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Persistence or Change in Leisure-Time Physical Activity Habits and Waist Gain During Early Adulthood: A Twin-Study

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Abstract

Objective—To determine the relationship between persistence or change in leisure-time physical activity habits and waist gain among young adults.

Design and Methods—Population-based cohort study among 3383 Finnish twin individuals (1578 men) from five birth cohorts (1975–1979), who answered questionnaires at mean ages of 24.4 y (SD 0.9) and 33.9 y (SD 1.2), with reported self-measured waist circumference. Persistence or change in leisure-time physical activity habits was defined based on thirds of activity metabolic equivalent h/day during follow-up (mean 9.5 y; SD 0.7).

Results—Decreased activity was linked to greater waist gain compared to increased activity (3.6 cm, $P<0.001$ for men; 3.1 cm, $P<0.001$ for women). Among same-sex activity discordant twin pairs, twins who decreased activity gained an average 2.8 cm (95%CI 0.4 to 5.1, $P=0.009$) more waist than their co-twins who increased activity (n=85 pairs); among MZ twin pairs (n=43), the difference was 4.2 cm (95%CI 1.2 to 7.2, $P=0.008$).

Conclusions—Among young adults, an increase in leisure-time physical activity or staying active during a decade of follow-up was associated with less waist gain, but any decrease in activity level, regardless baseline activity, led to waist gain that was similar to that associated with being persistently inactive.

Keywords

Physical activity; waist circumference; twins; longitudinal studies

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Introduction

Prevalence of general and abdominal obesity are high, and increasing both among children and adults, although there are some encouraging signs that the increase is slowing (1–4). Abdominal obesity is a major cardio-metabolic risk factor (5,6), and waist circumference measure is considered to be a valid marker of abdominal obesity (6,7), correlating better than body mass index (BMI) with intra-abdominal fat (6,8).

According to longitudinal studies long-term physical activity is related to smaller waist circumference (9,10) and less abdominal fat (11). However, constant physical activity may be insufficient to prevent age-related waist gain, because waist circumference seems to grow with time despite regular physical activity (10,12). Intervention studies have identified significantly reduced waist circumference after increased physical activity, even without substantial weight loss (13–15). Only a few longitudinal studies have examined the relationship between changed physical activity habits and concordant change in waist circumference, showing that increased physical activity was associated with a lower waist gain (12,16–18). However, longitudinal studies have not focused on early adulthood, when age-related weight and waist gain already seem to escalate (19,20), and many other changes in life occur (i.e. work and family related commitments); thus, young adulthood is a critical but largely unexplored period from the obesity epidemic viewpoint.

Along with environmental effects, genetics plays a role in the development of obesity (21,22) and exercise participation (23). Genetic predispositions can lead to genetic selection bias in studies of the relationship between physical activity and the development of obesity and chronic diseases, by favoring some individuals to attain high physical activity levels or appropriate body composition. The studies of monozygotic (MZ) and dizygotic (DZ) twin pairs make possible to standardize for childhood family environment and fully (MZ pairs) or partially (DZ pairs) for genetic background. Therefore, co-twin control studies are better in revealing the causal relations between physical activity and health outcomes than observational follow-up studies of nonrelated individuals. Of note, while routine daily activity has decreased in modern society, the role of leisure-time physical activity in modifying total energy expenditure has particularly been emphasized (24,25). The purpose of this study was to determine how the persistence or change in leisure-time physical activity during early adulthood is associated with waist gain.

Materials and Methods

Data collection

This study is part of the FinnTwin16 twin cohort study (26) investigating the role of genetic and environmental factors as determinants of different health behaviors, disease risk factors and chronic disease. Virtually all twins born in 1975–1979 were identified from the Finnish population register for FinnTwin16. The follow-up cohort includes about 5500 individuals and almost 2700 twin pairs. Data collection for this follow-up study started in 1991, and participants were sent the first questionnaire within two months of their 16th birthday. Later, questionnaires were mailed when participants were 17 and 18.5 years old. The 4th wave questionnaire was collected on 2000–2002, when the participants were on average 24.5 years old. The 5th wave of data collection was done in 2010–2012 when the participants were a mean age of 34.0 years.

Waves 4 and 5 were used for the present study. Wave 4, the baseline for this report, was done using a postal paper questionnaire, and wave 5, the follow-up was conducted using a web-based questionnaire, both including questions related to health, body composition and leisure-time physical activity. The response rates for the overall cohort were 84.5% and 71.9% for waves 4 and 5, respectively, with 77.9% of those replying at wave 4 also replying at wave 5.

The study was conducted according to ethical standards and the Declaration of Helsinki, and approved by the ethical committee of the Central Finland Hospital district. Participants gave their informed consent.

Participants

Altogether 3866 twin individuals from five consecutive birth cohorts (1975–1979) answered both questionnaires (baseline and follow-up). We included in this study all participants who answered at both collections the questions related to leisure-time physical activity, weight and height, and measured their waist circumference. All who had responded affirmative to being pregnant at the time of data collection were excluded from this study (n=263). After exclusions, the final study group consisted of 1578 men and 1805 women (total N=3383, including 1109 twin pairs of which 393 were known to be MZ pairs and 679 DZ pairs) (Figure 1). Determination of zygosity was based on accurate and validated questionnaire method (27).

Measurement of waist circumference

Self-measurement of waist circumference was done using a supplied tape measure at both data collections; in wave 5, it was included in the mailed invitation letter that contained the access code to the Internet survey. The instructions with an illustration for measuring waist circumference were included in the questionnaire. Waist circumference was measured while standing, at either the narrowest part of the waist, or if that was not found, the midpoint between the lowest part of the ribs and top of the hip bone. The intra-class correlation between self-measured and healthcare professional-measured waist circumference (n=24) is 0.97 (P<0.001) (9). A change in waist circumference was calculated as the difference between follow-up and baseline data collection.

Assessment of leisure-time physical activity

The assessment of leisure-time physical activity was based on a series of questions covering leisure-time physical activity and physical activity during journeys to and from work. These questions were identical at waves 4 and 5. Validity information of physical activity questions is available in detail elsewhere (9). The questionnaire included three structured questions about leisure-time physical activity. First, average monthly frequency of activity with seven response alternatives: 1) not at all, 2) less than once a month, 3) 1–2 times a month, 4) about once a week, 5) 2–3 times a week, 6) 4–5 times a week, 7) about every day.

Second, average duration of one session of activity with four response alternatives: 1) under 30min, 2) 30min - under 1h, 3) 1h - under 2h, 4) 2h or more. Third, intensity of activity 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. Physical activity during journeys to and from work was included to leisure-time physical activity, and it was assessed with a question about the average time used for walking, bicycling, jogging, skiing or/and roller-skating in one day for work journeys with five response alternatives: 1) under 15min, 2) 15min - under 30min, 3) 30min - under 1h, 4) 1h or more, 5) I do not work or study. The frequency for this commuting activity was set at five times a week and intensity as corresponding to walking. A leisure-time physical activity MET (metabolic equivalent) index was calculated by assigning a multiple of the resting metabolic rate (intensity×duration×frequency). It was expressed as a sum score of leisure time physical activity MET hours per day as described earlier (28) with modifications to account for the slightly different response alternatives of the related questions in the present questionnaires.

Persistence or change in leisure-time physical activity habits was evaluated by dividing participants into sex-specific thirds using tertiles computed from the leisure-time physical activity MET index at baseline and follow-up (Table 1). The participants in the first thirds were categorized as inactive, in the second as moderately active, and in the third as active. Persistence or change in leisure-time physical activity habits was based on remaining in the same category during the follow-up or changing to another category (nine groups in total).

Assessment of confounding factors

Baseline BMI (kg/m^2), calculated from self-reported height and weight (29), as well age at follow-up and the number of children at follow-up were used as continuous variables in adjusted analysis. Work-related physical activity at follow-up was assessed with the question about how strenuous work or studies are physically, see classification in table 1. The question was slightly modified from Kujala et al. (30). Educational level was defined as a highest level reached at follow-up. This question about education completed was re-categorized as follows: 1) primary and compulsory education (nine years), 2) secondary vocational and academic (up to 12 years), 3) tertiary education (>12 years, i.e. university and polytechnics) (31). Chronic diseases were reported as having/not having chronic disease or handicap interfering daily activities (32). Alcohol use at follow-up was assessed by asking the frequency of drinking any alcohol (32), and responses were classified into five categories (see table 1). Smoking status was defined as 1) current smoker, 2) occasional smoker, 3) quitter, 4) never smoked, according to structured question (32).

Statistical analysis

Data were analyzed using Stata 12.0 (Stata Corp., College Station, TX, USA) and SPSS Statistics 20.0 (IBM Corp., Armonk, NY, USA). All individual–based analyses were done separately for men and women and carried out by taking into account clustered observations of twins within pairs. The differences in characteristics of the participants between leisure-time physical activity categories (inactive, moderately active, active) were analyzed with the adjusted Wald test for continuous variables and Pearson's χ^2 test for categorical variables.

The F-test (analysis of variance) with the clustered option for twin pairs was used to compare differences in waist gain during follow-up among nine different leisure-time physical activity groups (persistently inactive vs. other groups).

To further confirm the role of decreased or increased leisure-time physical activity in waist gain, we re-categorized all same sex (MZ and DZ) twin pairs as well only MZ twin pairs in which one twin was more active than the co-twin. With these categories, we performed pairwise comparison of waist gain between 1) those who decreased activity (any change from higher third to a lower one) and who increased activity (any change from a lower third to a higher one); 2) the persistently inactive and those who changed from inactive to moderately active or active; and 3) the persistently active and those who changed from active to moderately active or inactive. Normally distributed data were analyzed with two-sided paired-sample t-tests and non-normally distributed data with the Wilcoxon signed-rank test. The same re-categorizing and comparison were done also at the individual level. In all analyses the level of statistical significance was set at P <0.05.

Results

Characteristics of participants

Over an almost 10- year follow-up (mean 9.5 y; SD 0.7, median 10.0 y), the mean waist circumference increased 7.0 cm (SD 8.1) for men and 6.1 cm (SD 8.2) for women. BMI increased during the follow-up 1.9 kg/m^2 (SD 2.4) for men and 1.8 kg/m^2 (SD 2.8) for women. Characteristics of the study participants stratified by leisure-time physical activity level (active, moderately active, inactive) and sex at baseline and follow-up are shown in Table 1. Waist circumference differed significantly among activity groups in both men and women at baseline and follow-up. Inactive men had an average greater body weight than moderately active or active men, and BMI differed among all groups at follow-up, but not at baseline. Active women had lower mean body weight and BMI than moderately active and inactive women both at baseline and follow-up. Active and moderately active men appeared to be slightly more educated than inactive men, and the latter more often had work with a high occupational loading. In women, those who were not working or studying were more often inactive than those who were working. Both men and women who had children were less often physically active than those without children. Participants with chronic diseases were distributed equally across all leisure-time groups, except that inactive men more often had chronic diseases than others at follow-up. Less active people were more often current smokers and daily alcohol users, especially among men.

Association between persistence or change in leisure-time physical activity and waist gain in individual based analysis

Waist circumference increased in both sexes in all leisure-time physical activity groups (persistence or change) (mean waist gain from 3.7 to 9.7 cm by group) during the follow-up (Figure 2, Table 2). When comparing the waist gain of persistently inactive people to all other groups (Figure 2, Table 2), persistently active men or men who increased activity during follow-up gained less waist than the persistently inactive respondents did (P<0.05). Men who decreased activity or stayed only moderately active got waist similar to that associated with being persistently inactive. Women, who stayed at least moderately active or increased activity during follow-up, gained less waist than persistently inactive women (*P*<0.01). Women who decreased activity level during the follow-up got waist as those who stayed persistently inactive. Further, the highest mean waist gain occurred in men and women who changed from active to inactive during the follow-up. Adjusting for potential confounders, such as age, baseline waist circumference and BMI, work-related physical activity, educational level, number of children, chronic diseases, smoking status and alcohol use, did not change the results substantially (Table 2).

When comparing waist gain of all participants who decreased leisure-time physical activity (men 8.4 cm; 95%CI 7.6 to 9.2, women 7.5 cm; 95%CI 6.7 to 8.2) to those who increased activity during follow-up (men 4.8 cm; 95%CI 3.9 to 5.6, women 4.3 cm; 95%CI 3.6 to 5.0), the difference was statistically significant (*P*<0.001) (Figure 3a). The persistently inactive (men 8.1 cm; 95%CI 6.9 to 9.2, women 8.4 cm; 95%CI 7.1 to 9.6) gained more circumference than those, who were inactive at baseline but increased activity (men 5.2 cm; 95%CI 4.0 to 6.4, women 4.7 cm; 95%CI 3.7 to 5.6) during follow-up. Persistently active respondents (men 6.3 cm; 95%CI 5.6 to 7.1, women 4.7 cm; 95%CI 3.9 to 5.5) gained significantly less circumference than those who were active at baseline but decreased activity (men 8.5 cm; 95%CI 7.6 to 9.4, women 7.7 cm; 95%CI 6.7 to 8.7) during follow-up.

Pairwise analysis among physical activity discordant twin pairs

Among leisure-time physical activity discordant twin pairs, twins who decreased physical activity during the follow-up gained an average 2.8 cm (95%CI 0.4 to 5.1, *P*=0.009) more waist than their co-twins who increased physical activity (n=85 pairs); among MZ twin pairs (n=43), the difference was 4.2 cm (95%CI 1.2 to 7.2, *P*=0.008) (Figure 3b and c, Table 3). These pairwise differences remained statistically significant when each waist measure was first divided by the corresponding BMI value (*P*=0.027 for all pairs, 0.027 for MZ pairs). When comparing persistently inactive twins to their co-twins who were inactive at baseline but increased activity during follow-up, the mean difference in waist gain was 4.7 cm (95%CI 1.3 to 8.0) for all 41 pairs (*P*=0.007) and 4.0 cm (95%CI, −0.8 to 8.8) for 22 MZ pairs (*P*=0.10). Although the difference in waist gain between those who were active at baseline but decreased activity during follow-up and those who were persistently active was not significant among MZ twin pairs (n=43) (1.2 cm; 95%CI −1.9 to 4.4, *P*=0.44), it was among all same-sex twin pairs (n=85)(2.9 cm; 95%CI 0.5 to 5.3, *P*=0.02).

Discussion

In this twin cohort study of young adults, an increase in leisure-time physical activity (shifting from a lower third to a higher one) or staying active was associated with less waist gain over the almost 10-year follow-up period. Any decrease in leisure-time physical activity during the follow-up, regardless of starting category, led to a waist gain similar to that of persistently inactive respondents.

Earlier studies among young adults have reported rather similar age-related mean waist circumference growth during follow-up (10) as well as among middle-aged and older populations (12,16). In particular our results stress the associations between changes in physical activity and waist gain. Although similar associations have been observed previously (12, 16–18), prior studies did not focus on early adulthood, a period when age-related weight and waist gain already seem to escalate (19,20), even as many other changes in lifestyle and health occur. Earlier follow-up studies have also often focused on the relationship between prolonged physical activity habits and weight and waist gain (9,10). What is important to note from the current findings is that decreasing physical activity regardless of baseline activity level is related to increased waist gain. This may have an influence on the results of those studies which only look at the predictive value of baseline physical activity on follow-up waist or obesity. In our study 52% of men and 57% of women changed their leisure-time physical activity habits according to our criteria. More research is needed on to determine how to prevent increased waist gain among those who must decrease physical activity for various reasons.

Our results did not substantially change after adjusting the effect of physical activity change on waist gain for potential confounders such as baseline waist circumference, BMI, work-related physical activity, educational level, number of children, chronic diseases, smoking status or alcohol use. We could not adjust our results for energy intake; however, our earlier study in older twins showed that although the physically active were leaner, their daily energy intake was higher than that of their inactive co-twins (33).

As genetics plays a role in exercise participation (23) and development of obesity (21,22), it may be easier for some individuals to achieve high levels of physical activity and appropriate body composition. This may lead to selection bias in observational follow-up studies of nonrelated individuals, and make it difficult to assess the true extent of the causal relation between physical activity and health outcomes. With pairwise analysis among all same-sex twin pairs and MZ twin pairs, we could consider genetic background and childhood environment, including differences in, for example, social class and education, family structure and parenting practice. Pairwise analysis confirmed the importance of maintaining or increasing leisure-time physical activity and the risk of decreasing activity for waist gain, and gave evidence for causal relation between physical activity and reduced waist gain. As expected, the relatively small number of physical activity discordant MZ pairs reduced the power to detect possible differences in some comparisons.

We focused particularly on leisure-time physical activity instead of total daily activity because modifying total daily energy expenditure through leisure-time physical activity is emphasized currently while physical activity related to daily routines (e.g. work and household) has decreased (24,25). We decided to use age-specific thirds when participants were divided to physical activity classes (inactive, moderately active, active), since average physical activity level seems to change with time in population. Use of age-specific cut-offs leads to better statistical power. In our study sample the number of participants, who were active at baseline and then even increased their level of physical activity at follow-up, remained low. Consequently, analysis concerning this interesting target group was not carried out. Both assessment of leisure-time physical activity and waist circumference measurement were self-reported, which can lead to reporting bias, but made large observational data collection possible. Because we had two follow-up points, it is not possible to determine when changes in leisure-time physical activity occurred, or interpret causality. However, our pairwise analyses among monozygotic physical activity discordant twin pairs gave evidence for causal relation between physical activity and reduced waist gain. We focused particularly on waist gain instead of BMI because abdominal obesity is an independent risk factor for all-cause mortality (34) and cardio-metabolic diseases (35–37). Furthermore, when the waist circumference was divided by the corresponding BMI value, the change in this ratio differed significantly between the twins who decreased physical activity compared to their co-twins who increased physical activity, supporting the importance of waist measurement as an indicator of the effect of physical activity. Compared to the general population the BMI values of our twins are similar level or slightly lower (38) meaning that the generalizability of the results is good.

In conclusion, regardless of physical activity level, waist circumference increased during young adulthood. To attenuate this waist gain, increased leisure-time physical activity or staying active seemed to be essential for both sexes. In contrast, despite the starting level, any decrease in leisure-time physical activity led to waist gain that was similar to that associated with being persistently inactive. These findings deliver an important public health message to promote high leisure-time physical activity habits from early adulthood onward to prevent age-related abdominal obesity. Physical activity level seems often to decrease during early adulthood, and thus our results highlight also the need to establish how increased waist gain can be attenuated among those people.

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'What is already known about this subject?'

- Abdominal obesity is an alarming health problem, and leisure-time physical activity has the potential to prevent age-related waist gain.
- Physical activity is related to smaller waist circumference and less abdominal fat. However, constant physical activity may be insufficient to prevent age-related waist gain.

'What this study adds?'

- Changes in an easily measured waist circumference, which correlates well with many cardio-metabolic risk factors, are associated with the changes in leisure-time physical activity habits already in early adulthood.
- Our pairwise analyses among monozygotic physical activity discordant twin pairs (comparing twins who decreased activity to their co-twins who increased activity), controlled for segregating genes. This gives evidence for causal relation between physical activity and reduced waist gain.

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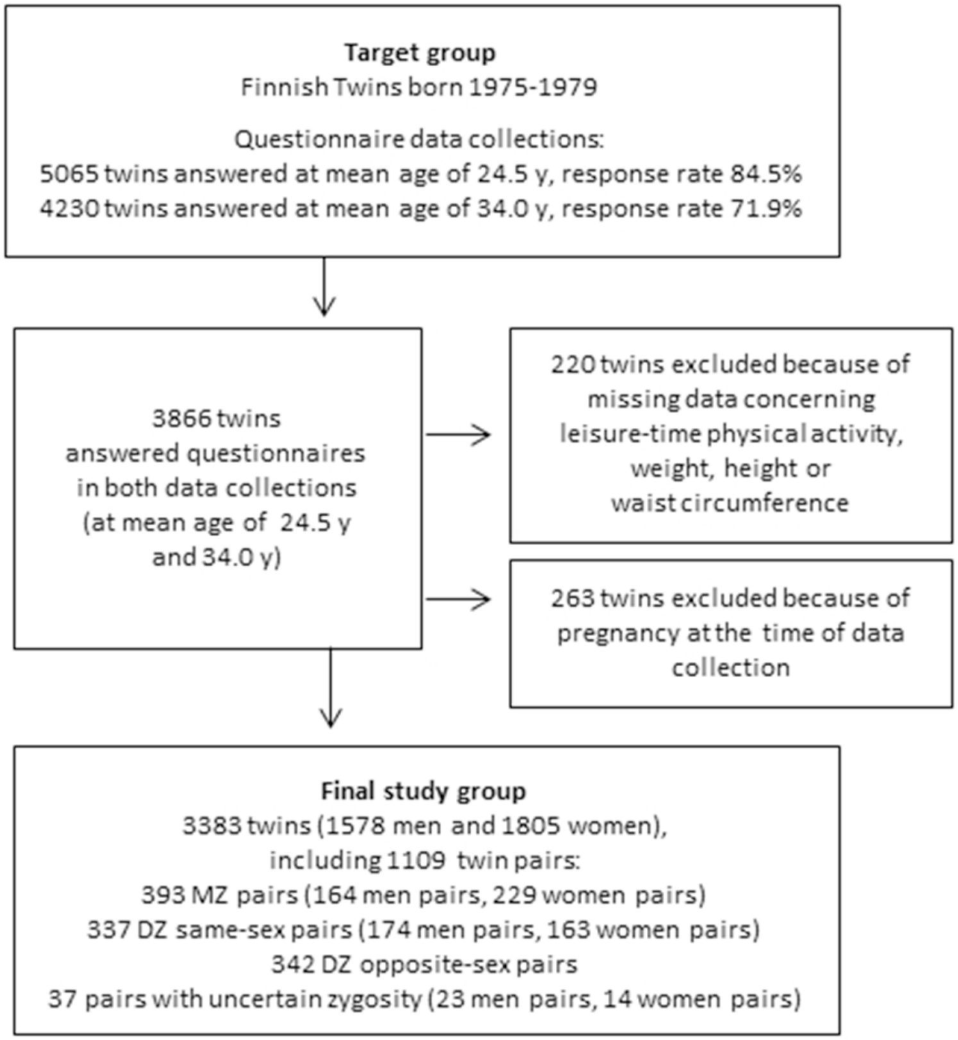

Figure 1.
Flow chart of participants and data collection.

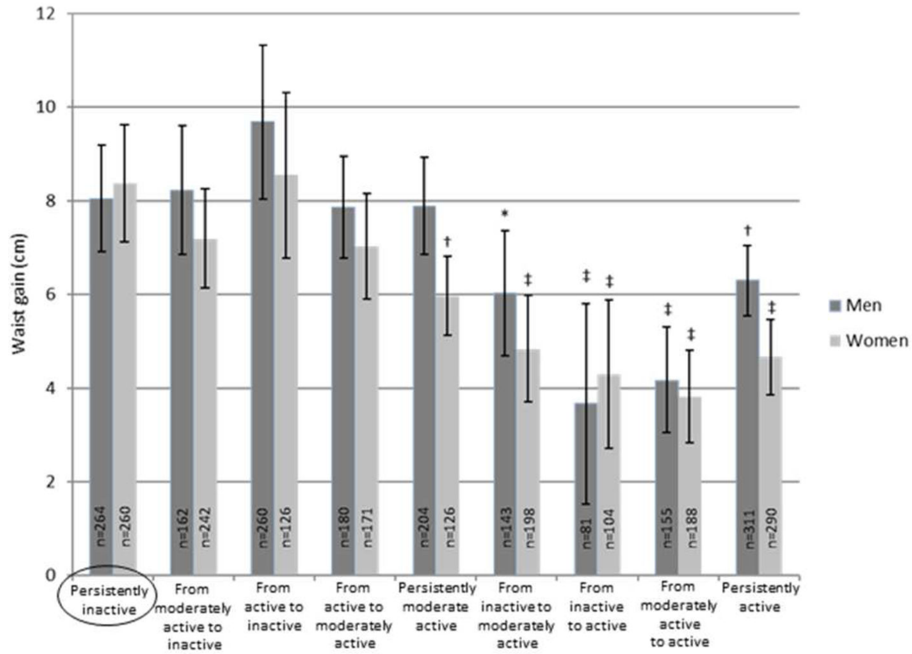

Figure 2.

Persistence or change in leisure-time physical activity and waist gain (cm, mean and 95%CI) during follow-up. Significant differences are coded (persistently inactive as a reference group): * *P*<0.05, † *P*<0.01, ‡ *P*<0.001.

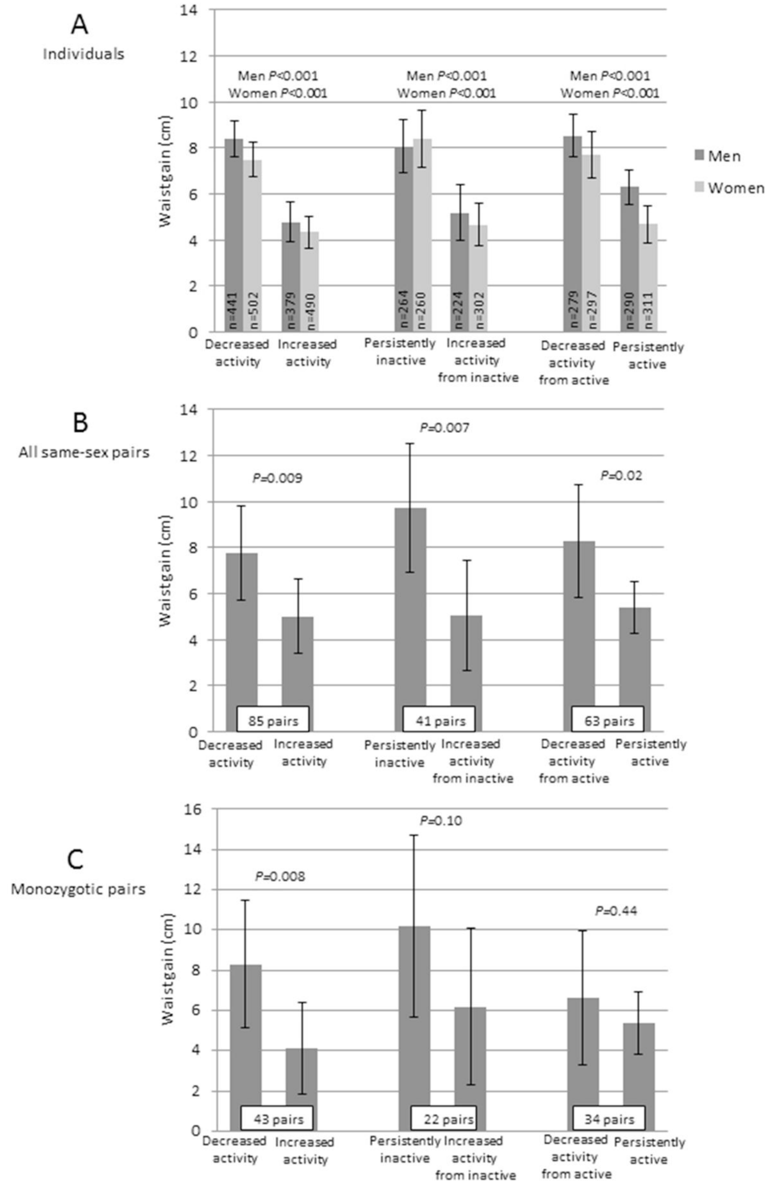

Figure 3.

Differences in waist gain (cm, mean and 95%CI) during follow-up (decreased activity: changed from upper third to a lower one; increased activity: changed from a lower third to upper one). **A.** Sex-specific differences among individuals taking into account clustered observation of twin pairs. **B.** Pairwise difference among leisure-time physical activity discordant same sex twin pairs. **C.** Pairwise differences among leisure-time physical activity discordant monozygotic twin pairs.

Table 1

Characteristics of participants at baseline and at follow-up by sex and leisure-time physical activity categories[a]

	Men (N=1578)							
	Baseline				Follow-up			
	Inactive (n=488)	Moderately active (n=521)	Active (n=569)		Inactive (n=525)	Moderately active (n=527)	Active (n=526)	
LTPA MET hours per day[b]	**MET<2.3**	**2.3≤MET<6.8**	**MET≥6.8**	***P*[c]**	**MET<2.2**	**2.2≤MET<5.4**	**MET≥5.4**	***P*[c]**
Age, mean (SD), y	24.4 (0.9)	24.4 (0.9)	24.4 (1.0)	-	34.0 (1.2)	33.8 (1.1)	33.8 (1.2)	*†
Weight, mean (SD), kg	77.7 (13.7)	76.1 (11.8)	77.1 (10.2)	-	85.1 (14.8)	82.6 (13.9)	81.8 (11.6)	*†
Height, mean (SD), cm	179.3 (6.6)	179.3 (6.3)	179.9 (6.7)	-	179.5 (6.6)	179.2 (6.3)	179.9 (6.9)	-
BMI, mean (SD), kg/m^2	24.1 (3.7)	23.6 (3.1)	23.8 (2.6)	-	26.4 (4.1)	25.7 (3.8)	25.2 (3.1)	*†‡
Waist circumference, mean (SD), cm	87.3 (11.1)	85.2 (9.1)	83.7 (7.1)	*†‡	95.2 (12.0)	92.1 (10.3)	89.7 (9.0)	*†‡
				P				*P*
Work-related physical activity, n (%)				<0.001				0.005
Sedentary	185 (38.1)	254 (49.0)	273 (48.1)		208 (39.7)	267 (50.7)	258 (49.0)	
Standing or walking at work	72 (14.8)	100 (19.3)	117 (20.7)		100 (19.1)	92 (17.5)	110 (20.9)	
Light manual work	114 (23.5)	94 (18.1)	102 (18.0)		115 (21.9)	93 (17.6)	95 (18.1)	
Heavy manual work	73 (15.0)	44 (8.5)	59 (10.4)		74 (14.1)	57 (10.8)	45 (8.6)	
Not working or studying	42 (8.6)	26 (5.0)	15 (2.7)		27 (5.2)	18 (3.4)	18 (3.4)	
Educational level, n (%)								<0.001
Primary					21 (4.0)	19 (3.6)	11 (2.1)	
Secondary					303 (57.8)	224 (42.5)	245 (46.6)	
Tertiary					200 (38.2)	284 (53.9)	270 (51.3)	
Children, [n (%)]				<0.001				0.02
Yes	74 (15.2)	47 (9.0)	38(6.7)		315 (60.2)	295 (56.0)	272 (51.7)	
No	412 (84.8)	474 (91.0)	531 (93.3)		208 (39.8)	232 (44.0)	254 (48.3)	
Chronic diseases, n (%)				0.39				0.02
Yes	62 (12.2)	52 (10.1)	64 (11.4)		98 (18.7)	73 (13.9)	67 (12.8)	
No	421 (87.2)	464 (89.9)	497 (88.6)		426 (81.3)	453 (86.1)	457 (87.2)	
Smoking status, n (%)				<0.001				<0.001
Current (daily) smoker	219 (44.9)	146 (28.0)	95 (16.7)		153 (29.1)	86 (16.3)	75 (14.3)	
Occasional smoker	64 (13.1)	83 (15.9)	102 (17.9)		70 (13.3)	74 (14.1)	50 (9.5)	

	Men (N=1578)							
	Baseline				Follow-up			
	Inactive (n=488)	Moderately active (n=521)	Active (n=569)		Inactive (n=525)	Moderately active (n=527)	Active (n=526)	
LTPA MET hours per day[b]	**MET<2.3**	**2.3≤MET<6.8**	**MET≥6.8**	***P*** [c]	**MET<2.2**	**2.2≤MET<5.4**	**MET≥5.4**	***P*** [c]
Quitters	55 (11.3)	82 (15.7)	89 (15.6)		121 (23.0)	120 (22.8)	115 (21.9)	
Never smoked	150 (30.7)	210 (40.3)	283 (49.7)		181 (34.5)	246 (46.8)	286 (54.4)	
Alcohol use, n (%)				0.03				0.003
Daily	21 (4.3)	10 (1.9)	8 (1.4)		44 (8.4)	24 (4.6)	17 (3.2)	
1–2 times/week	281 (57.7)	311 (59.8)	319 (56.2)		318 (60.7)	316 (60.0)	294 (55.9)	
1–2 times/month	120 (24.6)	123 (23.7)	168 (29.5)		95 (18.1)	117 (22.2)	126 (24.0)	
Less than once a month	42 (8.6)	39 (7.5)	42 (7.4)		41 (7.8)	41 (7.8)	53 (10.1)	
Never	23 (4.7)	37 (7.1)	31 (5.4)		26 (5.0)	29 (5.5)	36 (6.8)	

	Women (N=1805)							
	Baseline				Follow-up			
	Inactive (n=562)	Moderately active (n=635)	Active (n=608)		Inactive (n=591)	Moderately active (n=611)	Active (n=603)	
LTPA MET hours per day[b]	**MET<2.5**	**2.5≤MET<5.5**	**MET≥5.5**	***P*** [c]	**MET<2.0**	**2.0≤MET<5.0**	**MET≥5.0**	***P*** [c]
Age, mean (SD), y	24.3 (0.9)	24.3 (0.9)	24.3 (0.9)	-	33.9 (1.3)	33.9 (1.2)	33.9 (1.2)	-
Weight, mean (SD), kg	61.8 (12.0)	61.5 (10.0)	59.9 (7.9)	†‡	67.4 (14.8)	66.2 (13.2)	63.9 (10.3)	†‡
Height, mean (SD), cm	165.4 (5.8)	165.8 (5.4)	166.6 (5.9)	†‡	165.6 (5.8)	165.8 (5.8)	166.4 (5.6)	†
BMI, mean (SD), kg/m^2	22.5 (4.0)	22.3 (3.3)	21.6 (2.5)	†‡	24.6 (5.2)	24.1 (4.6)	23.0 (3.4)	†‡
Waist circumference, mean (SD), cm	76.1 (10.2)	74.9 (8.6)	72.4 (7.0)	*†‡	83.0 (13.2)	80.7 (11.1)	77.9 (9.5)	*†‡
				P				*P*
Work-related physical activity, n (%)				<0.001				<0.001
Sedentary	222 (39.6)	294 (46.3)	289 (47.5)		238 (40.3)	228 (37.3)	261 (43.4)	
Standing or walking at work	83 (14.8)	128 (20.2)	131 (21.5)		84 (14.2)	143 (23.4)	131 (21.8)	
Light manual work	114 (20.4)	126 (19.9)	127 (20.9)		131 (22.2)	143 (23.4)	140 (23.3)	
Heavy manual work	23 (4.1)	15 (2.4)	18 (3.1)		13 (2.2)	7 (1.1)	16 (2.7)	
Not working or studying	118 (21.1)	71 (11.2)	43 (7.1)		124 (21.0)	90 (14.7)	54 (9.0)	
Educational level, n (%)								0.002
Primary					20 (3.4)	5 (0.8)	14 (2.3)	

	Women (N=1805)							
	Baseline				Follow-up			
	Inactive (n=562)	Moderately active (n=635)	Active (n=608)		Inactive (n=591)	Moderately active (n=611)	Active (n=603)	
LTPA MET hours per day[b]	**MET<2.5**	**2.5≤MET<5.5**	**MET≥5.5**	***P*** [c]	**MET<2.0**	**2.0≤MET<5.0**	**MET≥5.0**	***P*** [c]
Secondary					242 (40.9)	263 (43.0)	213 (35.3)	
Tertiary					329 (55.7)	343 (56.1)	376 (62.4)	
Children, n (%)				<0.001				<0.001
Yes	121 (21.5)	84 (13.2)	41 (6.7)		431 (72.9)	372 (61.0)	326 (54.1)	
No	441 (78.5)	551 (86.8)	567 (93.3)		160 (27.1)	238 (39.0)	277 (45.9)	
Chronic diseases, n (%)				0.25				0.46
Yes	74 (13.3)	69 (11.0)	62 (10.2)		104 (17.6)	107 (17.5)	92 (15.3)	
No	484 (86.7)	557 (89.0)	543 (89.8)		486 (82.4)	503 (82.5)	511 (84.7)	
Smoking status, n (%)				<0.001				0.05
Current (daily) smoker	173 (30.8)	144 (22.7)	100 (16.4)		109 (18.4)	105 (17.2)	70 (11.6)	
Occasional smoker	90 (16.0)	78 (12.3)	97 (16.0)		52 (8.8)	47 (7.7)	59 (9.8)	
Quitters	80 (14.2)	97 (15.3)	69 (11.3)		120 (20.3)	126 (20.7)	125 (20.7)	
Never smoked	219 (39.0)	316 (49.8)	342 (56.2)		310 (52.5)	332 (54.4)	349 (57.9)	
Alcohol use, n (%)				0.92				0.007
Daily	3 (0.5)	1 (0.2)	3 (0.5)		14 (2.4)	3 (0.5)	2 (0.3)	
1–2 times/week	238 (42.3)	259 (40.7)	254 (41.8)		220 (37.2)	259 (42.4)	248 (41.1)	
1–2 times/month	201 (35.8)	242 (38.1)	221 (36.4)		175 (29.5)	192 (31.4)	178 (29.5)	
Less than once a month	91 (16.2)	96 (15.1)	101 (16.6)		145 (24.5)	116 (19.0)	135 (22.4)	
Never	29 (5.2)	37 (5.8)	28 (4.6)		38 (6.4)	41 (6.7)	40 (6.6)	

Abbreviations: LTPA, leisure-time physical activity; MET, metabolic equivalent; SD, standard deviation; BMI, body mass index

[a] Physical activity category by LTPA MET h/day: lowest tertile: inactive; middle tertile: moderately active; highest tertile: active

[b] Leisure-time physical activity and physical activity during journeys to and from work

[c] Continuous variables; significant differences (*P*<0.05) between activity groups are coded:

[*] inactive vs. moderately active,

[†] inactive vs. active,

[‡] moderately active vs. active

Table 2

Differences in waist gain during follow-up by sex and adjusted for potential cofounders. Model with each potential confounder added individually to a model with waist gain as the dependent variable and physical activity as the independent variable.

Persistence or change in leisure-time physical activity		Waist gain[a]	No covariates in the model	Waist gain adjusted for: Age (y)[c]	Baseline WC (cm)[c]	Baseline BMI (kg m^{-2})[c]	Work-related physical activity[d]	Educational level[d]	Children[c]	Chronic diseases[d]	Smoking status[d]	Alcohol use[d]
	N (%)	Mean (95%CI), cm	P^b									
MEN												
1. Persistently inactive	264 (16.7)	8.1 (6.9 to 9.2)	Reference group									
2. From moderately active to inactive	162 (10.3)	8.2 (6.9 to 9.6)	0.85	0.87	0.91	0.84	0.92	0.70	0.70	0.83	0.82	0.85
3. From active to inactive	99 (6.3)	9.7 (8.0 to 11.3)	0.11	0.12	0.14	0.11	0.11	0.09	0.23	0.14	0.14	0.14
4. From active to moderately active	180 (11.4)	7.9 (6.8 to 9.0)	0.82	0.78	0.49	0.83	0.72	0.88	0.69	0.85	0.92	0.97
5. Persistently moderate active	204 (12.9)	7.9 (6.9 to 8.9)	0.84	0.79	0.62	0.85	0.73	0.82	0.55	0.85	0.86	0.93
6. From inactive to moderately active	143 (9.1)	6.0 (4.7 to 7.4)	0.03	0.02	0.02	0.03	0.02	0.04	0.04	0.03	0.02	0.04
7. From inactive to active	81 (5.1)	3.7 (1.5 to 5.8)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	<0.001	<0.001
8. From moderately active to active	155 (9.8)	4.2 (3.1 to 5.3)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
9. Persistently active	290 (18.4)	6.3 (5.6 to 7.1)	0.01	0.01	0.003	0.01	0.01	0.04	0.02	0.02	0.02	0.03
WOMEN												
1. Persistently inactive	260 (14.4)	8.4 (7.1 to 9.6)	Reference group									
2. From moderately active to inactive	205 (11.4)	7.2 (6.1 to 8.3)	0.16	0.15	0.14	0.16	0.15	0.23	0.74	0.17	0.19	0.16
3. From active to inactive	126 (7.0)	8.5 (6.8 to 10.3)	0.88	0.90	0.94	0.86	0.86	0.73	0.91	0.79	0.82	0.73
4. From active to moderately active	171 (9.5)	7.0 (5.9 to 8.2)	0.11	0.11	0.06	0.12	0.12	0.19	0.65	0.14	0.14	0.15
5. Persistently moderate active	242 (13.4)	6.0 (5.1 to 6.8)	0.002	0.002	0.001	0.002	0.002	0.003	0.17	0.002	0.002	0.003
6. From inactive to moderately active	198 (11.0)	4.8 (3.7 to 6.0)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	<0.001	<0.001	<0.001
7. From inactive to active	104 (5.8)	4.3 (2.7 to 5.9)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02	<0.001	<0.001	<0.001
8. From moderately active to active	188 (10.4)	3.8 (2.8 to 4.8)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
9. Persistently active	311 (17.2)	4.7 (3.9 to 5.5)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.009	<0.001	<0.001	<0.001

Abbreviations: WC, waist circumference; BMI, body mass index; CI, confidence interval

[a]Overall observed change in waist circumference between baseline and follow-up

[b] *P* value for difference in waist gain during follow-up compared to persistently inactive

[c] used as continuous variable

[d] used as categorical variable

Table 3

Pairwise differences in waist gain during follow-up between leisure-time physical activity discordant twin pairs.

	All same sex twin pairs	Waist gain during follow-up				Monozygotic twin pairs	Waist gain during follow-up			
		Twin 1	Twin 2				Twin 1	Twin 2		
	Pairs, N	Mean (SD), cm	Mean (SD), cm	Mean difference (95%CI)	*P*	Pairs, N	Mean (SD), cm	Mean (SD), cm	Mean difference (95%CI)	*P*
Decreased activity (twin 1) vs. increased activity (twin 2)	85 (men=31)	7.7 (9.5)	5.0 (7.5)	2.8 (0.4 to 5.1)	0.009	43 (men=16)	8.3 (10.3)	4.2 (7.3)	4.2 (1.2 to 7.2)	0.008
Persistently inactive (twin 1) vs. from inactive to moderately active or active (twin 2)	41 (men=16)	9.7 (8.8)	5.1 (7.6)	4.7 (1.3 to 8.0)	0.007	22 (men=9)	10.2 (10.1)	6.2 (8.8)	4.0 (−0.8 to 8.8)	0.10
From active to moderately active or inactive (twin 1) vs. persistently active (twin 2)	63 (men=30)	8.3 (9.8)	5.4 (4.5)	2.9 (0.5 to 5.3)	0.02	34 (men=15)	6.6 (9.5)	5.4 (4.4)	1.2 (−1.9 to 4.4)	0.44

Abbreviations: SD, standard deviation; CI, confidence interval