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Relationships between walking and percentiles of adiposity in older and younger men

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Running title: Walking and weight in men

Background: To assess the relationship of weekly walking distance to percentiles of adiposity in elders (age≥75 years), seniors (55≤age<75 years), middle-age men (35≤age<55 years), and younger men (18≤age<35 years old).

Methods: Cross-sectional analyses of baseline questionnaires from 7,082 male participants of the National Walkers' Health Study.

Results: The walkers' BMIs were inversely and significantly associated with walking distance (kg/m^2 per km/wk) in elders (slope ± SE: -0.032±0.008), seniors (-0.045±0.005), and middle-aged men (-0.037±0.007), as were their waist circumferences (-0.091±0.025, -0.045±0.005, and -0.091±0.015 cm per km/wk, respectively), and these slopes remained significant when adjusted statistically for reported weekly servings of meat, fish, fruit, and alcohol. The declines in BMI associated with walking distance were greater at the higher than lower percentiles of the BMI distribution. Specifically, compared to the decline at the 10th BMI percentile, the decline in BMI at the 90th percentile was 5.1-fold greater in elders, 5.9-fold greater in seniors, and 6.7-fold greater in middle-age men. The declines in waist circumference associated with walking distance were also greater among men with broader waistlines.

Conclusions: Exercise-induced weight loss (or self-selection) causes an inverse relationship between adiposity and walking distance in men 35 and older that is substantially greater among fatter men.

Keywords: Physical activity, walking, adiposity, men

Introduction

Men who are physically active during leisure are less likely to be obese (1,2). Walking is among the most popular recreational activities (3), and is specifically endorsed to meet current health recommendations (4,5). Elders are more likely to choose walking for exercise than their younger counterparts (6).

Some cross-sectional studies (7), particularly those employing pedometers rather than survey instruments (8,9), demonstrate an association between walking distance and measures of adiposity. Other study designs provide mixed findings on whether walking is sufficient to promote weight loss or to prevent weight gain (10,11,12,13). Substantial walking effort may be required to maintain healthy weight, e.g., 45 to 60 minutes daily of brisk walking has been suggested for preventing meaningful weight gain in men during middle age (14,15). Some suggest that age may influence the effects of exercise on adiposity, i.e., that the relationship between BMI or body fat and physical activity becomes stronger with age until age 64, then diminish somewhat thereafter (16). This difference between older and younger men could relate to age-related differences in fat accumulation and the loss of lean body mass in older men. Fat-free mass is generally stable until age 60 and decreases thereafter (17). Fat mass increases during middle age and possibly thereafter until age 75 (17).

Prior cross-sectional studies have primarily employed two approaches to describe the relationship of walking to adiposity: 1) assessing the relationship to expected adiposity levels, as in calculating means or regression slopes; 2) assessing the relationship to the proportion of the sample that exceeds thresholds levels (i.e., BMI greater than 25 or 30 kg/m^2). Recently we have created and applied statistical tools for measuring the relationship between an independent variable and the percentiles of the dependent variables (18). We have shown that decreases in adiposity associated with running distance were nonsignificant at the lower percentiles of adiposity, but became increasingly greater for higher percentiles (18).

The current study examines the relationship of self-reported weekly walking distance to BMI and waist circumferences in a large sample of primarily older male walkers. Because walkers were targeted, the analyses include individuals who participate in higher levels of moderate-intensity activity than other studies.

Materials and Methods

A two-page questionnaire completed by subscribers of Walking Magazine (Boston, MA) solicited information on demographics, walking history, weight history, diet (vegetarianism and the current weekly intakes of alcohol, red meat, fish, fruit; vitamin C, vitamin E and aspirin), smoking, prior history of heart attacks and cancer, and medications for blood pressure, thyroid, cholesterol or diabetes.

Body mass index (BMI) was calculated as the weight in kilograms divided by height in meters squared. Self-reported waist circumferences were elicited by the question "Please provide, to the best of your ability, your body circumference in inches" without further instruction. The relationship of waist circumference to walking distance is expected to be weakened by different perception of where the circumference lies. However, unless the perceived location varies systematically in relation to distance, this subjectivity is unlikely to produce the relationships reported in the tables and figures. The circumference dimensions, rather than its ratios with hip circumference, are reported because waist circumference has been shown to be a better indicator of intra-abdominal fat (19). The study protocol was reviewed by the University of California Berkeley Committee for the Protection of Human Subjects, and all subjects provided a signed a statement of informed consent.

Statistical analyses Statistics are presented as mean (±SE) or slopes (±SE) unless otherwise noted. Our approach (18) for estimating the slope for the kth percentile of Y (dependent variable) versus X (independent variable) involves partitioning the independent variable into deciles and determining the percentiles of dependent variable within each partition. Simple linear regression was then used to calculate the slope of the kth percentile of Y versus X. Standard errors and significance levels were determined by bootstrap resampling (20). These bootstrap estimates were created as follows: 1) sampling with replacement was used to create a bootstrap data set of weekly walking distance and adiposity; 2) the bootstrap sample was then partitioned into distance deciles based on the distribution of walking distances; 3) within each distance decile, BMI or waist circumferences were sorted from smallest to largest, and the kth percentiles (k=5%, 6%, 7% ...95%) for each were identified, and average weekly distance for the entire decile was calculated; 4) least squares regression was then applied to estimate the apparent change in BMI or waist circumference at the kth percentile per km/wk across the ten deciles; 5) steps 1-4 were repeated ten thousand times in order to estimate the standard error for the regression slopes (calculated as the standard deviation of the bootstrap samples)(20).

If walking greater distances causes the same BMI change regardless whether the individual's BMI is relatively high or low, then the regression slopes for all percentiles of the BMI distribution will be the same (i.e., parallel). Different (i.e., nonparallel) regression slopes could indicate that walking affects various portions of the BMI distribution differently. Bootstrap resampling was used to estimate the difference between two regression slopes (e.g., the 75% slope minus the 25% slope) and the corresponding standard error. Bootstrap resampling was also used to test whether the slopes increased or decreased progressively from the 5% to the 95% of the BMI distribution. Two-tailed significance levels were calculated as 2*minimum (p, 1-p), in which p is the proportion of times that the bootstrap slopes, difference in slopes, or linear contrast was less than zero.

Results

Of the 8,539 men who provided complete information on age and weekly walking distance, we excluded 465 men for thyroid medication use, 591 men for diabetes medication use, 379 men for smoking cigarettes currently, and 85 men for following strict vegetarian diets. Of the remaining 7,398 men, 7,082 (95.7%) provided complete heights and weights so that BMI could be calculated and 6,015 (81.3%) men reported waist circumferences. Table 1, which present the characteristic of the sample by self-reported walking distance, suggests that longer-distanced walkers tended to be slightly younger, consume more fish, fruit and alcohol, and eat less meat.

Figure 1 (upper panel) plots the average BMI (Y-axis) by weekly walking distance (X-axis) stratified by age. The graphs demonstrate consistent declines in BMI with increasing weekly distance in men 35 and older. The corresponding regression slopes appear in Table 2, along with slopes for waist circumference versus distance walked. In agreement with Figure 1, the slopes were significant in men 35 and older but not in younger men, and remained significant when adjusted for reported weekly servings of fruit, fish, meat, and alcohol. When age groups are more broadly defined as seniors (aged 55-74 years) and middle-age men (aged 35-54 years), the slopes were -0.045 ± 0.005 and -0.037 ± 0.007 kg/m^2 per km/wk, respectively for BMI and -0.122 ± 0.012 and -0.091 ± 0.015 cm per km/wk, respectively for waist circumference.

The lower panel presents the relationship of weekly walking distance to the 10th, 50th (median) and 90th percentile of BMI. The decrease in BMI with distance was weakly discernible at the 10th BMI percentile (leanest walkers), apparent at the 50th percentile, and most pronounced at the 90th percentile (fattest walkers) in men 35 years and older.

Figure 2 provides more detailed analyses of the relationships of weekly walking distance to the percentiles of BMI and waistline. The vertical axis gives the regression slope (BMI or waist circumference vs. weekly walking distance) corresponding to the percentiles along the horizontal axis for BMI (upper panel) or waist distribution (lower panel). Smaller age classes were combined because their plots did not suggest their separate displays were warranted; thus curves are presented for elders (≥75 years), senior (75> age ≥55 years old), and middle-age male walkers (55> age ≥35 years old). The range of percentiles whose slopes are statistically different from zero (β•0 at $P<0.05$) are designated by the solid portions of the bars at the bottom of each graph. For example, in elders the decrease in BMI per km/wk walked was -0.018 at the 10th BMI percentile, -0.025 at the 25th percentile, -0.036 at the 50th percentile (median), -0.056 at the 75th percentile and -0.100 at the 90th percentile, and the regression slopes were all significant between 17th and 95th sample percentiles, inclusive. The slope (BMI decrease per km walked) became progressively more negative (steeper decline) for higher percentiles of the sample distribution, particularly above the median. The regression slopes of the elders, seniors, and middle-aged men did not differ significantly from each other at any percentile (analyses not displayed). Compared to the decline at the 10th BMI percentile, the decline in the 90th BMI percentile was 5.1 fold greater in elders, 5.9-fold greater in seniors, and 6.7-fold greater in middle-age.

The bottom panel of Figure 2 displays the corresponding regression slopes for waist circumferences vs walking distance. In all age groups, the decrease per km/wk walked became progressively greater for higher percentiles of the waist circumference. Statistical significance was generally achieved above the median waist circumference, and their slopes did not differ significantly between age groups at any percentile.

Discussion

This report shows that walkers' BMI and waist circumference were inversely and significantly associated with weekly walking distance in elders, seniors, and middle-age men. There were no statistically significant differences in the slopes between age groups for men 35 and older.

Other studies report both significant and nonsignificant relationships between BMI and walking, and findings in experimental studies to demonstrate the efficacy of walking in promoting weight loss in men studied longitudinally are mixed (7,8,9). In part, the variation in findings for survey based studies may relate to inaccuracy in recalling distances in nonselective populations (21,22). In contrast Figure 1 suggests a highly reproducible discordant relationship between self-reported weekly distance and BMI, which is likely due to our recruitment of a walking cohort that specifically engages in this activity for regular exercise. We found that waist circumference, an indicator of abdominal visceral fat (23), also consistently decreased in association with weekly walking distance in all five age classes of men greater than 35 years old. Preventing gains in abdominal visceral fat may be particularly important in avoiding the health complications associated with metabolic syndrome, such as hypertension, diabetes, and cardiovascular disease (24).

Elsewhere, we have described the relationship of weekly running distance to adiposity in a comparable cross-sectional survey of 60,617 male runners (25). The current study of walkers and the previous study of runners employed similar survey instruments and study designs, and both were identified primarily from periodical subscription lists targeted to their specific activity. The slopes relating BMI and waist circumferences to weekly walking distance in men 55 to 74 (-0.045 ± 0.005 kg/m^2 and -

0.122±0.012 cm per km, respectively), and 75 years and older (-0.032±0.008 kg/m^2 and -0.091±0.025 cm per km, respectively) agree with the corresponding slopes for weekly running distance in men 50 and older (-0.038±0.001 kg/m^2 per km/wk, -0.096 ±0.002 cm per km/wk, respectively) reported previously (25). The average BMI decline per weekly km walked in male walkers 25 to 55 years old (-0.037±0.007 kg/m^2 per km/wk) also agrees well with the slopes for male runners 35-54 years old (-0.036±0.001 kg/m^2 per km/wk (25)). There are also close agreements between the slopes relating waist circumference to walking distance (cm per km/wk) in walkers 35-55 years old (reported in this paper as -0.091±0.025) and slopes previously published for running distance (25) in 35-40 year-old (-0.083± 0.003), 40 to 45 year-old (-0.085± 0.003), 45-50 year-old (-0.091± 0.003) and 50 to 55 year-old men (-0.097± 0.003).

We found no significant relationship between walking distance and either BMI or waist circumferences in male walkers 18-35 years old. The sample size for this group was admittedly small, and thus provided limited statistical power to detect a relationship, however, the nonrelationship in younger walkers is also consistent with the nonsignificant association we previously reported for male runners 18-25 years old (25). They are also consistent with cross-sectional data suggesting smaller differences in BMI between sedentary and physically active younger men vis-a-vis older men (16).

In this paper, we reported that the decline in BMI associated with walking distance was greater at the higher (e.g., 90th) than lower (e.g., 10th) percentiles of the BMI distribution. This was observed despite the purported tendency for overweight individuals to overreport their physical activity (26), which is expected to weaken the slope. Others have also observed that the attenuation of age-related weight gain from exercising is greater in overweight than normal weight men (27). Compared to the decline at the 10th BMI percentile, the decline in BMI at the 90th percentile was 5.1-fold greater in elders, 5.9-fold greater in seniors, and 6.7-fold greater in middle-age men. The dependence of the slope on the percentile of the BMI distribution has additional implications. In particular it suggests that the traditional regression slope: 1) is relevant to only a small proportion of the population distribution; 2) substantially overestimates the relationship in the majority of lean men; and 3) substantially underestimates the relationship in men of greatest clinical interest, i.e., those who are most overweight and at greatest morbidity and mortality risk. For example, the traditional regression slope for BMI vs distance in 55-74 year old walkers has a 95% confidence interval from -0.035 to -0.055 kg/m^2 per km/wk. Comparing this interval with the curve in the upper panel of Figure 2 for these men shows that this includes the slopes between the 46th and 79th percentile of the BMI distribution, thereby overestimating the relationship in the lower 45th percentage of the sample and underestimating the relationship in the upper 20th percent.

Different slopes for different percentiles of BMI and waist circumferences have important connotations for the statistical analyses of epidemiologic data. Statistical adjustment for BMI is often employed when establishing the health benefits of moderate (including walking) and vigorous-intensity physical activities on disease endpoints or biological factors related to their etiology (28). However this presupposes that the functional relationships of physical activity to adiposity are parallel for all percentiles of the population distribution, which figure 2 suggest is not true. The traditional least squares regression slope for men 75 and over (-0.032±0.008 kg/m^2 per km/wk) is about one-third the slope at the 90th percentile (-0.0994 kg/m^2 per km/wk), and to the extent that obese men contribute to the relationship between activity and disease end points, the adjustment will be inadequate.

Our findings are particularly relevant to lifestyle choices in older men, who are more likely to choose walking for physical activity than younger men. Walking may promote leanness or prevent age-related weight gain. However, these data are cross-sectional, so it is not possible to separate the effects of self-selection from exercise-induced weight loss (29). However, others have shown experimentally that walking produces weight loss, and we have shown in male runners surveyed 2.6 years after baseline that changes in weekly running distance were inversely related to changes in both BMI and waist circumferences (30). Whether the consequence of selection or energy expenditure, our analyses suggest that the after age 35, the relationships of adiposity to walking distance is similar regardless of age.

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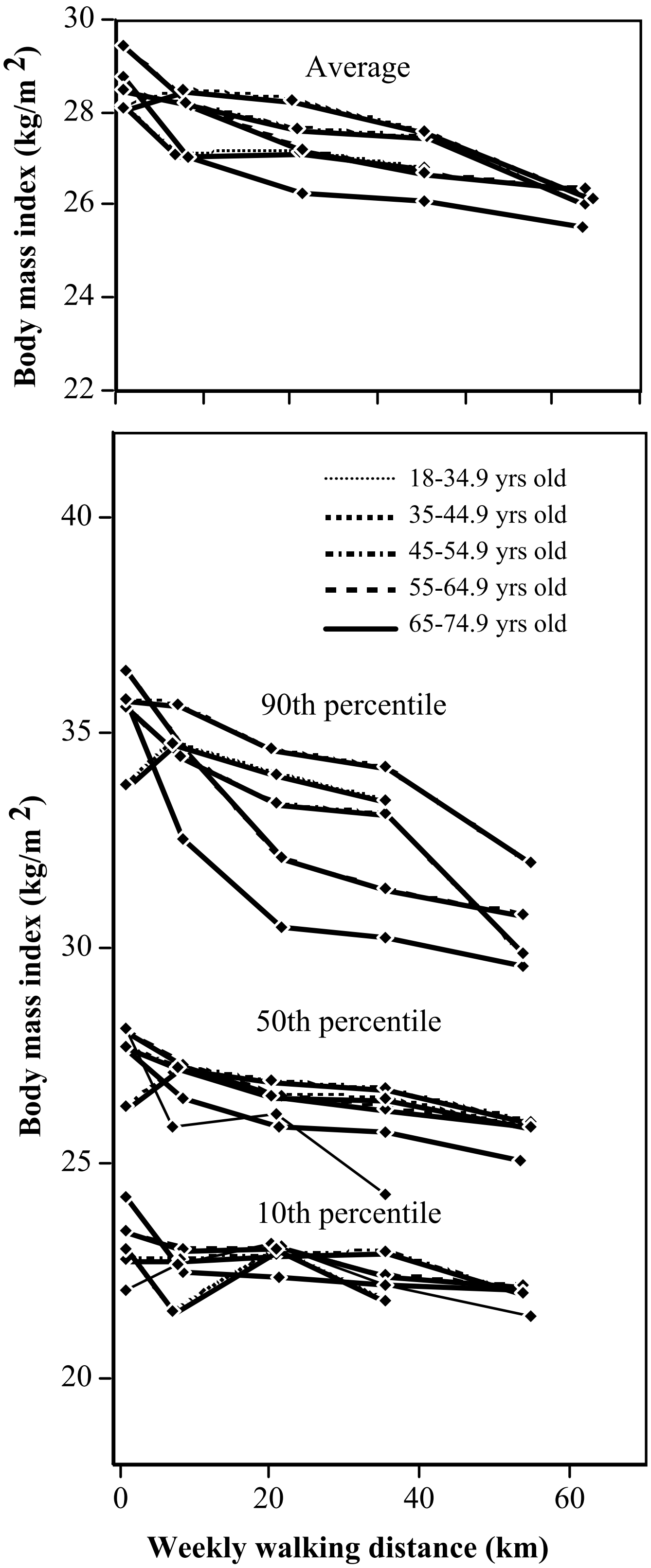
Table 1. Characteristics of male walkers

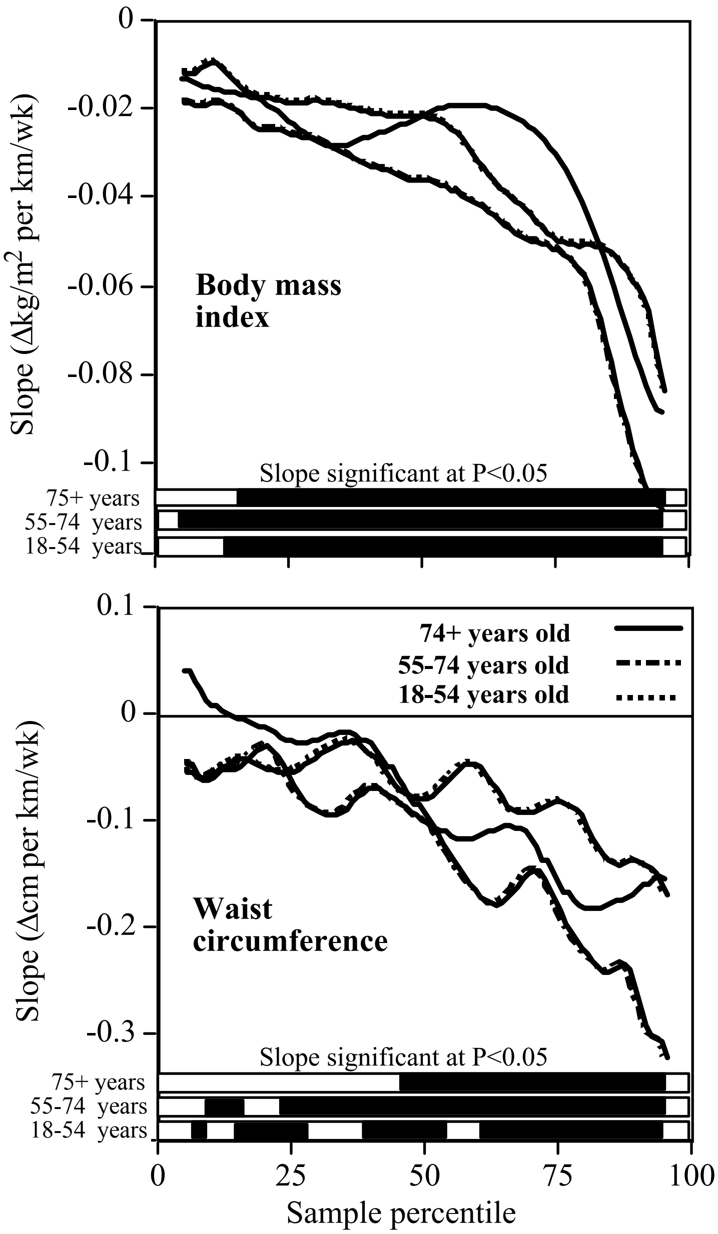
	km per week walked				
	<2	2-14.9	15-29.9	30-44.9	•45
Percent of Sample	5.97	32.45	37.94	15.96	7.66
Age (years)	60.86 ± 15.92	61.14 ± 14.12	60.93 ± 12.31	60.44 ± 12.28	58.83 ± 12.82
Education (years)	15.74 ± 3.16	15.94 ± 2.87	16.05 ± 2.75	15.77 ± 2.97	15.52 ± 2.82
Alcohol (ml/wk)	61.67 ± 102.18	70.51 ± 114.11	77.27 ± 117.64	82.32 ± 124.67	86.97 ± 147.97
Beef (servings/wk)	3.86 ± 3.32	3.36 ± 3.07	3.21 ± 2.85	3.06 ± 2.96	2.92 ± 2.94
Fish (servings/wk)	1.47 ± 1.69	1.78 ± 1.90	1.75 ± 1.58	1.80 ± 1.50	1.94 ± 2.08
Fruit (servings/wk)	8.38 ± 7.24	9.76 ± 7.93	10.97 ± 8.00	11.43 ± 8.64	12.48 ± 9.93
Years walked	17.86 ± 17.04	15.10 ± 15.04	10.60 ± 12.19	12.84 ± 12.78	14.53 ± 12.88
Body mass index (kg/m^2)	28.09 ± 5.20	27.53 ± 4.87	26.84 ± 4.14	26.61 ± 4.14	25.88 ± 3.81
Waist circum-ference (cm)	97.16 ± 12.87	94.91 ± 10.94	93.50 ± 9.52	92.48 ± 9.39	90.41 ± 9.39
Hip circum-ference (cm)	103.14 ± 109.5	101.41 ± 107.7	100.90 ± 107.2	100.63 ± 106.7	99.22 ± 106.52
Chest circum-ference (cm)	109.55 ± 12.82	107.77 ± 10.81	107.26 ± 9.70	106.76 ± 10.14	106.52 ± 10.09

Table 2. Regression slope of adiposity vs. weekly walking distance in men with and without adjustment for reported intakes of meat, fish, fruit and alcohol.				
	BMI		Waist circumference	
	Unadjusted	Adjusted for meat, fish, fruit, and alcohol	Unadjusted	Adjusted for meat, fish, fruit, and alcohol
75 years and older	-0.032±0.008‡	-0.027±0.008‡	-0.090±0.025†	-0.074±0.026†
65-75 years old	-0.040 ±0.006§	-0.038±0.007§	-0.118 ±0.017§	-0.107±0.017§
55-64 years old	-0.050 ±0.007§	-0.044±0.007§	-0.126 ±0.018§	-0.107±0.018‡
45-54 years old	-0.037 ±0.008‡	-0.027±0.008§	-0.092 ±0.017‡	-0.070±0.018‡
35-44 years old	-0.035 ±0.014*	-0.032±0.014*	-0.100 ±0.032†	-0.090±0.032†
18-34 years old	0.010 ±0.021	0.002±0.021	0.089 ±0.053	0.088±0.054
Statistical significance levels are designated for 0.01<P≤0.05 (*), 0.001<P≤0.01 (†); 0.0001<P≤0.001 (‡); and P≤0.0001 (§)				

Figure 1. Cross-sectional relationship of men's body mass index to weekly walking distance.

Figure 2. Regression slopes for percentiles of body mass index (top panel) and waist circumference versus weekly walking distance (bottom panel) as a function of percentile (e.g. decrease in BMI per km/wk walked was -0.018 at the 10th BMI percentile, -0.025 at the 25th percentile, -0.036 at the 50th percentile (median), -0.056 at the 75th percentile and -0.100 at the 90th percentile in men 75 years and older). The solid portions of the bars at the bottom of the graph designate those percentiles having slopes significant different from zero at $P<0.05$.


Average
90th percentile
50th percentile
10th percentile
18-34.9 yrs old
35-44.9 yrs old
45-54.9 yrs old
55-64.9 yrs old
65-74.9 yrs old
Body mass index (kg/m 2)
Weekly walking distance (km)
30
28
26
24
22
40
35
30
25
20
0
20
40
60



Slope (Δkg/m² per km/wk)
0
-0.02
-0.04
-0.06
-0.08
-0.1
Body mass index
Slope significant at P<0.05
75+ years
55-74 years
18-54 years
Slope (Δcm per km/wk)
0.1
0
-0.1
-0.2
-0.3
74+ years old
55-74 years old
18-54 years old
Waist circumference
Slope significant at P<0.05
75+ years
55-74 years
18-54 years
0
25
50
75
100
Sample percentile