

# Improving the Accuracy of Self-Reports on Diet and Physical Exercise: The Co-Twin Control Method

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The objective was to examine the association between several obesity-related nongenetic behaviors and body mass index (BMI) and waist circumference (WC) in young adult twins using reports from both twins on their similarities and differences. A total of 713 monozygotic (MZ) and 698 same-sex dizygotic (DZ) twin pairs aged 22–28 years filled in structured questionnaires to compare their eating, physical activity and dieting behavior with their co-twin's behavior, and to report their own eating and exercise habits. In both MZ and DZ pairs, the co-twins for whom both twin pair members concordantly answered that this twin eats more, snacks more, eats more fatty foods and sweet and fatty delicacies, chooses less healthy foods, eats faster and exercises less, had significantly higher BMIs (0.6–2.9 kg/m<sup>2</sup>) and WCs (1.5–7.5 cm). Multivariate regression analysis identified co-twin differences in the amount of food consumed as the strongest independent predictor of intrapair differences in BMI ( $\beta = 0.63$  and  $1.21$ , for MZ and DZ, respectively,  $p < .001$ ) and WC ( $\beta = 1.52$  and  $3.53$ , for MZ and DZ, respectively,  $p < .001$ ). Higher leisure-time physical activity and healthier dietary choices clustered in the same subjects. The measurement of habitual dietary intake and physical activity has previously relied on subjective self-reports that are prone to misreporting. By using comparative measures within twin pairs we found that the amount of food consumed is the major contributor to obesity independent of genetic predisposition.

**Keywords:** body mass index, waist circumference, nutrition assessment, exercise, co-twin control method

It has remained difficult to show any consistent associations between energy intake and specific eating patterns, such as high-fat food intake or healthy eating patterns and body mass index (BMI) in observational studies (Togo et al., 2001). Previous studies have associated snacking patterns with higher energy intake (Berteus Forslund et al., 2005; Hampl et al., 2003),

but not always with BMI (Hampl et al., 2003). There is increasing evidence that several other characteristics of eating behavior such as eating frequency, breakfast skipping, eating fast or dieting also contribute to the development of obesity (Andrade et al., 2008; Korkeila et al., 1999; Ma et al., 2003). Inaccurate self-reports of dietary intake may in part explain the inconsistent findings of several previous studies. It is difficult to assess the exact amount of foods consumed, because there is considerable short-term variability in food intake (Palaniappan et al., 2003) and individuals have difficulties to accurately estimate portion sizes (Kretsch et al., 1999). Furthermore, under-reporting of energy intake is a major concern in dietary surveys, especially among obese subjects (Goris et al., 2000), and is likely to distort the association between self-reported food intake and obesity (Hu et al., 2000). Under-reporters report a diet more compatible with dietary recommendations, so that they under-report foods high in sugar, fat and energy to a larger extent than foods generally considered healthy, such as vegetables and yoghurt (Goris et al., 2000; Lafay et al., 2000). Hence, reporting bias in dietary assessment has made it difficult to establish consistent associations between eating patterns and obesity in epidemiological studies.

Misreporting is a common problem also in studies assessing physical activity (Rzewnicki et al., 2003). Over-reporting of physical activity and under-reporting of 'unhealthy' food items may arise from the wish to give socially desirable answers (Adams et al., 2005; Hebert et al., 2008). The tendency to respond in a manner consistent with perceived social norms may become less likely when reporting on another

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person. Thus, one approach to increase the accuracy of self-reported eating and physical activity behavior is to compare responses from individuals who know each other well. Twins from large representative cohorts are ideal for this purpose. Both mono- (MZ) and dizygotic (DZ) co-twins are particularly well acquainted with each other's lifestyle; in addition, MZ twins also share the same genes, and MZ twins discordant for eating or physical activity patterns are thus especially suitable while searching for obesity-related nongenetic behaviors. However, few studies have used the particular option of mutual responses from twin pair members to examine eating and physical activity behaviors in obesity or to enhance accuracy in self-reported behaviors (Rissanen et al., 2002).

The purpose of the present study was to determine the extent to which amounts of food, eating and physical activity patterns and nonexercise activities were related to adiposity (body mass index (BMI) and waist circumference (WC)) by using self-reported data and co-twin assessments on various behaviors in a cohort of young adult Finnish twins. We also tested whether healthy and unhealthy habits tend to cluster within respondents.

## Methods and Procedures

### Study Population

The participants were recruited from a population-based, longitudinal study of five consecutive birth cohorts (1975–1979) of Finnish twins (the FinnTwin16 cohort, 2,733 full pairs respondent at baseline) (Kaprio et al., 2002). Local ethics committees and internal review boards in Helsinki and Bloomington, Indiana reviewed and approved the study protocol. All twins had been sent a questionnaire in adolescence at 16, 17, 18½, and again as young adults at 22–28 (mean 24.4) years of age. Response rates were high (83–97%) on all occasions. The present study includes all twin pairs that responded to the last questionnaire. We excluded from the analyses subjects with unknown zygosity ( $n = 263$ ) and missing data on height or weight ( $n = 17$ ) as well as those where only one twin pair member had responded to the last follow-up questionnaire ( $n = 238$ ). The final data included 713 MZ and 698 same-sex DZ twin pairs ( $n = 2822$  individuals).

### Methods

Height, weight and waist circumference were self-reported and used to compute body mass index (BMI, kg/m<sup>2</sup>). The comparability of self-reported and measured data was ascertained in 566 twins on average 663 days after the completion of the questionnaire. The intraclass correlation for BMI was 0.94 and for waist circumference 0.73. The kappa value for obesity (BMI > 30) was 0.66 (95% CI 0.58 to 0.74) and for abdominal obesity (waist circumference in men 94 cm, women 80 cm) 0.60 (0.52 to 0.69) (Saarni et al., 2009).

Co-twin comparisons of eating behavior and physical activity were assessed by a mailed question-

naire, where the subjects were asked to compare their behavior with their co-twin's behavior during the last 12 months. 'Which one of you' was asked for 13 statements (for example 'eats more') listed in Appendix A with response alternatives 'Me', 'My co-twin', 'There is no difference between us', 'Do not know'.

Usual dietary habits during the previous 12 months were assessed by a quantitative 24-item food-frequency questionnaire. The questionnaires were designed as self-administered and respondents were asked how often they consumed the foods listed using five frequency response categories (*Never, A couple times a month or more rarely, A couple times a week, Once per day, Several times per day*). The answer categories were recoded into weekly consumption frequencies.

We calculated weekly hours of physical activity based on the following two questions: 'How often do you exercise in your leisure time?' and 'How long do you exercise per occasion?' The response alternatives were: 'Not at all', 'Less than once a month', '1–2 times a month', 'About once a week', '2–3 times a week', '4–5 times a week', and 'Every day' and 'Less than 30 minutes', 'Half an hour to under one hour', 'One hour to under 2 hours' and 'Two hours or more'. Intensity of physical activity was assessed based on the following question: 'Is your physical activity during leisure-time about as strenuous on average as: walking, alternately walking and jogging (slow running), jogging or running?' We assigned the following metabolic equivalent (MET) values: 4 (for exercise intensity corresponding to walking), 6 (alternately walking and jogging), 10 (jogging), and 13 (running).

### Statistical Methods

Differences between co-twins in self-reported food intake and physical activity behaviors were analyzed by paired  $t$  test. The twins were asked to compare their eating habits and physical activity patterns with those of their co-twins (Appendix A). To obtain a high degree of accuracy, we analyzed which of the co-twins had a larger BMI or WC only in pairs where both co-twins gave the same, internally consistent answer (both co-twins responded that either Twin 1 or Twin 2 had the habit and the other did not) by paired  $t$  test. Multivariate regression analysis was carried out to determine which dietary and physical activity behaviors were significant independent predictors of intrapair differences in BMI and WC and this analysis included all twin pairs. Therefore, the intrapair difference in BMI or WC was entered as a dependent variable and eating and physical activity-related behaviors were entered as independent variables into the model. The twin pair where the co-twin with the higher BMI or WC exhibited the behavior and the co-twin with the lower BMI or WC did not was coded as 1. The twin pair where the co-twin with the lower BMI or WC exhibited the behavior and the co-twin with the

higher BMI or WC did not was coded as -1. All other pairs (those with no differences in BMI or WC or those with inconsistent answer) were coded as 0. The statistical significance was considered attained if  $p < .05$ . The statistical analyses were performed using the Stata statistical software (release 9.0; Stata Corporation, College Station, Texas).

## Results

### Descriptive Data

Descriptive values for age, measures of body size, physical activity and food group intake are listed by gender and zygosity in Table 1. Women had lower BMIs than men ( $22.2 \pm 3.4$  vs.  $23.8 \pm 3.1$  for MZ and  $22.5 \pm 3.7$  vs.  $23.9 \pm 3.1$  for same-sex DZ twins, respectively). Women consumed 'healthy' foods and sweet foods more frequently and high-fat foods less frequently than did men.

### Self-Reported Food Intake and Physical Activity of Co-Twins With Consistent Answers

The results of the co-twin assessments (Appendix A) corresponded with self-reported food intake data from the food frequency questionnaires (Table 2). As the results for DZ pairs were similar, separate results for DZ pairs are not shown. The intake of only a few food items was found to differ between the more and less snacking twins. These were salty snacks, fish, and sweet foods, such as chocolate, sweet desserts and candies or jellies. Twins who reported to eat more fatty foods than their co-twins reported a higher weekly consumption of fried foods, creamy foods, fried potatoes or french fries, pizza and salty snacks, chocolate, sausages and meat. Twins who reported to eat more sweet and fatty delicacies reported more weekly servings of chocolate, sweet desserts and other sweets. They also reported a higher frequency of consumption of fatty foods that were not sweet, such as salty snacks.

Eating healthier was significantly associated with higher intakes of fresh vegetables, fruits, cooked vegetables, porridge and breakfast cereals, low-fat cheese and fish. Eating healthier was also significantly associated with lower intakes of fried foods, hamburgers, pizza, fried potatoes or french fries, chocolate and sausages. There was no significant difference in the weekly consumption of berries, rice or pasta, chicken or yoghurt between co-twins (data not shown). The co-twins for whom both twin pair members concordantly answered that this twin exercises more, reported 2.4 and 3 (for MZ and DZ, respectively) more hours of physical activity per week and exercised at a higher intensity level than their less active co-twins (Figure 1).

### Intrapair Differences in BMI and WC in Behaviorally Discordant Twin Pairs

In both MZ and DZ pairs, the co-twins who ate more, ate more snacks, ate more fatty foods, ate more sweet and fatty delicacies (chocolate, pastries, ice cream), chose less healthy foods and ate faster had significantly higher BMI and larger WC than their co-twins (Table 3). The largest intrapair differences in BMI and WC were observed between the more and less eating co-twins. MZ twins who ate more than their co-twins had  $1.9 \text{ kg/m}^2$  higher BMI and  $5.5 \text{ cm}$  larger WC than their twin siblings. Among DZ twins the differences were larger,  $2.8 \text{ kg/m}^2$  and  $7.5 \text{ cm}$ , respectively. Being less concerned about appearance was associated with higher BMI and WC in DZ pairs. Dieting more frequently was associated with greater BMI, but not WC, in DZ pairs. The co-twins who exercised more had lower BMI and WC in both zygosity groups. The co-twins who had more everyday activities and fidgeted more had lower BMI values and lower WC in DZ twins. Eating regularly and eating more sweets (candies or jellies) were not associated with differences in BMI or WC.

**Table 1**

Descriptive Statistics for Age, Measures of Body Size, Physical Activity and Food Group Intake by Gender and Zygosity

	Women		Men	
	Monozygotic pairs	Dizygotic pairs	Monozygotic pairs	Dizygotic pairs
Number of twin individuals	862	750	564	646
Age (years)	$24.4 \pm 0.0$	$24.3 \pm 0.0$	$24.5 \pm 0.0$	$24.4 \pm 0.0$
Body mass index ( $\text{kg/m}^2$ )	$22.2 \pm 0.1$	$22.5 \pm 0.1$	$23.8 \pm 0.1$	$23.9 \pm 0.1$
Waist circumference (cm)	$74.8 \pm 0.3$	$75.2 \pm 0.3$	$85.1 \pm 0.4$	$85.4 \pm 0.5$
Self-reported physical activity				
Hours per week	$3.5 \pm 3.1$	$3.4 \pm 3.1$	$3.4 \pm 0.1$	$3.2 \pm 0.2$
MET (metabolic equivalent)	$7.8 \pm 0.1$	$7.7 \pm 0.1$	$9.5 \pm 0.1$	$9.4 \pm 0.1$
Food group intake (frequency/week)				
'Healthy' foods	$38.6 \pm 0.7$	$38.2 \pm 0.7$	$28.3 \pm 0.7$	$27.2 \pm 0.6$
High-fat foods	$6.3 \pm 0.1$	$5.9 \pm 0.1$	$8.5 \pm 0.2$	$8.3 \pm 0.2$
Sweet foods	$7.4 \pm 0.2$	$7.4 \pm 0.2$	$6.1 \pm 0.2$	$6.1 \pm 0.2$

Note: Data are mean  $\pm$  SEM. Number of twin individuals for waist circumference are  $n = 810$  (monozygotic females),  $n = 710$  (dizygotic females),  $n = 538$  (monozygotic males),  $n = 612$  (dizygotic males). Data for physical activity and food group intake is unavailable for some subjects (maximum 3%). Values relate to subjects for whom data are available. The food groups were identified by factor analysis in a previous study using the same questionnaire (Keskitalo et al., 2008).

**Table 2**Mean ( $\pm$  SEM) Weekly Food Intake Based on Food Frequency Questionnaire in Monozygotic Co-Twins with Consistent Answers

Food items	Twin and co-twin who eats							
	Snacks <i>n</i> = 155 pairs		Fatty food <i>n</i> = 113 pairs		Sweet and fatty delicacies <i>n</i> = 119 pairs		Healthy food <i>n</i> = 148 pairs	
	More often	Less often	More often	Less often	More often	Less often	More often	Less often
Fresh vegetables	5.4 $\pm$ 0.4	5.9 $\pm$ 0.4	5.1 $\pm$ 0.4	6.2 $\pm$ 0.5*	5.1 $\pm$ 0.4	6.1 $\pm$ 0.5*	6.8 $\pm$ 0.5	5.0 $\pm$ 0.4***
Fruits	6.3 $\pm$ 0.4	6.0 $\pm$ 0.4	5.9 $\pm$ 0.5	6.4 $\pm$ 0.5	6.1 $\pm$ 0.5	6.2 $\pm$ 0.5	7.0 $\pm$ 0.5	5.8 $\pm$ 0.5*
Cooked vegetables	2.8 $\pm$ 0.2	3.0 $\pm$ 0.2	2.4 $\pm$ 0.2	3.3 $\pm$ 0.3**	2.6 $\pm$ 0.2	2.8 $\pm$ 0.2	3.1 $\pm$ 0.3	2.5 $\pm$ 0.2*
Porridge, muesli, cereals	3.2 $\pm$ 0.3	3.6 $\pm$ 0.3	3.0 $\pm$ 0.3	4.2 $\pm$ 0.4**	3.3 $\pm$ 0.4	3.8 $\pm$ 0.4	4.1 $\pm$ 0.3	3.3 $\pm$ 0.3*
Reduced fat cheese	3.5 $\pm$ 0.4	4.4 $\pm$ 0.5	3.2 $\pm$ 0.4	4.3 $\pm$ 0.5	3.4 $\pm$ 0.5	3.7 $\pm$ 0.5	4.7 $\pm$ 0.5	3.0 $\pm$ 0.4**
Fish	1.3 $\pm$ 0.1	1.7 $\pm$ 0.1**	1.4 $\pm$ 0.1	1.6 $\pm$ 0.2	1.4 $\pm$ 0.2	1.5 $\pm$ 0.1	1.8 $\pm$ 0.1	1.3 $\pm$ 0.1**
Fried foods	1.2 $\pm$ 0.1	1.1 $\pm$ 0.1	1.5 $\pm$ 0.2	1.0 $\pm$ 0.1***	1.4 $\pm$ 0.1	1.1 $\pm$ 0.1*	1.0 $\pm$ 0.1	1.6 $\pm$ 0.1***
Hamburgers	1.0 $\pm$ 0.1	0.9 $\pm$ 0.1	1.1 $\pm$ 0.1	0.9 $\pm$ 0.1	0.9 $\pm$ 0.1	0.9 $\pm$ 0.1	0.8 $\pm$ 0.1	1.0 $\pm$ 0.1*
Pizza	1.1 $\pm$ 0.1	1.0 $\pm$ 0.1	1.3 $\pm$ 0.1	1.1 $\pm$ 0.1*	1.1 $\pm$ 0.1	1.0 $\pm$ 0.1	1.0 $\pm$ 0.1	1.3 $\pm$ 0.1**
Fried potatoes or French fries	1.3 $\pm$ 0.1	1.2 $\pm$ 0.1	1.5 $\pm$ 0.1	0.9 $\pm$ 0.1***	1.3 $\pm$ 0.1	1.0 $\pm$ 0.1*	0.9 $\pm$ 0.1	1.5 $\pm$ 0.1***
Creamy foods	1.2 $\pm$ 0.1	1.3 $\pm$ 0.1	1.4 $\pm$ 0.1	1.0 $\pm$ 0.1**	1.3 $\pm$ 0.1	1.1 $\pm$ 0.1	1.0 $\pm$ 0.1	1.4 $\pm$ 0.1**
Salty snacks	1.5 $\pm$ 0.1	1.1 $\pm$ 0.1**	1.5 $\pm$ 0.1	1.1 $\pm$ 0.1**	1.5 $\pm$ 0.1	1.0 $\pm$ 0.1***	1.1 $\pm$ 0.1	1.4 $\pm$ 0.1
Chocolate	2.1 $\pm$ 0.1	1.5 $\pm$ 0.1***	2.0 $\pm$ 0.2	1.6 $\pm$ 0.1*	2.4 $\pm$ 0.2	1.5 $\pm$ 0.1***	1.7 $\pm$ 0.1	2.0 $\pm$ 0.1*
Sweet desserts	2.5 $\pm$ 0.1	1.8 $\pm$ 0.1***	2.6 $\pm$ 0.2	2.1 $\pm$ 0.2	3.0 $\pm$ 0.2	1.9 $\pm$ 0.2***	2.2 $\pm$ 0.1	2.5 $\pm$ 0.2
Other sweets	2.6 $\pm$ 0.2	2.1 $\pm$ 0.1**	2.4 $\pm$ 0.2	2.2 $\pm$ 0.1	2.8 $\pm$ 0.2	2.1 $\pm$ 0.2***	2.3 $\pm$ 0.1	2.5 $\pm$ 0.2
Sausage	3.3 $\pm$ 0.4	2.7 $\pm$ 0.3	3.4 $\pm$ 0.4	2.4 $\pm$ 0.3*	3.3 $\pm$ 0.4	2.5 $\pm$ 0.3	2.3 $\pm$ 0.3	3.4 $\pm$ 0.4**
Meat	4.1 $\pm$ 0.3	4.7 $\pm$ 0.4	4.2 $\pm$ 0.3	3.5 $\pm$ 0.3*	4.6 $\pm$ 0.4	4.5 $\pm$ 0.4	3.8 $\pm$ 0.3	4.1 $\pm$ 0.3

Note: The co-twins were asked to rate themselves in relation to their co-twins: 'Which one of you eats more snacks, more fatty food, more sweet and fatty delicacies and more healthy food?' The response alternatives are shown in Appendix A. The table shows self-reported food intake per week as assessed by food frequency questionnaire of the co-twins who consistently and independently reported who has the habit and who has not. Food intake data is unavailable for some subjects (maximum 4 twin pairs for single food item and 10 twin pairs for food groups). Values relate to subjects for whom data are available. Significant differences between co-twins (paired *t* test): \*\*\* $<$ .001, \*\* $<$ .01, \* $<$ .05.

### Independent Predictors of Intrapair Difference in BMI and WC

In multivariate analyses, differences in the amount of food consumed between co-twins was the strongest independent predictor of intrapair differences in BMI and WC among both zygosity groups (Table 4). In addition, differences in the intake of snacks and sweet and fatty delicacies and exercise habits between co-twins persisted as independent predictors of intrapair differences in BMI. Co-twin differences in the eating rate were independently associated with intrapair differences in BMI in MZ pairs. In DZ pairs, differences in dieting, being worried about appearance and fidgeting between co-twins were independently associated with intrapair differences in BMI. The results for WC generally resembled those for BMI, although co-twin differences in snacking, eating rate, being worried about appearance and fidgeting were not independently associated with intrapair differences in WC (Table 4). In addition, the twins who were more 'active' in daily life than their co-twins were more likely to have lower WC in MZ pairs. We observed that twins who ate more sweets than their co-twins were more likely to have lower BMI and WC, although this association was only significant in MZ pairs and can be due to correlations between the intake of sweets and sweet and fatty delicacies.

### Self-Reported Food Intake of Physical Activity Discordant Twin Pairs

We further examined whether being physically active was associated with healthier food choices. The active MZ twin member consumed more fruits, cooked vegetables, breakfast cereals (porridge, muesli, cereals) and rice or pasta and less fried foods and fried potatoes or french fries (Figure 2). There was no difference in the weekly consumption frequency of sweet foods (chocolate, sweet dessert, candies or jellies) or meat between the more and less active twin members (data not shown). In DZ pairs, the more exercising twin consumed also more boiled potatoes, yoghurt, chicken, fresh vegetables and less salty snacks. In contrast to MZ pairs, the more exercising DZ twin did not consume less fried potatoes or french fries than his less exercising co-twin (data not shown).

### Discussion

The use of comparative measures within twin pairs, as in our study, provided a unique opportunity for studying the contribution of several eating and exercise behaviors on BMI and WC independent of genetic predispositions. Within twin pairs, the amount of food consumed, snacking patterns, the consumption frequency of different food groups and several other

**Table 3**Pairwise Eating and Physical Activity-Related Behaviors and Body Mass Indexes (BMI, kg/m<sup>2</sup>) and Waist Circumferences (WC, cm) in Co-Twins with Consistent Answers

Behavior claim for which both co-twins agree that Twin 1	Mean BMI						Mean WC					
	Monozygotic pairs			Dizygotic pairs			Monozygotic pairs			Dizygotic pairs		
	N	Twin1	Twin2	N	Twin1	Twin2	N	Twin1	Twin2	N	Twin1	Twin2
Eats more	210	23.9	22.0***	264	25.0	22.2***	196	82.0	76.5***	252	85.3	77.8***
Eats more snacks	155	23.3	22.1***	214	24.4	22.3***	147	79.4	75.7***	200	82.0	77.2***
Eats more fatty foods	113	23.0	21.7***	172	23.9	22.3***	109	80.7	76.2***	164	81.6	77.0***
Eats more sweet & fatty delicacies (chocolate, pastries, ice cream)	119	23.0	21.9***	183	23.7	22.0***	115	79.6	74.7***	176	80.8	76.5***
Eats more healthy foods	148	22.1	23.2***	212	22.4	23.5***	140	76.5	79.5***	201	77.4	80.1***
Eats more regularly	195	22.7	22.6	233	23.1	22.9	185	78.0	77.6	222	79.9	79.0
Eats more slowly	135	22.0	22.7***	202	22.7	23.4*	128	76.6	78.1*	193	78.9	80.8*
Eats more sweets (candies or jellies)	133	22.5	22.6	215	22.9	22.5	131	78.1	77.6	206	79.3	77.7
Is more worried about appearance	118	22.7	22.7	188	22.4	23.1*	115	76.8	77.5	180	76.1	79.2***
Goes on diets more often	91	23.1	23.0	137	24.2	22.7***	86	77.9	79.5	129	80.3	78.2
Exercises more	239	22.3	22.9***	323	22.6	23.6***	228	76.6	79.3	309	77.6	81.8***
Walks instead of taking a car or elevator, or makes other 'active' choices in daily life	123	22.3	22.9**	192	22.5	23.4**	117	77.2	80.0***	183	77.6	80.4**
Makes more movement during normal non-exercise activities (i.e. fidgeting)	97	22.0	22.4	158	22.4	23.8***	92	75.5	77.7**	146	77.2	80.9***

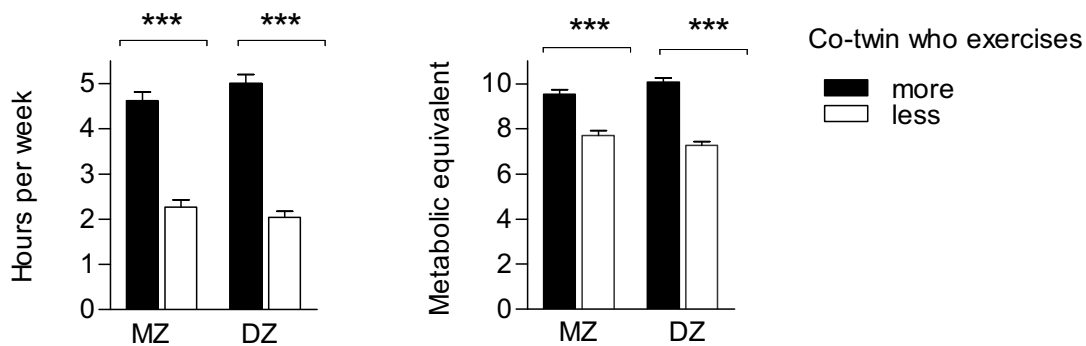
Note: Data are mean. The co-twins were asked to rate themselves in relation to their co-twins: 'Which one of you ...'. The questions and response alternatives are shown in the Appendix. N = number of twin pairs with consistent answers. Twin 1 = Twin who has the habit, Twin 2 = Twin who does not have the habit. Significant differences between co-twins (paired t test): \*\*\* $p < .001$ , \*\* $p < .01$ , \* $p < .05$ .

eating and physical activity-related behaviors contributed to considerable intrapair differences in BMI and WC in young adult twins.

The most striking finding of the present study was that co-twins that differed in the amount of food eaten showed the largest intrapair difference in BMI and WC. We found that those differences in the overall food intake between co-twins were the strongest independent predictor of intrapair differences in BMI and WC. Recent studies on portion-sizes revealed that individuals with a higher BMI consume larger portions of main meals, especially of energy-dense and high-carbohydrate meals (Berg et al., 2009; Burger et al., 2007). However, the association between energy intake and BMI is less clear. Several observational studies exist that found either no association or an inverse association between the two variables (Berg et al., 2009; Jackson et al., 2003; Miller et al., 1990; Patrick et al., 2004). Hassapidou et al. (2006) found lower self-reported energy intake of overweight and obese adolescents than in their lean counterparts. This has led investigators to conclude that the positive energy balance causing overweight and obesity is not attributable to higher energy intakes, but to low levels of energy expenditure (Rocandio et al., 2001), differences in diet composition (Miller et al., 1990) or eating

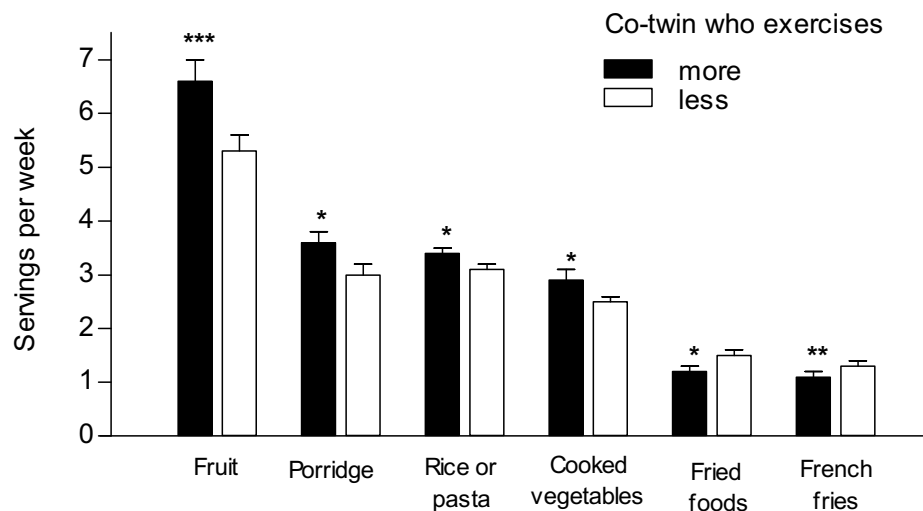
behaviors such as dieting (Keskitalo et al., 2008). Many authors, however, have discussed underreporting of energy intake as a possible explanation for the lack of a positive association between energy intake, or eating patterns and weight status (Berg et al., 2009; Hassapidou et al., 2006; Kerr et al., 2009). In the present study, we may have reduced the social desirability bias due to underreporting by including not only self-reports, but also proxy reports of the co-twins. We therefore suggest that the quantity of food consumed does indeed play a major role in weight maintenance.

Co-twin differences in the intake of snacks and sweet and fatty delicacies as well as the eating rate were significant independent predictors of intrapair differences in BMI. High intake of snack food is likely to result in high BMI, particularly as the energy-density of snacks as well as the portion sizes has increased markedly in young adults (Zizza et al., 2001). Our data showed that co-twins who snacked more, chose significantly more salty snacks, chocolate, sweet pastries, ice cream and sweets, known to be the most common selected snacks in Finland (Ovaskainen et al., 2006). The twin for whom both co-twins reported that he/she eats more sweet and fatty delicacies reported a higher consumption of fried foods, fried potatoes or french fries, salty snacks, chocolate,



**Figure 1**

Pairwise physical activity behavior compared to self-reported physical activity behavior between co-twins with consistent answers ( $n = 238$  MZ and 316 DZ pairs). The co-twins were asked to rate themselves in relation to their co-twins: ‘Which one of you exercises more?’ The response alternatives are shown in Appendix A. The bars represent self-reported physical activity behavior of the co-twins who consistently and independently reported who exercises more. Data are mean  $\pm$  SEM. MZ, monozygotic. DZ, dizygotic. Significant differences between co-twins (paired  $t$  test): \*\*\* $p < .001$ .



**Figure 2**

Food items significantly different between the more and less exercising twin ( $n = 238$  MZ twin pairs). The co-twins were asked to rate themselves in relation to their co-twins: ‘Which one of you exercises more?’ The response alternatives are shown in Appendix A. The bars represent self-reported food intake as assessed by food frequency questionnaire of the co-twins who consistently and independently reported who exercises more. The food item french fries included also fried potatoes and the food item porridge included also muesli and cereals. Food intake data is unavailable for some subjects (maximum 3%). Values relate to subjects for whom data are available. Data are mean  $\pm$  SEM. Significant differences between co-twins (paired  $t$  test): \*\*\* $p < .001$ , \*\* $p < .01$ , \* $p < .05$ .

sweet desserts and other sweets and had significantly higher BMIs. However, in the FinnTwin12 cohort, another five-year birth cohort study, no association between self-reported fatty food use or liking and BMI was found in individual-level analyses (Keskitalo et al., 2008). Eating sweets (candies or jellies) was not associated with greater BMI or WC in the present study, which agrees with the previous report that sugar consumption is not always associated with obesity (Hill et al., 1995).

Using both co-twin assessments and self-reported data we were able to show that co-twin differences in physical activity were related to intrapair differences in BMI and WC. Although causality between physical activity and obesity cannot be demonstrated from this

cross-sectional study, a previous prospective study from this same population reported that adolescent inactivity is a strong predictor of adult obesity, especially abdominal obesity (Pietiläinen et al., 2008). The present study adds to the literature showing that non-exercise activities such as making ‘active’ choices in daily life (i.e., walking instead of taking a car or elevator) and making more movement during normal non-exercise activities (i.e., fidgeting) are also associated with measures of obesity. These behaviors have not been extensively studied in obesity and could be further investigated in prospective studies designed specifically for this purpose.

The clustering of physical activity and healthy dietary choices is well documented (Gillman et al.,

**Table 4**

The Multivariate Association ( $\beta \pm SE$ ) Between Co-Twin Differences in Eating and Physical Activity-Related Behaviors and Intrapair Differences in Body Mass Indexes (BMI, kg/m<sup>2</sup>) and Waist Circumferences (WC, cm)

Eating or physical- activity-related behavior	BMI		WC	
	Monozygotic	Dizygotic	Monozygotic	Dizygotic
Eating more (on the whole)	0.63 ± 0.13***	1.21 ± 0.19***	1.52 ± 0.46***	3.53 ± 0.54***
Eating more snacks	0.42 ± 0.15**	0.56 ± 0.22*	1.07 ± 0.56	0.47 ± 0.66
Eating more fatty foods	0.22 ± 0.20	0.15 ± 0.27	1.36 ± 0.74	0.94 ± 0.83
Eating more sweet & fatty delicacies	0.48 ± 0.18**	0.46 ± 0.24*	2.73 ± 0.66***	1.43 ± 0.70*
Eating more sweets (candies or jellies)	-0.45 ± 0.16**	-0.33 ± 0.21	-1.59 ± 0.59**	0.11 ± 0.62
Selecting food more according to healthiness	-0.15 ± 0.17	0.02 ± 0.25	-0.58 ± 0.66	-0.92 ± 0.77
Eating more regularly	0.8 ± 0.12	0.03 ± 0.19	0.43 ± 0.45	-0.27 ± 0.56
Eating more slowly	-0.27 ± 0.14*	-0.04 ± 0.19	-0.40 ± 0.51	-0.47 ± 0.56
Being more worried about appearance	0.5 ± 0.15	-0.48 ± 0.21*	0.44 ± 0.57	-1.11 ± 0.61
Going on diets more often	0.26 ± 0.18	1.22 ± 0.26***	-0.69 ± 0.69	2.53 ± 0.74***
Exercising more	-0.21 ± 0.11*	-0.65 ± 0.17***	-0.78 ± 0.40*	-2.56 ± 0.52***
Walking instead of taking a car or elevator, or making other 'active' choices in daily life	-0.20 ± 0.15	1.3 ± 0.22	-1.33 ± 0.56*	-0.01 ± 0.63
Making movement during normal non-exercise activities (i.e. fidgeting)	-0.05 ± 0.16	-0.53 ± 0.22*	-0.68 ± 0.60	-0.89 ± 0.65

Note: The co-twins were asked to rate themselves in relation to their co-twins: 'Which one of you...'. The questions and response alternatives are shown in Appendix A. The twin pair where the co-twin with the higher BMI or WC exhibited the behavior and the co-twin did not was coded as 1 and the twin pair where the co-twin with the lower BMI or WC exhibited the behavior and the co-twin did not was coded as -1. All other pairs were coded as 0. *P*-values: \*\*\* ≤ .001, \*\* ≤ .01, \* ≤ .05.

2001), and was observed also among our young adult twins. This is of particular importance, because physical activity and nutrition established at early age tend to maintain throughout adult life and are major factors in the prevention of obesity (Jackson et al., 2003; Patrick et al., 2004).

In the present study, several health-related behaviors were associated with BMI and WC differences within both, DZ and MZ pairs. The consistent results in MZ twins provide evidence that eating and physical activity behavior contribute to weight differences independently of genetic factors. Interestingly, MZ twins had slightly lower within-pair differences in BMI and WC than DZ twins. This is probably due to the greater genetic similarity in MZ than in DZ twins. BMI and its rate of change are known to be subject to major genetic influences (Hjelmborg et al., 2008; Schousboe et al.; 2003). In addition, there is recent evidence that genetic effects contribute to the individual differences in food consumption (Keskitalo et al., 2008) and physical activity (Stubbe et al., 2006).

Previous studies examining the associations between food intake and obesity in the population have almost always relied on self-reported data, often identified eating patterns by factor analysis or cluster analysis, and occasionally used dietary indexes to measure diet quality (Gao et al., 2008; Heidemann et al., 2008; Hu et al., 2000; Kennedy et al., 1995). The current study differs from those previous studies, as we asked twins to compare their eating and physical activity behavior with that of their siblings, in this

case their same-aged co-twins. We included twins as mutual proxy respondents to increase the accuracy in self-reported eating and physical activity behavior. Hamilton and Mack (2000) have previously used mutual responses of twin pairs in case-control studies of breast cancer, with the specific purpose to attain information on anthropometric and childhood risk factors. One earlier study among MZ Finnish twins discordant for obesity has used mutual responses of twins to assess past eating habits and to ensure accuracy in self-reported data. Most obese twins recalled to have eaten larger amounts of food, more high-fat foods and more sweets than their lean co-twins, and most lean twins confirmed this (Rissanen et al., 2002).

Our study has several strengths but also limitations. A major limitation of this analysis is the cross-sectional nature of the data. We cannot determine whether differences in eating and physical activity behaviors have arisen before or after the weight differences between co-twins. The strengths include a large representative population sample of twins, with cross-twin evaluations serving as an important source of internal validation. The use of comparative measures between twins increases the accuracy of responses in questions that were specifically designed to address obesity-related habits. We were able to demonstrate several eating habits that were associated with measures of obesity. Moreover, MZ twins control in an ideal way for the genetic effects on body weight while matching for gender, age, childhood socioeconomic background and other environmental experiences. The use of

mutual responses of twins in a pair is reasonable, because twins are well informed about their co-twin's behavior (Hamilton & Mack, 2000). The use of other similar informants (nearly same-aged non-twin siblings, long-standing spouses or partners, best friends or even parents) needs to be explored as a methodological approach to improve the inherently poor reporting of dietary and exercise behaviors that rely on single informants about themselves.

## Conclusion

This study provides compelling evidence for the contribution of acquired eating and physical activity patterns on obesity. By using comparative measures within twin pairs, we found that the overall amount of food consumed is the major contributor to obesity independent of genetic predisposition. Leisure-time physical activity was associated with both healthier dietary choices and decreased BMI and WC within twin pairs. The inclusion of mutual responses of twins presents one approach to improve the accuracy of self-reported eating and physical activity behavior.

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## Disclosure Statement

The authors declared no conflict of interest.

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## Appendix A

Which of you, you or your co-twin ...

- Eats more?
- Eats more snacks?
- Eats more fatty foods?
- Eats more sweet & fatty delicacies (chocolate, pastries, ice cream)?
- Eats more sweets (candies or jellies)?
- Selects food more according to healthiness?
- Eats more regularly?
- Eats more slowly?
- Is more worried about appearance?
- Goes on diets more often?
- Exercises more?
- Walks instead of taking a car or elevator, or makes other 'active' choices in daily life?
- Makes more movement during normal non-exercise activities (i.e., fidgeting)?

Response alternatives were: Me, My co-twin, There is no difference between us, Do not know.