Author(s): Waller, Katja; Kaprio, Jaakko; Kujala, Urho

Title: Associations between long-term physical activity, waist circumference and weight gain: a 30-year longitudinal twin study.

Year: 2008

Version:

Please cite the original version:

Waller, K., Kaprio, J., & Kujala, U. (2008). Associations between long-term physical activity, waist circumference and weight gain: a 30-year longitudinal twin study.. International Journal of Obesity, 32, 353-361. https://doi.org/10.1038/sj.ijo.0803692

Associations between long-term physical activity, waist circumference and weight gain: a 30-year longitudinal twin study

A short running head: Physical activity and weight gain in twins

Katja Waller, M.Sc.[1], Jaakko Kaprio, M.D., Ph.D.[2], Urho M. Kujala, M.D., Ph.D.[1]

[1] Department of Health Sciences, University of Jyväskylä, Jyväskylä, Finland

[2] Department of Public Health, University of Helsinki & Department of Mental Health and Alcohol Research, National Public Health Institute, Helsinki, Finland

Corresponding author: Katja Waller, M.Sc., Department of Health Sciences, PO Box 35, University of Jyväskylä, FIN-40014 Jyväskylä, Finland, Tel work:+358 14 260 2192, Tel mobile: +358 44 3685661, Fax: +358 14 260 4600, E-mail: katja.waller@sport.jyu.fi

Jaakko Kaprio, MD, PhD, Department of Public Health, PO Box 41 (Mannerheimintie 172), University of Helsinki, FIN-00014 Helsinki, Finland
Tel work: +358 9 191 27 595, E-mail: jaakko.kaprio@helsinki.fi

Urho M. Kujala, MD, PhD, Department of Health Sciences, PO Box 35, University of Jyväskylä, FIN-40014 Jyväskylä, Finland
Tel work: +358 14 260 2171, E-mail: urho.kujala@sport.jyu.fi

Article 3417 words, structured abstract 292 words, 48 references, three tables and four figures

Structured Abstract

Background and Objective: Physical activity level and obesity are both partly determined by genes and childhood environment. To determine the associations between long-term leisure-time physical activity, weight gain and waist circumference and whether these are independent of genes and childhood effects.

Design and Subjects: The study design is a 30 year follow-up twin study in Finland. For this study 146 twin pairs were comprehensively identified from the large Finnish Twin Cohort. These twin pairs were discordant for both intensity and volume of leisure physical activity in 1975 and 1981 and were healthy in 1981. At follow up in 2005, both members of 89 pairs were alive and participated in a structured telephone interview. In the interview self-measured weight and waist circumference, and physical activity level for the whole follow-up were assessed. Paired tests were used in the statistical analyses.

Main Outcome Measures: Waist circumference at 30 year follow up (2005) and change in weight from 1975 – 2005.

Results: In the 42 twin pairs discordant for physical activity at all time-points during the 30 year period the mean weight gain from 1975 through 2005 was 5.4 kg (95% CI 2.0-8.9) less in the active compared to inactive co-twins (paired t-test, $p=0.003$). In 2005 the mean waist circumference was 8.4 cm (95% CI 4.0-12.7) less in the active compared with inactive co-twins ($p<0.001$). These trends were similar for both MZ and DZ twin pairs. Pairwise differences in weight gain and waist circumference were not seen in the 47 twin pairs, who were not consistently discordant for physical activity.

Conclusion: Persistent participation in leisure-time physical activity is associated with decreased rate of weight gain and with a smaller waist circumference to a clinically significant extent even after partially controlling for genetic liability and childhood environment.

Key words: weight gain; waist circumference; physical activity; twins; longitudinal study

Introduction

Over one billion of the world's population can be considered to be overweight (body mass index, BMI ≥25 kg/m^2), including 300 million obese individuals (BMI ≥30 kg/m^2).[1] Both obesity, and particularly the accumulation of intra-abdominal adipose tissue, are considered to be risk factors for the development of several metabolic disorders such as glucose intolerance, dyslipidaemia and hypertension,[2, 3] as well as for mortality.[4]

Various studies have shown that physical fitness and the ability to achieve high levels of physical activity have a genetic component.[5-7] Genetic predisposition also underlies the tendency for weight change and other metabolic syndrome-related diseases.[8-11] A large twin study across eight countries confirmed that genetics, non-shared environment and gender have an important role in variation in BMI.[12] The Framingham family study[13] found that the heritability of long-term weight change is 0.24, while twin studies have estimated higher values.[14] Since the gene pool changes slowly, the causes of the obesity epidemic are mainly environmental,[10, 15] and it has been suggested that a sedentary lifestyle could be as important as diet in the development of obesity.[16, 17] While there is accumulating evidence to show that the rate of weight gain is reduced by physical activity,[18, 19] more long-term studies controlling for different associated factors are needed.

We followed the Finnish Twin Cohort for 30 years to study the associations between physical activity and adult weight gain, waist circumference and other indicators of metabolic syndrome in twin pairs discordant for leisure-time physical activity. Our twin pair study design takes into account genetic predisposition and childhood environment. It is important to be able to take into account genetic and childhood effects as both physical activity and weight gain are influenced by these. Dizygotic (DZ) twins share on average half of their segregating genes, while monozygotic (MZ) pairs are genetically identical. Both kinds of pairs nearly always have the same childhood environment. Among our data of 146 pairs, twin pairs lived together until a mean age of 19.3 years, with no difference by zygosity or whether the difference in physical activity persisted throughout adult life or not.

Methods

Subjects

The Finnish Twin Cohort includes all same-sex twin pairs born in Finland before 1958 and with both co-twins alive in 1967.[20] For the present analysis, initial inclusion criteria were employment (including women working at home and students) in 1981 and complete questionnaire data on leisure physical activity in 1975 and 1981. All pairs where at least one of the twins had died or had a chronic disease, except hypertension, by the end of 1982 were excluded.[6, 20, 21] The healthy cohort comprised 5663 same sex twin pairs (3551 DZ, 1772 MZ and 340 pairs with unknown zygosity).[6] Zygosity determination was based on an accurate and validated questionnaire method.[22]

Among these 5663 twin pairs, 146 pairs were discordant for leisure-time physical activity for both participation in vigorous activity and volume of activity in both 1975 and 1981 (for determination see later). The final study sample at the 2005 follow-up comprised 111 twin pairs (222 subjects) as only those pairs were included in which both twins were still alive, both were known to be living in Finland and both spoke Finnish as their mother tongue. Of these 222 subjects one had died during the interview period and 18 did not participate in the interview due to illness (4), unwillingness (13) or unavailability (1). Therefore 203 subjects took part in the interview. Those 203 subjects included 89 twin pairs (40 male, 49 female, 72 DZ, 17 MZ pairs) all of whom had completed all the physical activity questions in the interview in 2005.

Assessment of predictors

The subjects had been mailed similar questionnaires in 1975 and 1981. These included questions on weight, height, physical activity, occupation, alcohol use, smoking and physician-diagnosed diseases. Physical activity habits elicited by identical questions in 1975 and 1981 were used as the baseline predictor in the present study.

Assessment of vigorous physical activity was based on the following question: Is your physical activity during leisure-time about as strenuous on average as: 1) walking, 2) alternately walking and jogging, 3) jogging, 4) running. Those who chose 2, 3 or 4 were classified as engaging in vigorous activity. Assessment of leisure activity volume (MET index) was based on a series of structured questions on leisure physical activity (monthly frequency, mean duration and mean intensity of sessions) and physical activity during journeys to and from work. The index was calculated by assigning a multiple of resting metabolic rate (MET score) to each activity and by calculating the product of activity, intensity X duration X frequency.[21] The MET index was expressed as the sum-score of leisure MET hours/day. Those subjects whose volume of activity was ³ 2 MET hours/day (corresponding to about 30 min walking per day) were classified as physically active.[6] Among the 89 pairs who were included in the final study sample and who were discordant for leisure-time physical activity in both 1975 and 1981, the mean difference between the active and inactive co-twins was 3.55 MET hours/day in 1975 (paired t-test, $p<0.001$) and 4.93 in 1981 ($p<0.001$). Similar results were seen for male, female, MZ and DZ pairs. In prospective studies using the original twin cohort the MET index has been shown to be a predictor of mortality, type 2 diabetes, coronary heart disease and need of hospital care.[6, 21, 23-25]

Follow-up assessment of physical activity level

After being sent an invitation letter, subjects were interviewed by telephone in 2005. Subjects provided an informed consent to participate in the study and the ethics committee of the University of Jyväskylä approved the study. All outcome assessments (including interview and data entry) were carried out blinded to baseline status. Two experienced and trained interviewers interviewed at random one co-twin from each pair. The interview included questions on weight, height, waist circumference, physical activity habits and occurrence of chronic diseases. The mean duration of the interviews was 50 minutes.

The interview included questions on current and past physical activity. Physical activity level was assessed by two sets of questions. The first, a shorter retrospective assessment (years 1980, 1985, 1990, 1995, 2000 and 2005) of physical activity volume (including calculation of MET index) and participation in vigorous physical activity, used the same questions as in 1975 and 1981. The mean MET index for all six measurements between 1980 and 2005 was calculated. To increase recall, subjects were asked their marital and work status for each year before the retrospective physical activity questions.[26] The intraclass correlation (ICC) between the questionnaire-based leisure physical activity MET index in 1981 (questionnaire responses from year 1981) and the interview-based retrospective MET index in 1980 (interviewed in 2005) was 0.56 ($p<0.001$).

The second, a detailed assessment of leisure-time physical activity volume over the previous 12 months (12-month MET index), was done using a modified version of the Kuopio Ischemic Heart Disease Risk Factor Study Questionnaire.[27] The assessment included questions on leisure physical activities (termed conditioning activities in earlier publications[28]), physical activities during journeys to and from work as well as daily activities such as gardening and berry picking. Each activity included a question on monthly frequency, mean duration and mean intensity of sessions.

The ICC between the shorter 2005 MET index and the detailed 12-month physical activity MET index was 0.68 ($p<0.001$) for leisure-time physical activity and 0.93 ($p<0.001$) for work journey.

Assessment of anthropometrics

In the interview subjects were asked their current weight, height, and waist circumference. Self-reported height and weight have been validated against measured values.[12, 29] The body mass index (BMI, kg/m^2) was calculated. Change in weight was calculated by subtracting the weight in 1975 or 1981 from the weight in 2005.

As the amount of abdominal fat can be estimated by measuring waist circumference[30] subjects were sent a tape measure prior to the interviews. They were asked to measure their waist circumference in the standing position according to an instruction clarified with a picture. The measurement was to be done at the narrowest part of the waist; if this could not be found, they were instructed to measure midway between the iliac crest and the lowest rib. In a separate validation study, a healthcare professional measured the circumference blinded to the subjects' (N=24) measurement, and the ICC between these was 0.97 ($p<0.001$).

Statistical Analysis

As we studied twin pairs all the statistical analyses were based on pairwise tests. First, analyses were conducted on all 89 pairs. Secondly, we carried out specific analyses for the 42 pairs who had remained consistently discordant for physical activity over the thirty-year follow-up and for 47 pairs who were not consistently discordant (discordance not in the same direction at one or more time points). The main results are also reported by gender and zygosity. To compare differences in outcome measurements between inactive and active co-twins, paired samples t-test, McNemar's test and conditional logistic regression were used. The level of significance was set at $p<0.05$ and all reported p-values are two-sided. Data were analyzed with the use of either SPSS 12.0 or Stata 8.0.

Results

No statistically significant pairwise differences were found between inactive and active co-twins in anthropometry, marital or socio-economic status at the baseline in 1975 (Table 1). In 1975 the inactive members of the twin pairs tended to be more often involved in heavier manual work compared to their active co-twins. This was not observed in 2005, as statistically non-significant differences were mainly seen in retirement and lighter work.

We found 42 pairs (5 MZ, 4 female and 1 male, and 37 DZ, 17 female and 20 male, pairs) who were consistently discordant for physical activity at all the 5-year time points across the 30-year period, and 47 pairs (12 MZ, 7 female and 5 male, and 35 DZ, 21 female and 14 male, pairs) who were not consistently discordant. Figure 1 shows the differences in MET indices between inactive and active co-twins from 1980 through 2005. DZ twin pairs seemed to stay discordant for longer and the discordances appear greater when compared with MZ pairs (Figure 2). The mean MET index from 1980 through 2005 was significantly higher in active than inactive co-twins in all twin pairs as well as in all subgroups (Table 2, Figure 3). Significant differences between inactive and active co-twins were observed in leisure-time physical activity but not in daily activities.

An increase in weight over time was seen in both inactive and active co-twins (Table 3). Among all 89 pairs, the active members gained 2.8 kg less weight during the 30-year follow-up than their inactive co-twins ($p=0.01$). Trends for weight gain were similar for male, female, DZ and MZ pairs (Figure 3). Among the 42 consistently discordant twin pairs the active twins gained significantly less weight (5.4 kg, 95% CI 1.95-8.87 kg, $p=0.003$) during 30-year follow-up when compared with their inactive co-twins, with similar trends in DZ (4.4 kg, 95% CI 0.90 – 7.96 kg, p=0.02) and MZ (12.6 kg, 95% CI -4.12 – 29.32 kg, p=0.11) pairs. However the results for pairs not consistently discordant for physical activity did not show any differences between inactive and active co-twins in 2005.

In 2005 waist circumference was 4.1 cm smaller (95% CI 1.4-6.7 cm, p=0.003) in active than inactive co-twins (Table 3). Again, trends were similar for male, female DZ and MZ pairs. Among the consistently discordant twin pairs (Figure 4) waist circumference was 8.4 cm smaller (95% CI 4.0-12.7 cm, p<0.001) among active co-twins with similar trends in DZ (7.8 cm, 95% CI 3.71 – 11.84 cm, p<0.001), MZ (12.6 cm, 95% CI -18.47 – 43.67 cm, p=0.32), male and female pairs. However, no pairwise difference was seen in waist circumference among pairs not consistently discordant.

Inactive co-twins had a higher risk of major weight gain (≥15 kg) during the thirty year follow-up (OR 2.18, 95% CI 1.07-4.45, p=0.03) compared to their active co-twins, the risk becoming even higher when further adjusted for weight and smoking in 1975 (OR 2.49, 95% CI 1.12-5.52, p=0.025). Inactive co-twins also had an increased but statistically non-significant risk of being obese (BMI ≥30) in 2005 (OR 2.75, 95% CI 0.88-8.64, p=0.08). Among 42 consistently discordant pairs inactive co-twins had an even higher risk of major weight gain (OR 4.3, 95% CI 1.24-15.21, p=0.02) than their active co-twins, the risk being further increased when adjusted for weight and smoking in 1975 (OR 7.99, 95% CI 1.04-61.12, p=0.045). They also had an increased risk of obesity in 2005 (OR 4.5, 95% CI 0.97-20.8, p=0.06).

Discussion

Our study shows that physical activity in adults is associated with decreased weight gain and with smaller waist circumference in twin pairs consistently discordant for leisure-time physical activity habits over 30 years. Trends were similar for both monozygotic and dizygotic twin pairs. The findings were most likely due to physical activity and not primarily influenced by genes or childhood environment.

The optimal study design for analysis would have been to use a large sample of activity-discordant monozygotic pairs; but we did not have sufficient numbers of discordant monozygotic pairs even in this large twin cohort. So, for the main analyses the monozygotic twin pairs were pooled with the dizygotic pairs. Among the baseline cohort of 5663 (31% MZ and 63% DZ) healthy twin pairs a sub-sample of 111 pairs were invited for a follow-up study, of which 89 (19% MZ and 81% DZ) twin pairs completed the follow-up. These twin pairs were then, based on the follow-up information, further divided into 2 groups, consistently discordant (12% MZ and 88% DZ) and not consistently discordant (26% MZ and 74% DZ) for physical activity. As indicated above, the number of monozygotic pairs in the sample constitutes a reduced proportion (19%) in the included sample than in the total cohort (31%). This is further reduced in the consistently discordant pairs (12%) indicating that consistently discordant monozygotic pairs are rare. The finding is in accordance with earlier twin studies[21, 31] and consistent with strong genetic influences on physical activity.[32, 33] In our study we also see that existing discordance seems to last for a shorter time among monozygotic pairs than in dizygotic pairs (figure 2). The same genes may predict lower weight gain as well as make it easier for some individuals to exercise more. However, we observed that when activity discordance continues, the trend is same for both zygosities in all our outcome measurements, even though the number of monozygotic pairs did not permit strong inference. As the trend was the same in both monozygotic and dizygotic pairs and the outcome difference was relatively high also among monozygotic pairs (12.6 kg in weight gain and 12.6 cm in waist circumference), it is likely that the association is also present in genetically controlled conditions. The significant difference in dizygotic pairs indicates that the association between physical activity and the outcome variables are not due to childhood environmental effects.

In line with our study, a decreased rate of weight gain with physical activity has been found in other studies,[34-39] although with shorter follow-ups and based on analyses of unrelated individuals. Haapanen et al. (1997)[35] found that inactive subjects had significantly higher risk of gaining ≥5 kg during a 10-year follow-up when compared with more active subjects. Sternfeld et al. (2004)[38] found that decreased activity over a 3-year follow-up was associated with higher weight gain (2.7 kg) in women. They also found that physical activity was inversely related to waist circumference. Hill and Wyatt (2005)[19] proposed that physical activity is important for weight maintenance because of its impact on energy expenditure, effects on body composition through enhancing fat-free mass and increasing total fat oxidation.

Weight may increase once participation in physical activity is reduced, indicating the need to adjust diet during periods of inactivity. This was seen in the not consistently discordant pairs, while weight was significantly different between the inactive and active co-twins in 1981 but no longer in 2005. However, it is noteworthy that the weight increase from 1975 to 2005 tended to be lower in both of the not consistently discordant twin pair members (means 9.1 and 9.6 kg) compared to inactive members of the consistently discordant pairs (13.0 kg). Thus, on the basis of non-paired analyses, and also in accordance with Schmitz et al. (2000)[36], periodical participation in physical activity also seems to slow down long-term weight gain. If looking at the truly prospective design (activity discordance 1975 – 1981 and weight gain 1981 - 2005), the weight gain was similar for both inactive and active co-twins (p=0.64) among all 89 pairs. This could be explained by converging amounts of physical activity, as most active co-twins decreased the amount of activity and inactive co-twins slightly increased it or remained the same. Even though the prospective design did not show a difference in weight gain between inactive and active co-twins, the final cross-sectional design showed a significant difference in waist circumference at follow-up. This could partly be explained by reverse causality as decrease in weight might lead to increased participation in physical activity. In our study even a small increase in exercise habits in passive co-twins seemed to slow down weight gain, although persistent activity was more beneficial. The correlation between pairwise differences in mean MET and in weight gain was significant ($r=-0.28$, $p=0.008$) reinforcing the dose-response relationship between long-term physical activity and a slow rate of weight gain.

It has been shown that exercise without weight loss is associated with a substantial reduction in total and abdominal fat.[40] As expected, waist circumference was clearly lower in active compared with inactive co-twins (figure 4). A ten-centimetre difference in waist circumference has high clinical significance as the outcome measurement has a strict association with other metabolic syndrome manifestations.[3] According to a study by Han et al. (1995)[41] the risk of having at least one other CVD risk factor was higher (OR=4.57, 95% CI 3.48 to 5.99) for men who had a waist circumference ≥102 cm compared to men with waist circumference <94 cm, whereas in women the risk was higher (OR=2.55 95 % CI 2.02 to 3.23) if waist circumference was ≥88 cm when compared with women who had waist circumference <80 cm. Whereas a study by Wang et al. (2005)[42] showed that men who had waist circumference ≥96.5 cm had higher risk (age-adjusted RR=5.0, 95% CI 3.4 – 7.2) of type 2 diabetes compared to men who had waist circumference <86.4 cm. A twin study by Rönnemaa et al. (1997)[43] found that among identical twins discordant for obesity, only those who differed most in visceral fat level had major alterations in insulin sensitivity and glucose tolerance. Aside from prevention of obesity and abdominal fat, physical activity has other benefits such as increased cardiovascular fitness, prevention of type II diabetes and coronary heart disease.[44, 45] It is also important to remember that the most direct effect of physical training is the increase in fitness, which is also known to reduce disease risk.[46, 47] Expectedly we also found that inactive co-twins tended to become breathless easier during walking and daily tasks when compared with active co-twins (p=0.06 for paired difference, results not shown).

Strengths and limitations

The strengths of our study were a very long follow-up period and twin study design. We partly controlled for genetic factors and the childhood environment by studying twin pairs comprehensively selected from the large Finnish Twin Cohort. One of the study limitations is the lack of comprehensive data on dietary habits. It would have been impossible to collect reliable dietary data for so long period with current data collection methods. A small number of MZ twin pairs only allowed us to compare whether the trends were similar to DZ twins. The direction was same in 4 out of 5 consistently discordant MZ pairs.

Retrospective physical activity data collection presents some limitations but we observed moderate correlations between the different physical activity assessments in the study. Also this type of data collection method is commonly used in the epidemiological physical activity research.[48] It would have been difficult to measure total energy expenditure for thirty years to validate the retrospective physical activity assessment. To maximize the participation rate and minimize the selection bias an interview-based study was conducted, leaving weight, height and waist circumference to be measured by the participants. Although self-measurements are a limitation they have shown to be valid and clinically relevant.

Conclusion

In conclusion, our findings give further evidence that persistent long-term participation in leisure-time physical activity is associated with decreased rate of weight gain and smaller waist circumference in adults. A ten-centimetre reduction in waist circumference across the population would produce significant benefits for public health.

Details of funding

This study was supported by the Finnish Ministry of Education, the Juho Vainio Foundation and the Yrjö Jahnsson Foundation. The Finnish Twin Cohort study was supported by the GENOMEUTWIN project (supported by the European Union Contract No. QLG2-CT-2002-01254) and the Finnish Twin Cohort Study is part of the Academy of Finland Centre of Excellence in Complex Disease Genetics.

The authors have no potential conflicts of interest related to the funding.

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Table 1. 1975 baseline characteristics of 89 twin pairs. *

Characteristics	**Inactive**	**Active**	**P value**
Age (Mean, range)	29 (18 – 48)	29 (18 – 48)	
Height	169.3 ± 8.5	169.5 ± 8.5	0.67
Weight	63.5 ± 12.5	63.9 ± 10.5	0.72
Ever smoked regularly by 1975 (N, %)	47 (52.8%)	40 (44.9%)	0.28
Alcohol grams/day (Mean ± SD)	6.1 ± 9.3	6.7 ± 8.5	0.62
Diagnosed hypertension (*N, %)*	3 (3.4%)	5 (5.6%)	0.69
Marital status (*N, %)*			0.16
Single	26 (29.2%)	38 (42.7%)	
Married	56 (62.9%)	48 (53.9%)	
Divorced	5 (5.6%)	2 (2.2%)	
Cohabiting	2 (2.3%)	1 (1.2%)	
Work-related physical activity in 1975 (*N, %)*			0.13
Sedentary	26 (29.5%)	31 (34.8%)	
Standing or walking at work	12 (13.6%)	20 (22.5%)	
Light manual labour	45 (51.1%)	34 (39.3%)	
Heavy manual labour	5 (5.7%)	3 (3.4%)	
Occupational group (*N, %)*			0.31
1 Upper white-collar	5 (5.6%)	8 (9.0%)	
2 Clerical work	26 (29.2%)	24 (27.0%)	
3 Skilled workers	31 (34.8%)	36 (40.4%)	
4 Unskilled workers	7 (7.9%)	7 (7.9%)	
5 Farmer	13 (14.6%)	2 (2.2%)	
6 Other (Students, army, retired, unknown)	7 (7.9%)	12 (13.5%)	

* Plus-minus values are means ±SD.

Table 2. MET indices (MET hours/day) for all pairs, consistently discordant and not consistently discordant pairs.*

Variable	**Inactive**	**Active**	**Mean difference (95% CI)**	**T-test, P value**
All 89 pairs				
Mean MET index 1980 – 2005	3.0 ± 3.1	7.2 ± 4.4	4.27 (3.16 to 5.38)	< 0.001
Daily activities 12-month MET index	1.9 ± 2.9	1.9 ± 2.7	-0.02 (-0.80 to 0.77)	0.96
Leisure time 12-month MET index	3.0 ± 2.5	5.3 ± 4.7	2.22 (1.15 to 3.30)	< 0.001
Total 12-month MET index	5.0 ± 4.1	7.2 ± 5.4	2.20 (1.00 to 3.41)	< 0.001
Consistently discordant pairs (42 pairs)				
Mean MET index 1980 – 2005	1.4 ± 1.2	9.1 ± 4.9	7.65 (6.20 to 9.10)	< 0.001
Daily activities 12-month MET index	1.6 ± 2.7	2.6 ± 3.6	1.01 (-0.27 to 2.28)	0.12
Leisure time 12-month MET index	1.9 ± 1.5	6.1 ± 5.9	4.14 (2.38 to 5.90)	< 0.001
Total 12-month MET index	3.5 ± 3.3	8.7 ± 6.7	5.15 (3.53 to 6.77)	< 0.001
Not consistently discordant pairs (47 pairs)				
Mean MET index 1980 – 2005	4.4 ± 3.6	5.6 ± 3.2	1.25 (0.15 to 2.34)	0.03
Daily activities 12-month MET index	2.2 ± 3.1	1.3 ± 1.4	-0.94 (-1.86 to -0.01)	0.05
Leisure time 12-month MET index	4.0 ± 2.9	4.5 ± 3.2	0.51 (-0.62 to 1.64)	0.37
Total 12-month MET index	6.3 ± 4.3	5.9 ± 3.5	-0.43 (-1.86 to 1.01)	0.55

* Plus-minus values are means ±SD. Mean MET index 1980-2005 calculated from the shorter retrospective physical activity assessment. 12-month = 12-month detailed physical activity assessment. Leisure time 12-month MET index includes work journey and leisure time physical activities. Total = Leisure-time + work journey + daily activities.

Table 3. Anthropometric measurements for all pairs, consistently discordant and not consistently discordant pairs.*

Variable	**Inactive**	**Active**	**Mean difference (95% CI)**	**T-test, P value**
All 89 pairs				
Height 1975 (cm)	169.3 ± 8.5	169.5 ± 8.5	0.24 (-0.86 to 1.34)	0.67
Weight 1975 (kg)	63.5 ± 12.5	63.9 ± 10.5	0.39 (-1.74 to 2.53)	0.72
Weight 1981 (kg)	67.1 ± 13.7	65.2 ± 10.7	-1.99 (-4.35 to 0.37)	0.10
Weight 2005 (kg)	74.7 ± 15.1	72.3 ± 11.7	-2.43 (-5.21 to 0.36)	0.09
Change in weight 1975 through 1981 (kg)	3.6 ± 4.7	1.3 ± 3.8	- 2.38 (-3.54 to -1.22)	<0.001
Change in weight 1981 through 2005 (kg)	7.6 ± 7.3	7.1 ± 5.9	- 0.44 (-2.30 to 1.42)	0.64
Change in weight 1975 through 2005 (kg)	11.2 ± 9.0	8.4 ± 7.1	-2.82 (-4.98 to -0.66)	0.01
BMI 1975	22.0 ± 2.9	22.2 ± 2.3	0.14 (-0.49 to 0.77)	0.66
BMI 1981	23.3 ± 3.4	22.6 ± 2.4	-0.73 (-1.46 to 0.01)	0.05
BMI 2005	25.9 ± 3.9	25.1 ± 3.0	-0.80 (-1.70 to 0.10)	0.08
Waist circumference (cm)	90.7 ± 12.1	86.7 ± 10.2	-4.05 (-6.67 to -1.42)	0.003
Consistently discordant pairs (42 pairs)				
Height 1975 (cm)	169.7 ± 8.5	169.3 ± 8.5	-0.39 (-2.22 to 1.44)	0.67
Weight 1975 (kg)	65.9 ± 12.9	64.4 ± 10.1	-1.50 (-4.88 to 1.88)	0.38
Weight 1981 (kg)	69.9 ± 14.6	65.0 ± 9.7	-4.86 (-8.72 to -0.99)	0.02
Weight 2005 (kg)	78.9 ± 15.4	72.0 ± 11.8	-6.91 (-11.19 to -2.62)	0.002
Change in weight 1975 through 1981 (kg)	4.0 ± 5.4	0.6 ± 4.2	-3.36 (-5.42 to -1.29)	0.002
Change in weight 1981 through 2005 (kg)	9.0 ± 8.5	7.0 ± 6.6	-2.05 (-5.01 to 0.91)	0.17
Change in weight 1975 through 2005 (kg)	13.0 ± 10.1	7.6 ± 7.8	-5.41 (-8.87 to -1.95)	0.003
BMI 1975	22.7 ± 2.9	22.4 ± 2.2	-0.30 (-1.24 to 0.65)	0.53
BMI 1981	24.2 ± 3.6	22.6 ± 2.2	-1.57 (-2.77 to -0.37)	0.01
BMI 2005	27.1 ± 4.0	25.1 ± 3.4	-2.05 (-3.48 to -0.61)	0.006
Waist circumference (cm)	94.2 ± 12.4	85.8 ± 10.2	-8.37 (-12.73 to -4.00)	<0.001
Not consistently discordant pairs (47 pairs)				
Height 1975 (cm)	168.9 ± 8.6	169.7 ± 8.6	0.79 (-0.57 to 2.14)	0.25

Table 3. Anthropometric measurements for all pairs, consistently discordant and not-persistently discordant pairs.* "(cont)."

Weight 1975 (kg)	61.4 ± 11.8	63.5 ± 10.9	2.09 (-0.63 to 4.80)	0.13
Weight 1981 (kg)	64.7 ± 12.4	65.3 ± 11.67	0.57 (-2.18 to 3.33)	0.68
Weight 2005 (kg)	71.0 ± 13.9	72.6 ± 11.6	1.58 (-1.79 to 4.94)	0.35
Change in weight 1975 through 1981 (kg)	3.3 ± 3.9	1.8 ± 3.5	-1.51 (-2.72 to -0.29)	0.02
Change in weight 1981 through 2005 (kg)	6.3 ± 5.8	7.3 ± 5.4	1.00 (-1.35 to 3.36)	0.40
Change in weight 1975 through 2005 (kg)	9.6 ± 7.6	9.1 ± 6.5	-0.51 (-3.14 to 2.13)	0.70
BMI 1975	21.4 ± 2.8	21.9 ± 2.3	0.53 (-0.34 to 1.39)	0.23
BMI 1981	22.6 ± 3.1	22.6 ± 2.6	0.01 (-0.88 to 0.89)	0.99
BMI 2005	24.8 ± 3.5	25.1 ± 2.7	0.32 (-0.76 to 1.39)	0.56
Waist circumference (cm)	87.7 ± 11.1	87.4 ± 10.2	-0.28 (-3.09 to 2.54)	0.84

* Plus-minus values are means ±SD. CI denotes confidence interval. The body-mass index is the weight in kilograms divided by the square of the height in meters. Change in weight 1975 through 1981 is weight in 1981 – weight in 1975 and respectively for 1981 through 2005 and for 1975 through 2005.

Titles and legends to figures

Figure 1.

Title: Leisure-time MET indices (mean±SE) in inactive and active members of the twin pairs from 1980 through 2005.

Legend: In figures A and B a significant difference ($p<0.001$) between inactive and active co-twins is seen in all measured years, but in C a significant difference is only seen in 1980 ($p<0.001$) and 1985 ($p<0.05$).

Figure 2.

Title: Leisure-time MET indices (mean±SE) in inactive and active members of the twin pairs from 1980 through 2005.

Legend: In figures A, C and D significant difference ($p<0.01$) between inactive and active co-twins is seen in all the years measured, but in figure B a significant difference ($p<0.01$) is only seen in 1980 and 1985.

Figure 3.

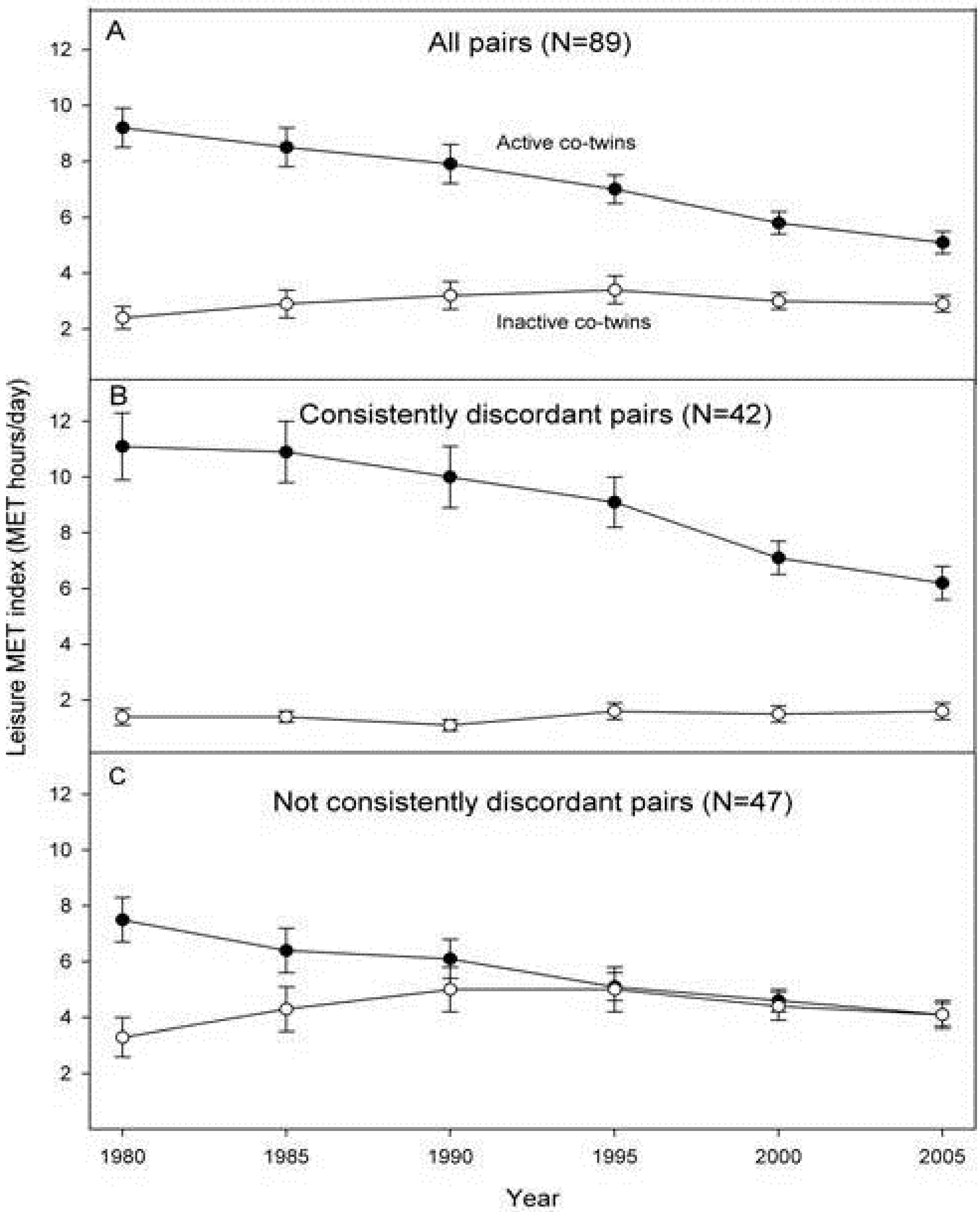
Title: Pairwise differences between inactive and active co-twins in mean MET index, total MET index in 2005, weight change and waist circumference.

Legend: Mean differences and P values from paired t-test between inactive and active members of twin pairs for mean MET index from 1980 through 2005, total MET index in 2005, weight change from 1975 through 2005 and waist circumference.

Figure 4.

Title: Waist circumference (mean±SE) difference for 42 consistently discordant pairs, for 21 consistently discordant male pairs and for 21 consistently discordant female pairs.

Figure 1.



A
All pairs (N=89)
Active co-twins
Inactive co-twins
B
Consistently discordant pairs (N=42)
C
Not consistently discordant pairs (N=47)
Leisure MET index (MET hours/day)
12
10
8
6
4
2
1980
1985
1990
1995
2000
2005
Year

Figure 2.

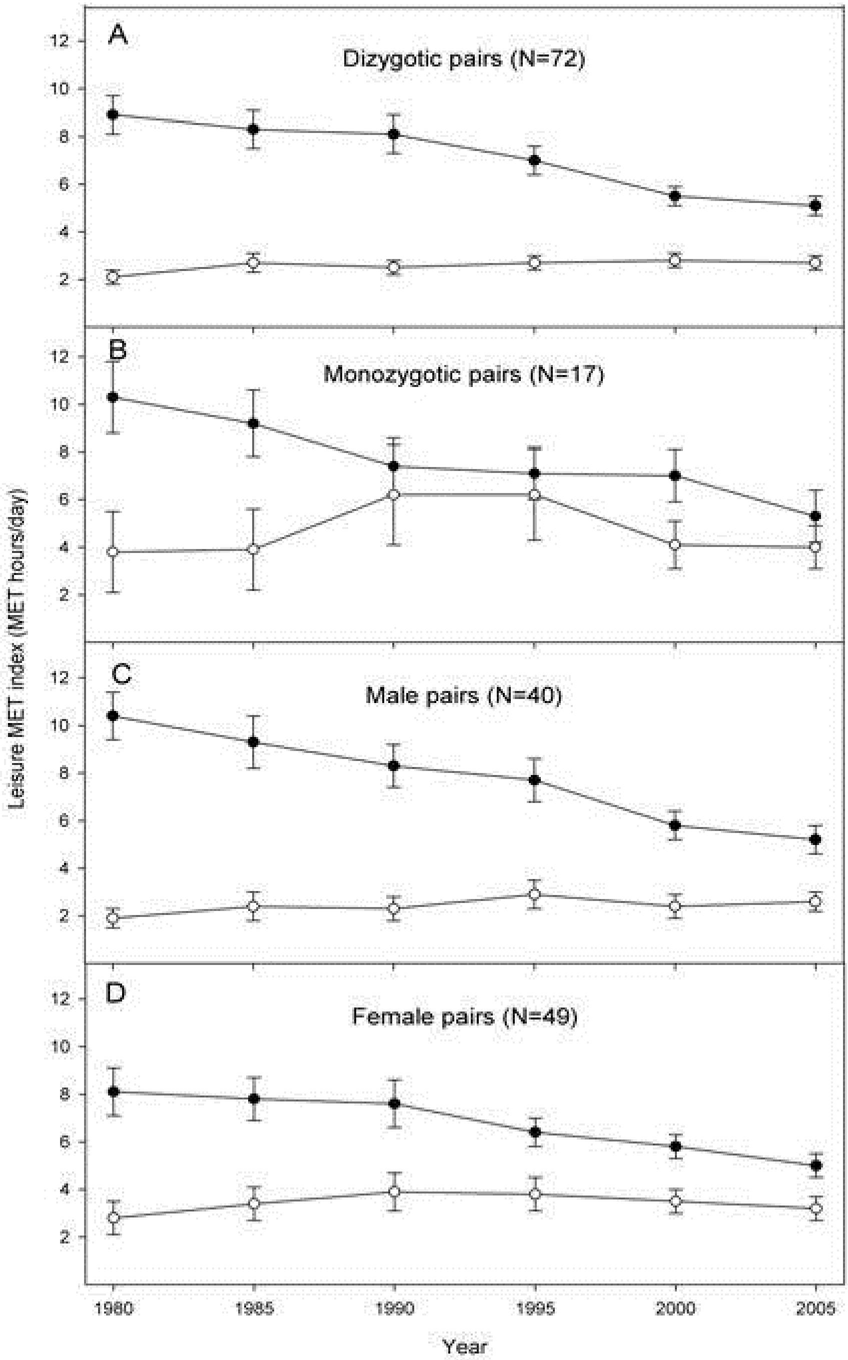
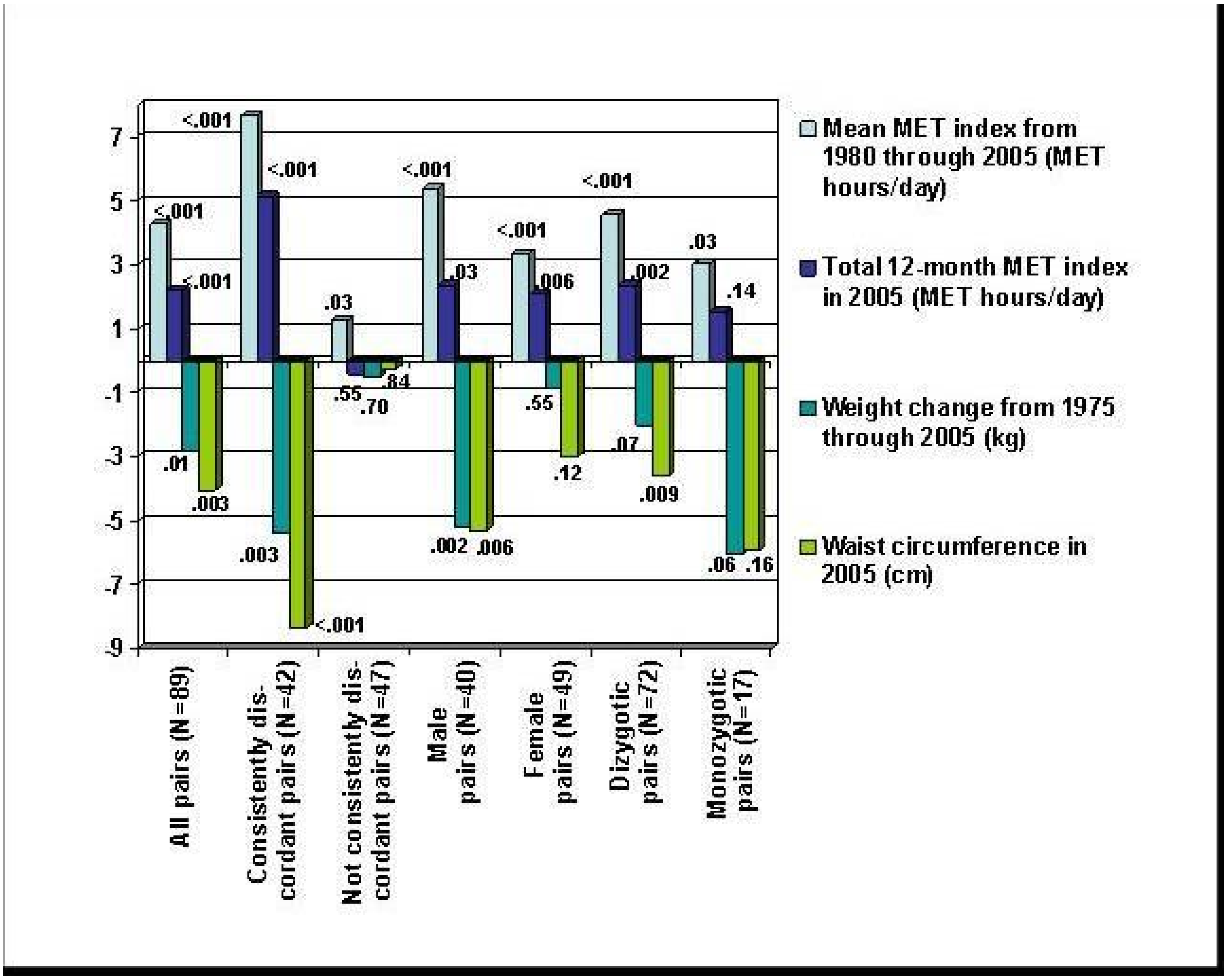
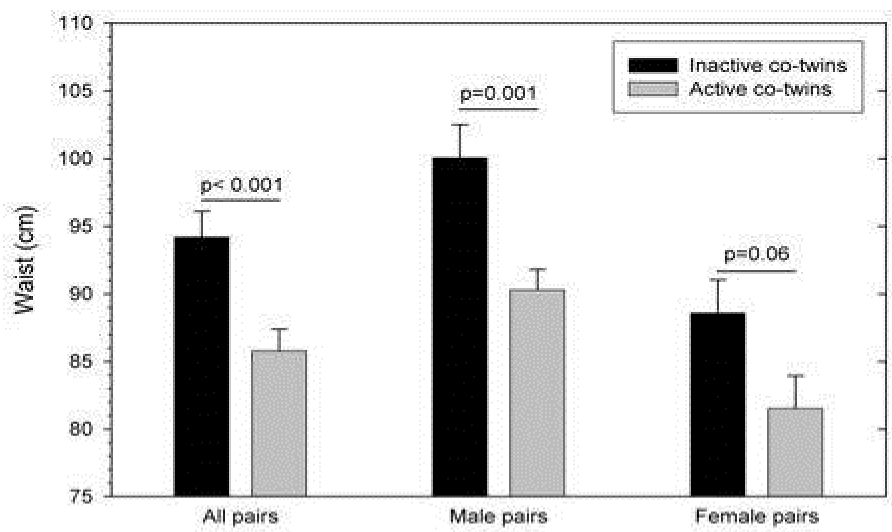

A
Dizygotic pairs (N=72)
B
Monozygotic pairs (N=17)
C
Male pairs (N=40)
D
Female pairs (N=49)
Leisure MET index (MET hours/day)
Year
1980
1985
1990
1995
2000
2005
2
4
6
8
10
12

Figure 3.



Mean MET index from 1980 through 2005 (MET hours/day)
Total 12-month MET index in 2005 (MET hours/day)
Weight change from 1975 through 2005 (kg)
Waist circumference in 2005 (cm)
7
5
3
1
-1
-3
-5
-7
-9
All pairs (N=89)
Consistently discordant pairs (N=42)
Not consistently discordant pairs (N=47)
Male pairs (N=40)
Female pairs (N=49)
Dizygotic pairs (N=72)
Monozygotic pairs (N=17)
<.001
<.001
.01
.003
<.001
<.001
.003
<.001
.03
.55
.70
.84
<.001
.03
.002
.006
<.001
.006
.55
.12
<.001
.002
.07
.009
.03
.14
.06
.16

Figure 4.



Waist (cm)
110
105
100
95
90
85
80
75
Inactive co-twins
Active co-twins
p< 0.001
p=0.001
p=0.06
All pairs
Male pairs
Female pairs