Short Communication

Dietary predictors of visceral adiposity in overweight young adults

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The purpose of the present study was to determine the dietary predictors of visceral adipose tissue (VAT) area in overweight young adults. A total of 109 young adults (fifty males and fifty-nine females) ate *ad libitum* in a university cafeteria for 14 d. All food and beverages consumed in the cafeteria were measured using observer-recorded weighed plate waste. Food consumption outside the cafeteria (i.e. snacks) was assessed by multiple-pass 24 h recall procedures. VAT was determined using computed tomography. Stepwise regression demonstrated that the best predictor of visceral adiposity in women was total dietary fat ($P \leq 0.05$). In men, the model for predicting visceral adiposity included Ca and total dietary fat. We concluded that total dietary fat is the best predictor of VAT area in both men and women. While this relationship was independent in women, in men there was a synergistic relationship between dietary fat consumption and Ca consumption in predicting VAT.

Excess abdominal fat is associated with increased mortality and risk of diabetes, hyperlipidaemia, hypertension and atherosclerosis[1]. Abdominal fat is composed of both subcutaneous and visceral fat. The detrimental influence of abdominal obesity on metabolic processes seems to be mediated by the visceral adipose tissue (VAT) depot, although there is some debate on the role of subcutaneous adipose tissue in these abnormalities, specifically the deep subcutaneous layers[1,2].

Factors that influence VAT have not been clearly defined in young adult populations[3,4]. Sex, genetics and sex hormones appear to play a role in the preferential deposition of VAT[5,6]. Physical activity may also play a role in VAT accumulation, especially in men[7,8]. While diet plays an obvious role in the accumulation of VAT, the complete role of diet on VAT has not been well described. Studies indicate that there is a positive relationship between energy consumption and VAT, but not all studies demonstrate a strong relationship[9,10]. Less is known about other components of the diet including macronutrient and micronutrient composition. The purpose of the present study was to examine the relationship between diet and VAT area in overweight young adults.

Methods

Design

This is a cross-sectional study using baseline data from participants who were originally recruited for the Midwest Exercise Trial[11]. There were four cohorts of participant that took part in the Midwest Exercise Trial. The time between cohorts was roughly 6 months between cohorts 1 and 2, 18 months between cohorts 2 and 3 and 12 months between cohorts 3 and 4. Participants were included in the study once and were not allowed to take part in subsequent cohorts.

Participants

Participants were aged between 17 and 35 years, sedentary, did not exceed 2093 kJ (500 kcal) of physical activity per week, and had a BMI between 25·0 and 34·9 kg/m^2[12]. Participants were healthy with no history of chronic disease. Additionally, all participants met or exceeded the 85th percentile for triceps skinfold thickness of the Second National Health and Nutrition Examination Survey. This measurement helped to eliminate subjects who were short and muscular rather than overweight.

Table 1. Demographic information by sex

(Mean values and standard deviations)

	Female (n 57)		Male (n 49)	
	Mean	SD	Mean	SD
Age (years)	22·5	4·7	23·0	4·0
Body weight (kg)	78·7	10·3	96·0*	11·8
Body fat (%)	35·9	4·7	27·6*	4·4
Visceral adipose tissue area (cm^2)	64·2	24·7	100·3*	38·8
Subcutaneous adipose tissue area (cm^2)	384·1	104·3	323·2*	100·0
Daily energy consumption (kJ)	10 324	1789	13 507*	2910
Total dietary fat (g)	86·1	23·3	124·1*	36·4
Total protein (g)	76·7	16·2	108·6*	24·9
Total carbohydrate (g)	355·4	66·2	411·7*	94·2
Total dietary Ca (mg)	800	325	1080*	440

* Mean value was significantly different from that of the females ($P \le 0.05$).

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the Institutional Review Board of the University. Written informed consent was obtained from all participants.

Assessments

Body weight and composition. Body weight was measured using a digital scale accurate to within 0·1 kg. Body composition was estimated by hydrostatic weighing using measured residual volume[11]. VAT area was determined using computed tomography (CT) at the L4-5 vertebral space. The CT examinations were performed using a CTi scanner (General Electric, Waukashau, WI, USA) at the University of Colorado Hospital (Denver, CO, USA)[11].

Energy intake and diet composition. Diet intake was *ad libitum* and was assessed for 14 d in the university cafeteria. All food and beverages consumed in the cafeteria were measured using observer-recorded weighed plate waste[13]. Food consumption outside the cafeteria was assessed by multiple-pass 24 h diet recall procedures[13]. This method of evaluating dietary intake was validated against doubly labelled water in fifty-two of the participants in the present study. Results from this validation showed that the participants were in energy balance during the assessment period[13].

The cafeteria featured a food court where different stations offered specialised items such as stir-fry, pasta, salads, sandwiches, pizza and grilled foods. Participants could typically choose from between eight and ten entrées at each meal. The cafeteria was open for a total of 9·5 h on weekdays and 5·5 h (brunch and dinner) on the weekends.

Results from the plate waste and from diet recalls were entered into a computerised nutrition database for analysis (Food Processor, version 7.1; ESHA Research, Salem, OR, USA).

Data analysis

Means and standard deviations were calculated for all independent and dependent variables. Stepwise regression was used to determine the best model for predicting visceral and subcutaneous adiposity for men and women. Variables included in the stepwise regression included total energy intake, dietary fat, dietary protein, dietary carbohydrate, saturated fat, Fe, vitamin A, folic acid, dietary fibre, Ca, alcohol, and Ca:protein ratio. Pearson product moment correlations were calculated to determine the relationship between diet components and VAT or subcutaneous adipose tissue. Independent *t* tests were used to determine differences between the sexes in descriptive and dietary variables. Significance was set at $P < 0.05$. Statistical analysis was performed using SAS (version 8.2; SAS Institute, Inc., Cary, NC, USA).

Results

Descriptive characteristics of the participants in the study are reported in Table 1. In general, men were heavier than women and had more lean tissue and less fat tissue ($P < 0.05$). Men had a higher VAT area, while women had a higher subcutaneous adipose tissue area ($P < 0.05$). Diet intake of the participants is reported in Table 2. Men consumed more energy and a greater percentage of the energy was from fat (34·6 *v.* 31·4 %) and protein (13·7 *v.* 12·4 %), while women consumed a greater percentage of their energy from carbohydrate (57·6 *v.* 51 %). In general, men consumed more Ca but had a similar Ca:protein ratio compared with women.

Stepwise regression demonstrated that total dietary fat was the best predictor of both VAT and subcutaneous adipose tissue area (r 0·36 and r 0·48; $P < 0.05$) in women (see Table 3). Saturated fat was similarly associated with both VAT and subcutaneous adipose tissue area in women (r 0·32

Table 2. Pearson correlations (r) of nutrients and visceral adiposity

	Visceral adipose tissue		Subcutaneous adipose tissue	
	Women	Men	Women	Men
Energy (kJ)	0·25	0·14	0·36*	0·09
Total dietary fat (g)	0·36*	0·21	0·48*	0·20
Total saturated fat (g)	0·32*	0·18	0·40*	0·20
Total protein (g)	0·15	0·13	0·11	0·18
Total carbohydrate (g)	0·11	0·06	0·17	−0·02
Total dietary Ca (mg)	0·02	−0·07	0·03	0·15
Ca:protein ratio	−0·09	−0·22	−0·07	0·11

* $P \le 0.05$.

Table 3. Stepwise summary table: dietary predictors of visceral and subcutaneous fat in women

	Visceral		Subcutaneous	
	T-statistic	P	T-statistic	P
Total dietary fat	2·89	<0·01	2·68	0·01
Folic acid	−1·25†	0·22	−0·87†	0·39
Total dietary fibre	−1·01†	0·31	−0·02†	0·98
Fe	−0·88†	0·38	−0·96†	0·34
Ca:protein ratio	−0·72†	0·47	−0·08†	0·94
Vitamin A	−0·69†	0·50	−1·38†	0·17
Total energy intake	−0·63†	0·53	−0·54†	0·59
Total dietary carbohydrate	−0·49†	0·62	−0·46†	0·65
Ca	−0·38†	0·70	−0·49†	0·62
Alcohol	0·27†	0·78	0·53†	0·60
Total dietary protein	−0·26†	0·80	−1·27†	0·21
Saturated fat	−0·08†	0·93	−0·70†	0·49

† Variables that did not enter the model with total dietary fat.

and r 0·40; $P < 0·05$), while total energy intake only predicted subcutaneous adipose tissue area (r 0·36; $P < 0·05$).

There was no single dietary component that predicted VAT area or subcutaneous adipose tissue area in men. Stepwise regression demonstrated that total dietary fat and Ca consumption in combination predicted VAT area (r 0·36; $P < 0·05$) in men (see Table 4).

Discussion

Total dietary fat predicted VAT in women but did not independently predict VAT in men. While dietary fat did not independently predict VAT in men, a synergistic relationship was observed between dietary fat consumption and Ca intake. If fat intake was similar, men who consumed more Ca had a lower VAT area.

Cross-sectional studies are generally in agreement that dietary fat is associated with excess body weight[14]. Less is known about the relationship between dietary fat and VAT. Greenfield *et al.* demonstrated a relationship between dietary fat and weight in adult women but failed to show a relationship with VAT[15]. It is unclear why there is a lack of

Table 4. Stepwise summary table: dietary predictors of visceral and subcutaneous fat in men

	Visceral		Subcutaneous	
	T-statistic	P	T-statistic	P
Total dietary fat	2·68	0·01	1·51†	0·14
Ca	−2·33	0·02	−0·46†	0·65
Total dietary fibre	0·92†	0·36	0·51†	0·61
Fe	−0·79†	0·43	−0·41†	0·69
Vitamin A	0·59†	0·55	0·13†	0·90
Total dietary protein	0·55†	0·59	1·30†	0·20
Folic acid	0·32†	0·75	0·56†	0·58
Saturated fat	0·34†	0·74	1·40†	0·16
Alcohol	−0·21†	0·84	−0·91†	0·37
Total dietary carbohydrate	−0·14†	0·89	−0·12†	0·90
Ca:protein ratio	0·13†	0·90	0·75†	0·46
Total energy intake	−0·00†	0·99	0·63†	0·53

† Variables that did not enter the model with total dietary fat and Ca.

agreement between these findings and the findings from the present study. It could be the result of methodological differences in assessing diet and VAT between the studies. In the Greenfield study, diet was assessed using the Oxford FFQ and VAT was assessed using dual-energy X-ray absorptiometry. These measurements may lack the precision necessary to determine the relationship between dietary fat and VAT.

In contrast, Dutia *et al.* in a published abstract showed a positive relationship between MUFA consumption and VAT accumulation in sedentary men and women[16]. Diet was measured using a 3 d food record and VAT was assessed using MRI. Based on the abstract, it is unclear if there were any sex differences or what nutrients were examined in addition to MUFA. The findings from the present study seem to support the role of fat consumption in the accumulation of VAT.

In addition to dietary fat, there is a growing body of literature demonstrating a negative association between increased Ca consumption and adiposity. The impact of Ca on adiposity may be especially important for visceral adiposity, since visceral fat is more metabolically active and sensitive to lipolysis than other adipose tissue[1]. It has been reported that increasing dietary Ca accelerates weight and fat loss in energy restricted obese adults, with preferential loss of trunk fat as measured by dual-energy X-ray absorptiometry[17]. It has been further shown that elevated Ca consumption alters plasma 1,25-dihydroxyvitamin D_3, which in turn alters local cortisol levels that may have an impact on the preferential loss of visceral adiposity[18].

The influence of Ca on VAT for men is consistent with the proposed mechanism. It is not clear why this same effect was not seen in women. In general, women have a lower VAT area and it seems to be less metabolically active than in men[1,9]. This is specifically true for the population of women in the present study, who were all young adults and less prone to deposit fat in the viscera. It has also been observed in another study in women of a similar age that Ca consumption was related to total body fat in participants who consumed less than 7853 kJ, but not in women who consumed more than 7853 kJ[19]. Only six women in the present study consumed less than 7853 kJ/d and this could be one of the reasons why no relationship was observed in women. In addition, Ca consumption was 800 (SD 325) mg in women, which is below the recommended intake and was roughly 280 mg lower than men in the study. This level of Ca consumption may be too low to influence fat metabolism and the accumulation of VAT in these women.

There are some limitations that should be considered when interpreting the results of the present study. It should be pointed out that the data available for this investigation did not include MUFA or PUFA. These dietary components may have an impact on VAT and deserve future consideration. In addition, because of the cross-sectional nature of the present investigation, causation cannot be established and caution should be taken in drawing conclusions from the data presented. Finally, because the dietary assessment took place in the cafeteria it is impossible to be sure that dietary patterns remained consistent with patterns established under normal eating conditions. While this is a limitation, the dietary assessment methodology employed in the study

directly measured food intake over 14 d and results from fifty-two of the participants demonstrated that they were in energy balance during the dietary assessment period when compared with doubly labelled water[13].

Conclusion

Total dietary fat is the best predictor of VAT area in both men and women. While this relationship was independent in women, in men there was a synergistic relationship between dietary fat consumption and Ca consumption in predicting VAT.

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