Cancer Study, Wirfält et al.[8]

The Malmö Diet and Cancer Study[8] examined associations between dietary patterns and cancer and cardiovascular disease in a Swedish population. Data from a sample (N = 1122) of men and women aged between 45 and 68 years were analysed for associations between diet and components of the metabolic syndrome.[8] The dietary patterns isolated in the Malmö study differed significantly from that of the Isle of Ely study, possibly due to cultural differences in diet, but also due to study design. Six dietary patterns were identified based on highest proportion of energy intake from food groups, unlike the previous Isle of Ely study which was based on frequency of consumption. Differences in dietary patterns are expected as those food groups that contribute a high proportion of energy to the diet would not need to be eaten frequently to rank highly in this analysis (e.g a high energy chocolate bar compared to low energy piece of broccoli).

The relationship between dietary patterns and components of the metabolic syndrome differed significantly between men and women. The "Many foods and drinks" pattern with moderate energy intake from cheese and fat meat, was associated with an increased risk of hyperglycaemia and central obesity in men. Men who scored highly for this dietary pattern had an odds ratio (OR) of 1.64 (95%CI 1.24, 2.17) for hyperglycaemia while women showed no significant association. The "Fibre bread" dietary pattern with high energy intake from fibre-

rich bread and fat meat was associated with a decreased risk of central obesity in men (OR 0.61, 95%CI 0.42, 0.89). For women, the "White bread" dietary pattern was associated with increased risk of hyperinsulinaemia (OR 1.39, 95%CI 1.02, 1.89) while the "Milk fat" dietary pattern was associated with reduced risk of hyperinsulinaemia (OR 0.58, 95%CI 0.40, 0.84). All relationships remained significant after controlling for physical activity and smoking, and other dietary factors such as alcohol, total fat and fibre intake, fatty acid ratios, folic acid, magnesium and antioxidants.

The CARDIA study, Pereira et al[9]

Pereira *et al.*,[9] investigated associations between food groups and the metabolic syndrome as part of the multicentre CARDIA project in the United States. Unlike the Isle of Ely and Malmö studies, this was a prospective study and involved a much younger cohort (18-30 years). Analysis of the CARDIA cohort did not identify dietary patterns, rather it evaluated food groups and nutrients in relation to incidence of the metabolic syndrome and its components.

A strong inverse association was found between consumption of dairy foods and the risk of metabolic syndrome, particularly in overweight subjects. After controlling for demographic features, non-dietary lifestyle factors and common dairy components such as saturated fat, magnesium, calcium and vitamin D, the OR for metabolic syndrome in overweight individuals decreased by 69% for those in the highest quintile for dairy intake compared to those in the lowest quintile. Among those who were not overweight, the OR for metabolic syndrome decreased by 28% for those in the highest quintile compared to the lowest. Similar relationships were found for both low-fat and high-fat dairy products.

A significant relationship was also found for dietary patterns with high intake of dietary fibre and protein. Fibre intake significantly reduced the risk of metabolic syndrome; for each 3g/1000 kcal increase in fibre intake the OR decreased by 34%. Dietary protein, however, appeared to increase the risk of metabolic syndrome with a 12% increase in OR for each 1% caloric increase in protein. This relationship was only significant for protein from animal sources, no association was found for plant proteins.

Results

The associations of dietary patterns with the metabolic syndrome found in these three epidemiological studies are summarised in Table 2. Dietary patterns high in fruit and vegetables were generally associated with reduced prevalence of metabolic syndrome and its components. Diets with a high intake of dairy foods had mixed results. In the Isle of Ely study, none of the dietary patterns associated with lower risk of metabolic syndrome components appeared to have a high dairy content. However, in the Malmö and the CARDIA studies, dietary patterns with high dairy food content demonstrated a significant protective effect.

Associations between dietary patterns with high meat intake and metabolic syndrome were inconclusive based on the Isle of Ely study. In the Malmö study, fat meat contributed significantly to the energy intake of dietary patterns associated with hyperglycaemia and hyperinsulinemia but showed an inverse association with central obesity. In the CARDIA study, high intake of protein from animal sources was associated with increased incidence of metabolic syndrome.

Only the Isle of Ely study mentioned the effect of a diet high in fish, finding a protective effect. Fried foods were noticeably absent from any protective dietary patterns. Cereals, like meat, belonged to dietary patterns which had both a positive and negative association with metabolic syndrome. The type of cereal and degree of processing appeared to be significant factors.

Discussion

One of the difficulties in comparing studies of the metabolic syndrome is the criteria for diagnosis. The WHO standard of diagnosis called for a minimum of three components of the syndrome which is also the criteria used in the most recent NHANES study.[4,9] The CARDIA study considered individuals to have metabolic syndrome when two or more of the core components are present. The Isle of Ely and the Malmö studies did not use a standard definition of metabolic syndrome, but rather looked for associations with core components.[7,8] Therefore the extent of the protective effect is unclear for those diagnosed by WHO criteria.

Table 2. Summary of associations between dietary factors and metabolic syndrome/components of metabolic syndrome

Diets high in:	Isle of Ely,Williams *et al.*, (2000)[7]	Malmo, Wirfält *et al*., (2001)[8]	CARDIA, Pereira *et al.*, (2002)[9]
Fruit	-ve association	no association	-ve association (fibre only)
Vegetables	Strong -ve association	-ve association	-ve association (fibre only)
Dairy	-ve association	+ve & -ve associations	Strong -ve association
Cereals			
Wholegrain	-ve association	-ve association	-ve association (fibre & plant protein)
Refined	+ve & -ve association	+ve association	not mentioned
Meat	+ve & -ve associations	+ve & -ve associations	+ve association
Fish	-ve association	Not mentioned	Not mentioned
Fried food	+ve association	Not mentioned	Not mentioned

The association of metabolic syndrome and dietary patterns high in fruit, vegetables and fish, and low in fried foods were consistent both between the three studies examined and the existing literature.[10,11] These components are well recognized as part of a healthy diet associated with low incidence of CHD and its risk factors.[11,14] The three studies examined[1-9] show conflicting effects of dairy foods, meat and cereals on CHD risk factors that are components of metabolic syndrome. Only those categories of food groups that show conflicting results or which feature prominently in the three studies reviewed will be discussed.

Fruit

Fruit did not appear to play a major role in the reviewed papers other than the Isle of Ely Study. In this study, Diet 1 was characterized by frequent consumption of fruit and associated with reduced risk for components of metabolic syndrome.[7] The only diet pattern in the Malmo Study with high energy intake from fruit did not have any association with risk of metabolic syndrome.[8] However a large body of literature exists attesting to the benefits of fruit and vegetable consumption on risk for components of metabolic syndrome.[11-16]

Recently a comprehensive review found that fruit and vegetables made a significant contribution to the optimal diet for prevention of heart disease.[12] This review supports the findings of a randomized intervention trial which examined secondary prevention of CVD in an Indian population.[13] Researchers found that cardiac patients who followed a low-fat diet, with increased fruit and vegetables (Group A) suffered less cardiovascular deaths and deaths due to other causes than patients (Group B) on a low-fat only diet (RR 0.59; 95%CI 0.46, 0.74).[13] Group A also showed a significant reduction in body weight, waist/hip ratio and glucose intolerance after six months of follow-up.[13]

While many studies do not separate the health effects of fruits and vegetables, it is possible to review the effects of biochemical components more commonly found in fruit. Results from a trial testing the effect of antioxidants on insulin secretion in rodents has found that anthocyanins from cherries and berries increase the body's production of insulin.[14] Researchers hypothesize these components may have a role in prevention of type 2 diabetes and insulin resistance in humans.[14]

Vegetables

Both dietary patterns associated with lower prevalence of metabolic syndrome in the Isle of Ely study (Diets 1 and 2) were characterized by frequent consumption of salad and/or green vegetables.[7] Potatoes and fried foods (including fried vegetables eg.crisps) were either irregu-larly consumed or not reported as being consumed at all as part of these diets.[7] Results from the Malmo Study were less consistent with those scoring highly for the "white bread" diet (no vegetables) at higher risk of hyperinsulinaemia (women) and dyslipidaemia (women and men).[8] Yet of the two diets where vegetables contributed a relatively high proportion of energy (the "low-fat high-fibre" (LFHF) and the "fibre bread" diets) only the LFHF diet was associated with reduced risk of central obesity (men only). While vegetables were not mentioned in the CARDIA Study, they are known as good source of fibre which this study found to have a strong negative correlation with metabolic syndrome.[9]

Many components of fruit and vegetables contribute to the beneficial nature of these foods, however trials involving individual vitamins, minerals and antioxidants frequently have been unable to replicate the same effectiveness as the whole food.[15] This is likely due to complex interactions between many different nutrients and phytochemicals found in fruit and vegetables.[16]

Dairy

Recent epidemiologic and intervention studies appear to support the findings of the CARDIA study that food patterns characterised by frequent intake of dairy foods can reduce the prevalence of metabolic syndrome and its components in those most at risk, including the overweight[9], hypertensives[17] and hypercholesterolemics.[18] These findings are in contrast to a popular belief that dairy foods, commonly high in dietary cholesterol, saturated fat and protein, actively contribute to the development of CHD risk factors.[19]

In a 1992 intervention trial by Buonopane, Kilara, Smith and McCarthy, one quart (0.95litres) of skim milk was added to the daily diet of hypercholesterolemic and normocholesterolaemic subjects.[18] After four weeks, a 6.6% reduction in serum cholesterol was seen in the subjects with high cholesterol at baseline. No change was found in subjects with normal levels of cholesterol at baseline. Significant reductions in both diastolic and systolic blood pressure were reported in both test groups. Hata *et al.,*[17] found similar results after supplementing the diet of elderly hypertensive subjects with 95ml of a fermented milk product daily. After eight weeks, systolic blood pressure had decreased by a mean of 9.4 mmHg and diastolic by 6.9 mmHg in the experimental group.[17]

In a recent review of the effects of milk products on cardiovascular disease risk factors, Pfeuffer and Schrezenmeir[19] concluded that calcium, bioactive pep-tides, conjugated linoleic acid and as yet unidentified components of milk may protect against hypertension and hyperlipidaemia. In addition, dairy products with characteristically high calcium content are proposed to have a role on reducing risk of obesity.[20] Zemel *et al.,*[20] reported an inverse relationship between calcium consumption and obesity from data collected in the NHANES III. Relative risk of being in the top quartile for body fat decreased from 1.00 for the lowest quartile of calcium intake to 0.75 for the second quartile, 0.40 for the third and 0.16 for the highest quartile.[20]

Other studies appear to contradict these findings. For example the FINRISK studies[21] found that high milk intake was positively associated with obesity in men and women aged 25-64 years. This association remained constant over the study's 15-year period. A 1996 Brazilian study[22] found a similar association in a similarly aged cohort. Three dietary patterns were identified through factor loading. The only dietary pattern to show reduced risk of obesity (13% reduction in men and 14% reduction in women) was the traditional diet which had a lower loading for butter and milk and higher loading for rice

Table 3. Summary of studies showing an association between dairy products and components of the metabolic syndrome.

Study	Dietary variables	Findings
Diets showing negative associations with components of metabolic syndrome		
CARDIA[9]‡	Milk and dairy foods (low-fat and regular)	Reduced risk of metabolic syndrome associated with diets high in dairy.
Isle of Ely[7]†	Milk, cheese	No significant loading for milk in dietary patterns described in the study; cheese was frequently consumed in diet associated with improved glucose tolerance and plasma non-esterified fatty acids
Buonopane[18] §	Skim milk	Additional skim milk consumption associated with lower plasma cholesterol in hypercholesterolemics and lower blood pressure.
Zemel *et al.*[20] †	Calcium from all sources	High calcium intake associated with decreased risk of obesity
Hata *et al.*[17] §	Fermented milk	Consumption of yoghurt-like product associated with decreased blood pressure in hypertensives.
Diets showing positive and negative associations		
Malmo[8]†	Cheese, high milk-fat margarine	Diet with high intake of cheese associated with increased risk of hyperglycaemia in men and reduced hyperinsulinaemia in women
Diets showing positive association		
Finrisk[21]‡	Milk and sour milk	Products associated with increased risk of obesity
Sichieri[22]†	Milk & butter	Diets high in milk and butter associated with higher risk of obesity

† Cross-sectional study; ‡ Prospective study; § Intervention study

and beans.[22] Table 3 summarises the evidence for both negative and positive associations of dairy products and components of metabolic syndrome.

The evidence for dietary patterns with high dairy intake as protective against metabolic syndrome remains inconclusive, although research to-date appears promising. Factors such as type of dairy product, fat and mineral content may influence the properties of the food and its association with metabolic syndrome. An additional factor is the known genetic variation in certain ancestral groups (eg. African Americans and East Asians) impacting on an individual's ability to digest and absorb components of dairy products.[23,24] Therefore ancestry may be a further confounding factor in the relationship between dairy intake and risk of metabolic syndrome.

Cereals

Our three review articles[7-9] demonstrated that dietary patterns characterised by high intake of cereal-based foods may have a negative or positive association with metabolic syndrome, depending on type of cereal and degree of processing (Table 4). Cereals, including grains (eg. wheat, oats, corn and rice), nuts and pulses (eg. peas, beans and lentils) are criticised in some popular press sources due their high carbohydrate content. Yet research shows that dietary patterns characterised by consumption of minimally processed cereals and higher dietary fibre reduces glycaemic and insulinaemic responses, and lowers the risk of type 2 diabetes and other CHD risk factors.[22] A large body of research now supports the role of minimally processed cereal foods as part of a dietary pattern associated with lower risk of diabetes and insulin resistance,[21-22,25,26] hypertension[27], high plasma cholesterol[28] and obesity.[28]

An intervention trial conducted by researchers at the University of Minnesota found that substituting foods made with wholemeal flour and whole grains for those made with white flour, significantly improved insulin sensitivity in overweight hyperinsulinemics within six weeks.[26] The whole-grain diet was found to be substantially higher in fibre (soluble and insoluble), potassium, magnesium and antioxidants (vitamins A and E), but lower in sodium, starch and energy (KJ).[26]

The Framingham Offspring Study[28], a large longitudinal study of cardiovascular disease and its risk factors, found that dietary patterns with a high intake of whole-grain cereals were associated with decreased risk of CHD risk factors. After adjustment for known CHD risk factors and intake of other food groups, associations for whole grains remained significant for reduced waist-hip ratio (WHR), LDL-cholesterol and fasting insulin.[28] The associations were most pronounced among overweight subjects. No significant associations were found for consumption of refined-grain foods.

Results of epidemiologic and intervention studies suggest an important role for minimally processed cereals as part of a dietary pattern for those at increased risk of metabolic syndrome. Processed cereals, in contrast, appear to be associated with an increased risk of components of the metabolic syndrome (Table 4).

Table 4. Summary of studies which examined associations between cereal-based foods and components of the metabolic syndrome.

Study	Dietary variables	Findings
Diets showing negative associations with components of metabolic syndrome		
Isle of Ely *et al.*[7]†	Pasta/rice, pulses	Associated with lower risk of central obesity, glucose intolerance, high plasma triglycerides and higher levels of HDL cholesterol. Lower risk of diabetes.
CARDIA[9] ‡	Fibre (all sources)	Diets high in fibre significantly decreased risk of metabolic syndrome.
Pereira *et al*[26]§	Wholemeal flour and wholegrain foods	When refined grains were replaced with whole-grain food, insulin sensitivity increased in overweight hyperinsulinaemics.
McKeown *et al.*[28] †	Wholegrain foods	Whole grain intake associated with lower WHR, LDL-cholesterol and fasting insulin ($p<0.05$).
Diet showing positive and negative associations		
Malmo[8]†	Fibre-rich bread, white bread	High energy intake from fibre-rich bread associated with decreased risk of central obesity. High energy intake from white bread associated with increased risk of hyperglycaemia in women.

† Cross-sectional study; ‡ Prospective study; § Intervention study

Meat

In the Malmö study[8], the "Fibre bread" diet characterized by high 'fat' meat consumption was associated with decreased risk of central obesity in men. The diets characterised by moderate meat consumption were associated with increased risk of hyperglycaemia in men (Many foods and drinks diet), increased risk of hyperinsulinaemia in women (White bread diet) and decreased risk of hyperinsulinaemia in women (Milk fat diet).[8]

However, the Isle of Ely study found that frequent meat consumption did not have a significant loading for any of the dietary patterns.[7] These apparently inconsistent results are unexpected as a significant body of research now suggests that a dietary pattern characterised by high meat content, particularly red meat, is associated with increased rates of CHD[30-32] and diabetes.[33]

The US Health Professionals study[32] identified two dietary patterns, the "prudent" and the "Western". The Western diet, characterised by frequent consumption of red meat and processed meats, was associated with increased risk of fatal CHD. Those in the highest quintile of the Western diet score had a 2.15 fold higher risk (95%CI 1.34, 3.46).[32] Similar relationships were found with CHD risk factors. Those in the highest quintile of the Western diet score were found to have a relative risk of 1.54 for type 2 diabetes. When food patterns were examined independently, processed meat had the strongest association for risk of diabetes (RR 1.48).

Other research has suggested that the high iron intake of such diets may contribute to insulin resistance. Hua *et al.*,[34] found that lacto-ovo vegetarians had greater insulin-sensitivity than meat-eaters with a plasma glucose level of 4.1 mmol/l compared to 6.9 mmol/l. When body stores of iron were reduced in meat-eaters via phlebotomy, insulin-mediated glucose disposal rates improved by approximately 40%.[34]

Central obesity is associated with increased risk of insulin resistance.[35] A large prospective study by the American Cancer Society found that likelihood of weight gain at the waist increased with higher intake of meat and decreased with higher intake of vegetables.[36] Men and women consistently in the highest quintile for meat consumption were 46% and 50% respectively more likely to gain weight at the waist over a ten-year period than those in the lowest quintile.[36] Table 5 shows the positive and negative associations of red meat with components of the metabolic syndrome.

Physiologic differentiation

One factor that should be considered is whether physiologic differences can influence the effect of particular dietary patterns on the risk of metabolic syndrome. The CARDIA study showed a strong association for dairy intake and reduced risk of metabolic syndrome only in the sample with BMI>25, with no association found for the non-overweight group.[9] The Diabetes Prevention Program Group (DPPG)[37] which studied the effect of dietary intervention on risk of metabolic abnormalities supports this influential role of excess body fat. Researchers found that type 2 diabetes was significantly reduced by 58% in the experimental group undertaking lifestyle change.[37] While showing a very significant result, it should be noted that the study sample only included those with a BMI of 24 or over. Two possibilities may explain why particular dietary patterns are associated with reduced risk of metabolic syndrome in the overweight and obese only. The first is that the metabolic state created by excess adiposity may influence the effect of diet and exercise on risk of metabolic syndrome. The alternate theory is based on a recent hypothesis that epigenetic changes as a result of nutritional imbalance during important windows of

Table 5. Summary of studies showing associations between meat and components of the metabolic syndrome

Study	Dietary variables	Findings
Diets showing negative associations		
Isle of Ely[7]†	Meat	No significant loading for red meat in dietary patterns described in the study; processed meat & sausage were rarely consumed in diet associated with reduced WHR, insulin intolerance, plasma triglycerides and increased HDL-cholesterol
Diets showing both positive and negative associations		
Malmo[8]†	Fat meat	Diets high in 'fat' meat were associated with increased risk of hyperglycaemia in men & hyperinsulinaemia in women, and decrease risk of obesity in men and hyperinsulinaemia in women.
Diets showing positive associations		
CARDIA[9]‡	Animal protein	Diets high in protein from animal sources increase risk of metabolic syndrome
US Health Professional[33]‡	Red and processed meat	Diets high in red and processed meats increased risk of CHD and diabetes
Hua, Stoohs & Facchini[34] §	Haem iron	Diets low in haem iron increase insulin sensitivity
American Cancer Society[36] ‡	Meat	Diets high in meat increase risk of weight gain at the waist

† Cross-sectional study; ‡ Prospective study; § Intervention study

development may predispose an individual, and possibly subsequent generations, to chronic disease later in life.[38] Hence imprinted genes may alter a range of biological processes that have in the past protected against chronic disease. Gallou-Kabani and Junien[38] suggest that due to the instability of epigenetic changes, they may be reversed (to a degree) by environmental stimuli including nutrition later in life. The researchers acknowledge that a great deal more research is required before this hypothesis can be accepted.

Conclusion

Regular consumption of fruit and vegetables is recommended to reduce the risk of developing metabolic syndrome.[10-12] Dairy-based foods also appear to offer significant protection as part of a varied diet,[9,17,18] although further research is required to elucidate the inconsistencies in the current literature.[21-22] Dietary patterns with regular intake of whole grain cereals, rather than highly processed cereals, appear to have a protective effect against many of the components of metabolic syndrome.[21,22,27,28]

There is a significant body of research supporting the negative impact of high meat intake on the risk of developing metabolic syndrome.[8,30-33] While some of the studies examined here reported no association for meat-based diets, there is little research to indicate a beneficial effect. The common conclusion of the three studies examined here (Isle of Ely, Malmö and CARDIA) is that no individual dietary component is wholly responsible for the association of diet with metabolic syndrome and its components. Rather it is likely the interaction between many components of the diet, or the overall diet quality, offers protection against metabolic syndrome. A wholistic view must be taken of diet quality, as individuals tend to consume a mixture of nutrients in a single meal, rather than isolated nutrients.

The development of a method of accurately measuring an individual's overall diet quality is a prerequisite for further research regarding the relationship between diet quality and metabolic syndrome. Further research is required into the modifying effect of adiposity on the relationship between dietary quality and chronic disease. Specific epigenetic patterns must also be identified that may be related to development of metabolic syndrome.

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Review Article

Dietary patterns and metabolic syndrome - a review of epidemiologic evidence

Amanda J Baxter BAppSc (Hons)[1], Terry Coyne PhD[2,3] and Christine McClintock PhD[3]

[1] *Queensland Institute of Medical Research, Brisbane, Australia*
[2] *School of Population Health, The University of Queensland, Brisbane, Australia*
[3] *Epidemiology Services Unit, Queensland Health, Brisbane, Australia*

饮食模式与代谢综合症-流行病学证据的回顾

代谢综合症与冠心病和II型糖尿病风险的升高相关，并在发展中国家和发达国家广泛流行。尽管改进生活方式被推荐为治疗综合症的手段，但是最有利于病人的饮食模式至今还未被确定。本文通过对Medline数据库中原始的研究论文进行调查，以确定可能与代谢综合症具有相关性的饮食方式，并发现3个大规模的流行病学研究符合本文的标准。研究发现：水果和蔬菜摄入量高的饮食模式通常与代谢综合症的低流行率相关。通常高肉类摄入量的饮食模式与代谢综合症的某些疾病相关，尤其能降低肌体的葡萄糖耐受性。高乳制品的摄入通常与代谢综合症中某些疾病风险的降低相关，但这与某些文献中所报道的高乳制品摄入是导致肥胖的风险因子的观点不一致。粗加工的谷类与代谢综合症风险的降低之间显示出一定的相关性，而深加工的具有高血糖生成指数的谷类通常与代谢综合症风险的升高相关。在各类与代谢综合症流行降低相关的饮食模式中，我们注意到没有油炸食品。结论：没有任何单一的膳食成分被看作是饮食模式与代谢综合症之间产生相关性的原因。相反，整体膳食质量才能预防生活方式疾病-如代谢综合症。对有些特殊条件需要进行更深入的研究，如超重和肥胖可能会对研究饮食对代谢综合症的发展产生影响。

关键词：代谢综合症、X综合症、文献、综述、饮食、饮食质量、饮食模