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Exercise attenuates the association of body weight with diet in 106,737 runners

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Abstract

Purpose—The high prevalence of obesity in Western societies has been attributed in part to high-fat, low-carbohydrate food consumption. However, people have also become less active, and inactivity may have increased the risk for weight gain from poor dietary choices. Analyses were performed to test whether diet-weight relationships were attenuated by vigorous exercise.

Methods—Age- and education-adjusted cross-sectional regression analyses of 62,042 men and 44,695 women recruited for the National Runners' Health Study. Reported meat and fruit intakes were analyzed separately and as indicators of high-risk diets.

Results—The runners were generally lean (mean±SD males: 24.15±2.81, females: 21.63±2.70 kg/m²) as measured by body mass index (BMI), educated (males: 16.42±2.47, females: 16.04±2.32 years), and middle-aged (males: 44.40±10.83, females: 38.21±10.08 years), who ran 5.30±3.23 km/d if male and 4.79±3.00 km/d if female. Running significantly attenuated BMI's relationship to reported meat and fruit intake in men ($P<10^{-8}$ and $P<10^{-12}$, respectively) and women ($P<10^{-15}$ and $P<10^{-6}$, respectively). Specifically, compared to running < 2 km/d, running >8 km/d reduced the apparent BMI increase per serving of meat by 43% in men (slope±SE: from 0.74±0.10 to 0.42±0.06) and 55% in women (from 1.26±0.13 to 0.57±0.09), and reduced the apparent BMI reduction per serving of fruit by 86% in men (from -0.28±0.04 to -0.07±0.02) and 94% in women (from -0.16±0.05 to -0.01±0.02). Running also significantly attenuated the concordant relationship between reported meat intake and waist and chest circumference in men ($P<10^{-9}$ and $P=0.0004$, respectively) and women ($P=0.0002$ and $P<10^{-5}$, respectively), and the concordant relationship between meat intake and hip circumference in women ($P<10^{-6}$).

Conclusion—Vigorous exercise may mitigate diet-induced weight gain, albeit not guaranteeing protection from poor dietary choices.

Keywords

Prevention; obesity; vigorous physical activity; diet-exercise interactions

Introduction

Excess body weight is the accumulated effects of small positive imbalances between energy consumption and expenditure over time [9]. However, these imbalances are small and difficult to detect in population studies [9]. Population studies may have greater success in identifying factors affecting energy balance rather than documenting the energy balance itself. In this regard, the strongest evidence appears to relate weight gain from higher meat and lower fruit, vegetable and starchy food intake [3,10,26,27,29]. These foods may be directly causative, or they may be indicative of high and low energy-density diets.

Most epidemiological studies estimate energy expenditure from the sum of different physical activities over a 24-hour day or during recreation [2]. These studies were recently interpreted as generally failing to show that physical activity affects weight gain prospectively [29]. In contrast, we have published strong and consistent dose-response relationships between runners' usual distance run and prospective weight gain [33]. Specifically, we have shown that running attenuates age-related weight gain prospectively in proportion to the exercise dose [33], and that increasing and decreasing exercise produces reciprocal changes in body weight [39]. Our data also suggest that an exercise hiatus may lead to a net weight gain even when exercise resumes at former levels [35]. Our greater success in identifying these relationships may relate to running being a vigorous physical activity (i.e., expending >6-fold the energy expenditure of being at rest) whose energy expenditure is more simply based on total distance run rather than the more-complicated sum-product of perceived time and intensity [2].

In 1997 we reported that BMI increased in association with greater meat and lesser fruit consumption, and that these relationships appeared to be attenuated by vigorous physical activity [31]. This initial observation, based on only 7054 men and 1837 women, did not provide the statistical power required to test whether the attenuation with physical activity was statistically significant. The current paper tests whether exercise can attenuate the effects of diet on total and regional adiposity in a very large sample of over 100,000 runners. The magnitudes of the interactions and their extreme statistical significance rule out any reasonable probability of their being due to chance. The attenuating effect of exercise for preventing weight gain due to high-risk diets is not currently recognized, and may provide an important intervention tool for combating obesity in the obeseogenic environment.

Methods

A two-page mailed questionnaire, sent to subscribers of a running magazine and to participants of running events, solicited information on demographics (age, race, education), running history (age when began running at least 12 miles per week, current average weekly mileage, and number of marathons over the preceding 5 years, best marathon and 10 km times), weight history (greatest and current weight; weight when started running; least weight as a runner; body circumferences of the chest, waist, and hips; bra cup size), diet (vegetarianism and the current weekly intakes of alcohol, meat, fish, fruit, vitamin C, vitamin E, and aspirin), current and past cigarette use, history of heart attacks and cancer, and medications for blood pressure, thyroid, cholesterol, or diabetes. Running distances were reported in miles per week, body circumferences in inches, and body weights in pounds. These values were converted to kilometers per day, centimeters, and kilograms, respectively. The test-retest correlations for self-reported distance run per week ($r=0.89$) [30] compares favorably with physical activity scores reported by others.

Intakes of meat, fish and fruit were based on the questions "During an average week, how many servings of beef, lamb, or pork do you eat", and "...pieces of fruit do you eat". Alcohol intake was estimated from the corresponding questions for 4-oz. (112 ml) glasses of wine, 12-oz. (336 ml) bottles of beer, and mixed drinks and liqueurs. Alcohol was computed as 10.8 g per 4-oz glass of wine, 13.2 g per 12 oz. bottle of beer and 15.1 g per mixed drink. Correlations between these responses and values obtained from 4-day diet records in 110 men were $r=0.46$ and $r=0.38$ for consumptions of meat and fruit, respectively. These values agree favorably with published correlations between food records and more extensive food frequency questionnaires for red meat ($r=0.50$), and somewhat less favorably for fruit intake ($r=0.50$) [8].

The runners' BMIs were calculated as the weight in kilograms divided by height in meters squared. Self-reported body circumferences of the waist, hip, and chest were in response to the question "Please provide, to the best of your ability, your body circumferences in inches" without further instruction. The relationships between circumferences and running distance are expected to be weakened by different locations of where waist, hip and chest circumferences were measured. However, unless the perceived location varied systematically in relation to running distance, the subjectivity would be unlikely to produce the relationships reported in the tables and figures. Self-reported height and weight from the questionnaire have been found previously to correlate strongly with their clinic measurements ($r=0.96$ for both) [32]. Self-reported waist circumferences are somewhat less precise as indicated by their correlations with self-reported circumferences on a second questionnaire ($r=0.84$) and with their clinic measurements ($r=0.68$) [32]. Chest circumference is a measure of upper body obesity that exhibits relationships to plasma leptin levels that are not apparent for waist or hip measurements [28]. Thoracic fat has also been related to low-density lipoprotein levels [23]. The study protocol was reviewed by the University of California Berkeley committee for the protection of human subjects, and all subjects provided a signed statement of informed consent.

Statistical analyses

Results are presented as mean $\pm$ SE or slopes $\pm$ SE except where noted. With the exception of the sample description of Table 1, all analyses were adjusted for age (age and age²), and education. Multiple regression analyses were used to test whether reported meat and fruit consumption affected the runners' BMI and body circumferences. Specifically, we tested whether the coefficient for a diet $\times$ distance interaction differed significantly from zero in a model that also included their separate main effects. In these analyses, diet was defined as meat intake alone, fruit intake alone, and the combination of meat and fruit intake. Specifically, reported meat and fruit were included as a single index value using their linear regression coefficient for the least active running category (i.e., within the <2 km/d category). We also divided the sample into running increments of <2 , 2-4, 4-6, 6-8, and ≥ 8 km/d and calculated the regression coefficients for diet (meat, fruit, or best linear combination) separately within each stratum.

We also tested whether the slope of the BMI vs. diet regression line decreased progressively with longer running distances. In these analyses, we applied a single regression slope for diet to all subjects, and then tested the significance of adding a separate slope for runners who ran <2 km/d (its significance implying that the slope for running ≥ 2 km/d was significantly less than <2 km/d). The analyses were then repeated including separate coefficients for both <2 km/d and 2-4 km/d (the significance of the 2-4 km/d coefficient implying that the slope for running ≥ 4 km/d was significantly less than 2-4 km/d), and separate coefficients for <2 km/d, 2-4 km/d, and 4-6 km/d (the significance of the 4-6 km/d coefficient implying that the slope for running ≥ 6 km/d was significantly less than 4-6 km/d).

Results

There were 106,737 subjects from the National Runners' Health Survey who provided completed data on height, weight, education, running distance, and intakes of meat and fruit who did not smoke. Table 1 displays their sample characteristics by distance run. The higher-mileage runners tended to be younger, slightly more educated, ate less meat and more fruit, and if male drank less alcohol. They were also leaner as measured by BMI and body circumferences. Fourteen and seven-tenth percent (14.7%) of the men reported consuming 0 servings of meat per day, 55.0% reported 0.1 to 0.5 serving/day, 24.5% reported 0.51 to 1.0 servings/day, and 5.9 % reported >1 servings/day. The corresponding percentages for

women were 31.8%, 53.3%, 13.2%, and 1.7%, respectively. Average daily fruit consumption for men and women respectively, were reported as follows: 2.7% and 2.0% reported zero intake, 42.1% and 41.4% reported 0.1 to 1 pieces, 31.5% and 34.4% reported 1.1 to 2 pieces, 16.5% and 16.3% reported 2.1 to 3 pieces, and 7.1% and 6.0% reported >3 pieces/day.

Associations with reported intakes of meat and fruit in the least active runners

Table 2 presents regression slopes of BMI and body circumferences vs. daily servings of meat and fruit by running distance category. The least active category ran < 2 km/d. Within this group, the men's BMI and waist circumference increased significantly in association with both higher meat intake and lower fruit intake. The women's BMI and circumferences of the waist, hip and chest also increased significantly with higher meat intake, and their BMI and waist circumference increased in association with lower fruit intake. The multivariate analyses of Table 3 include both foods simultaneously in the analyses, and show that meat and fruit contributed independently to BMI and body circumferences in these low-mileage runners. In fact, their coefficients differed little from their separate regression analyses of Table 2.

Attenuation of diet-weight relationships at higher activity levels

Table 2 displays the regression slopes relating diet to body size at different activity levels, and the significance of the interaction between distance run and diet on body size. The analyses suggest that meat had a significantly weaker relationship to BMI when running ≥ 8 km/d than <2 km/d in both men and women (43% and 55% reduction, respectively). Fruit intake was also more weakly related to BMI when running ≥ 8 km/d vis-a-vis <2 km/d in men (86% reduction) and women (94% reduction). Distance run also significantly affected the relationship of both meat and fruit to waist circumference. The relationships of men's chest circumferences to high meat and low fruit intake were also significantly attenuated by running mileage, as were the relationships of women's chest and hip circumferences to high meat intake.

The analyses of Table 2 do not show whether higher BMI and larger body circumferences were directly related to high meat and low fruit intake, or whether meat and fruit content are simply indicators of diets that increase the risk for weight gain. Assuming the latter, the linear combinations of Table 3 provide the best predictors of BMI and body circumferences, and serve as indicators of high-risk diets. For example, the Table shows that the best predictor of BMI was "0.73*meat-0.27*fruit" in men and "1.28*meat-0.13*fruit" in women. Separate linear combinations were calculated for male and female runners, and for BMI and each body circumference. These define the dietary indices for the analyses to follow.

The indices were used to produce the bar graph on Figure 1, which shows the attenuating effects of running distances on the diet-weight relationships. The analyses are the same as those presented in Table 2, except that the indices of high-risk diets replace meat and fruit. The coefficient (slope) for the <2 km/d running category is always one because it represents the subset of runners used to create the index. Coefficients (slopes) less than one measure the percent attenuation due to exercise, i.e., the degree to which exercise reduces the effect of the high-risk diet on BMI and body circumferences. For example, the relationship between the men's diet and BMI was given by the slope $1.0*(0.73*\text{meat}-0.27*\text{fruit})$ for <2 km/d, $0.68*(0.73*\text{meat}-0.27*\text{fruit})$ for 2-4 km/d, $0.56*(0.73*\text{meat}-0.27*\text{fruit})$ for 4-6 km/d, $0.41*(0.73*\text{meat}-0.27*\text{fruit})$ for 6-8 km/d, and $0.35*(0.73*\text{meat}-0.27*\text{fruit})$ for ≥ 8 km/d. Thus relative to the men who ran <2 km/d, the relationship of the high-risk diet to BMI was reduced by 32% in runners who ran 2-4 km/d, 44% for those who ran 4-6 km/d, 59% for those who ran 6-8 km/d and 65% for runners who ran or exceeded 8 km/d. This represented

a highly significant decline in the relationship of diet to BMI with increasing exercise ($P < 10^{-8}$). Comparable results were obtained in women.

More detailed comparisons of the bar graphs of Figure 1 (not displayed) showed that the impact of diet on BMI was significantly less for male and female runners who ran > 2 km/d than < 2 km/d ($P < 10^{-6}$ and $P < 10^{-10}$, respectively), ran > 4 km/d compared to 2-4 km/d ($P = 0.0002$ and $P = 0.0007$, respectively), and who ran > 6 km/d when compared to 4 to 6 km/d ($P = 0.0003$ in men only). Thus there are statistically significant incremental reductions in the effect of diet on BMI with increasing running distance through at least 6 km/d in men and 4 km/d in women.

Other analyses suggest that exercise attenuates the effect of diet on regional adiposity in a dose-dependent manner for both male and female runners. The effect of diet on runners' waist circumference decreased significantly with running mileage for both men ($P < 10^{-15}$) and women ($P = 0.0006$). More detailed comparisons showed that the impact of diet on waist circumferences was significantly less in men and women who ran > 2 than < 2 km/d ($P < 10^{-5}$ and $P = 0.02$, respectively), and men who ran > 4 than 2-4 km/d ($P < 0.0001$). The effect of diet on chest circumference was also attenuated by exercise ($P = 0.0001$ for both sexes), with the effect being significantly weaker > 2 than < 2 km/d (males: $P = 0.05$; females: $P = 0.0005$) and in males weaker > 4 than 2-4 km/d ($P = 0.05$). The impact of diet on women's hip circumference also declined with increasing mileage (diet $\times$ exercise interaction: $P = 10^{-6}$) such that women who ran > 2 were less strongly affected than those who ran < 2 km/d ($P = 0.002$).

Self-selection

Because these analyses are cross-sectional, it is possible that self-selection led to the observed associations of Figure 1. These analyses were therefore repeated when adjusted for the runners' pre-exercise BMI (i.e., BMI when they first started running 12 or more miles per week). The analyses suggest that self-selection did not account for the observed association. Specifically, the impact of diet on current BMI ($P < 10^{-15}$ for both sexes) and the attenuating effect of exercise (males: $P < 10^{-8}$; females: $P < 10^{-8}$) remained significant when adjusted for their pre-exercise BMI.

Discussion

Consistent with prospective epidemiological data [3,10,26,27,29], the associations of Table 2 show that reported average meat intake was positively associated with both BMI and waist circumference. The significant association was, in fact, replicated in ten separate subsets (i.e., males < 2 km/d, males 2-4 km/d, ..., females > 8 km/d). Fruit intake was also inversely associated with men's BMI, and achieved statistical significance in 5 separate subsets of the men's data. The epidemiological evidence relating adiposity to dietary intake is weaker for fruit than for meat [22,26,27,29], which explains, in part, the more variable association we observed between fruit and BMI (Table 3). Our limited dietary assessment precluded our being able to identify meat or fruit as the specific food responsible, and therefore we also considered their combined effects in an index that may reflect high vs. low energy-dense food, or greater fast-food or restaurant-prepared than home-prepared food consumption. The primary dietary determinant of body fat has been ascribed to the diet's energy density [1], although others suggest the evidence for this is inconclusive [29]. As these data are cross-sectional, it is not possible to prove a causal relationship between the diet and BMI or body circumferences from our data. Our survey questionnaire did not ask about intakes of vegetables or other foods that may also have contributed to total and regional adiposity.

Our analyses provide statistical confirmation of our initial report that there was a trend for vigorous physical activity to attenuate the association of BMI with higher meat and lower fruit consumption in a dose dependent manner [31]. They extend these initial results by showing that vigorous exercise also attenuates: 1) the concordance between men's waist circumference and meat intake; 2) the concordance of the men's chest circumference with higher meat intake and lower fruit intake; 3) the relationship between women's adiposity (BMI, and waist, hip, and chest circumference) and diet (Table 2).

The diminished effect of dietary composition on the BMI of higher mileage runners could be due to improved fat oxidation with exercise. Defects in whole body and skeletal muscle fatty acid oxidation [11] may predispose individuals to gain weight in an "obesogenic" environment [12]. The defect involves increased reliance on carbohydrate vis-a-vis fat oxidation, which are associated with gains in total weight and fat mass [40]. Manifestation of the defect includes a high respiratory quotient (RQ), which is characteristic of obese and post-obese individuals, and is shown to predict weight gain prospectively [4,17,40]. In obese individuals, the respiratory quotient has also been associated with low muscle lipoprotein lipase activity [40]. Lower postprandial uptake of free fatty acids by leg skeletal muscle has been shown to correlate with greater visceral fat mass [4]. The impaired ability of obese vis-à-vis lean individuals to oxidize fat may be exacerbated by diet, with obese individuals responding with a higher carbohydrate and lower fat oxidation after high carbohydrate consumption, and an inability to increase fat oxidation after high fat consumption [30], a condition described as metabolic inflexibility [7]. Plasma triglyceride concentrations, elevated in association with obesity, may be a marker for impaired fat oxidation [24]. Vigorous physical activity significantly increases the ability to oxidize fat [25], increases skeletal muscle lipoprotein lipase activity [21], reduces the respiratory quotient [25], and reduces plasma triglyceride concentrations [34].

The diminished effect of dietary composition on the BMI of higher mileage runners could also be due, in part, to improved coupling between energy intake and expenditure, such that episodic intakes of energy-dense foods are balanced by reduced energy intake at other times [18]. In sedentary individuals, reduced physical activity is not necessarily associated with reduced energy intake, whereas in more-active individuals energy intake and expenditure tend to be correlated [20]. At high physical activity levels, the coupling between expenditure and intake can be described as tight [14], with active males reported to be able to adjust future food consumption to drinks of disguised high- and low-energy content [13], and to low- and high-energy preloading [16,19]. The improved coupling may be the result of the acute regulation from satiety hormones released by the intestinal tract, or longer term effects related to leptin, insulin, and post-absorptive signals associated with macronutrient oxidation [18].

Caveats

The cross-sectional nature of the current analyses prevents our drawing causal inference between running distance, diet, and adiposity. Although it is possible that lean individuals may self-select to run longer distances, prior analyses of these runners suggest that self-selection accounts for only 25% of the association between running distance and BMI in men, and 58% in women [36]. Prospective analyses have also shown that their leanness is partially due to exercise-induced weight loss [39], and the attenuation of age-related weight gain in accordance to their exercise dose [33]. Our inability to attribute the observed associations to the runners' pre-exercise BMI also argues against self-selection. We also acknowledge that BMI may be a poor indicator of adiposity in high-mileage runners [15]. We also caution that the runners may represent a unique group of individuals who may not be representative of the general population, however, we believe that the basic biological processes relating exercise, diet, and body weight are likely to be shared by all individuals.

The majority of the men and women in these analyses fell within the healthy weight category as defined by $18.5 \leq \text{BMI} < 25 \text{ kg/m}^2$, nevertheless, the association described herein are of public health relevance since even within the healthy weight range, greater BMI is associated with a greater incidence of diabetes [37], hypertension [37], hypercholesterolemia [37], and coronary heart disease [37].

In conclusion, these observations suggest an important advantage to achieving and exceeding minimum guideline physical activity levels, which is to reduce the risk of weight gain by high-risk diets, as characterized by high meat and low fruit content. The mean energy expenditure of the men and women in our least active exercise category ($<2 \text{ km/day}$) averaged 398 ± 4 and $392 \pm 4 \text{ METmin/week}$, respectively (calculated as $61.2 \text{ METmin per km}$ [33]), which falls below the minimum physical activity level of $450\text{--}750 \text{ METmin/week}$ recommended by the American Heart Association and the American College of Sports Medicine [6]. They may also contradict the notion that the effect of physical activity on weight gain is limited to energy expenditure and the thermodynamics of energy balance, and may include the additional effects of improved fat oxidation and appetite regulation.

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Figure 1.
Bar chart of the regression slope for BMI vs. diet index at different running distances. Significance levels represent the significant of the slope within the range of running distances.

Table 1

Characteristics of runners by reported distance run per day.

	<2 km/day	2-4 km/day	4-6 km/day	6-8 km/d	8 km/d	Significance of trend (P)
Males						
Sample	6914	16352	18850	7606	12320	
Age (years)	45.63±11.71	45.53±10.86	44.92±10.33	44.20±10.60	42.12±10.81	<10 ⁻¹⁵
Education (years)	16.43±2.50	16.57±2.41	16.44±2.43	16.37±2.50	16.20±2.56	<10 ⁻¹⁵
Meat (servings/day)	0.49±0.42	0.45±0.40	0.41±0.38	0.39±0.37	0.36±0.37	<10 ⁻¹⁵
Fruit (pieces/day)	1.24±1.00	1.39±1.05	1.50±1.09	1.61±1.17	1.70±1.26	<10 ⁻¹⁵
Alcohol (g/day)	10.34±14.71	11.98±16.31	11.91±16.22	11.59±16.58	10.71±16.00	<10 ⁻⁵
BMI (kg/m ²)	25.42±3.42	24.75±2.80	24.20±2.62	23.65±2.45	22.89±2.34	<10 ⁻¹⁵
Waist circumference (cm)	90.68±8.86	90.33±7.90	89.81±7.80	89.15±7.88	87.89±8.25	<10 ⁻¹⁵
Chest circumference (cm)	104.25±8.57	103.49±7.62	102.61±7.40	101.46±7.28	99.96±7.59	<10 ⁻¹⁵
Females						
Sample	6669	12880	13031	5129	6986	
Age (years)	38.49±10.89	38.99±10.05	38.56±9.75	37.58±9.73	36.30±9.91	<10 ⁻¹⁵
Education (years)	16.00±2.37	16.07±2.31	16.09±2.29	16.02±2.28	15.93±2.36	0.004
Meat (servings/day)	0.32±0.33	0.28±0.30	0.25±0.29	0.22±0.28	0.19±0.27	<10 ⁻¹⁵
Fruit (pieces/day)	1.31±0.97	1.44±0.99	1.54±1.03	1.62±1.08	1.67±1.14	<10 ⁻¹⁵
Alcohol (g/day)	6.54±10.01	7.26±10.27	7.27±10.38	7.21±10.27	6.47±10.47	0.03
BMI (kg/m ²)	22.80±3.64	21.99±2.66	21.46±2.34	21.05±2.17	20.59±2.07	<10 ⁻¹⁵
Waist circumference (cm)	77.09±10.08	75.27±8.65	74.08±8.16	73.49±8.11	72.45±7.71	<10 ⁻¹⁵
Hip circumference (cm)	94.26±8.70	92.83±6.99	91.31±6.48	89.89±6.14	88.56±6.25	<10 ⁻¹⁵

Williams

	<2 km/day	2-4 km/day	4-6 km/day	6-8 km/d	8 km/d	Significance of trend (P)
Males						
Chest circum- ference (cm)	90.05±6.37	88.94±5.10	88.22±4.97	87.51±4.70	86.73±4.61	<10 ⁻¹⁵

82.2% of men and 73.6% of women provided waist circumference, 78.1% of men and 86.2% of women provided chest circumference, and 84.1% of women provided hip circumference data.

Table 2

Regression slopes for body mass index and circumferences vs. reported intakes of meat (kg/m² or cm per servings/d) and fruit (kg/m² or cm per pieces/d) adjusted for age and education, stratified by running distance.

	Dependent variable			
	BMI (kg/m ²)	Waist circum- ference (cm)	Chest circum- ference (cm)	Hip circum- ference (cm)
Meat (servings/d)				
Males				
<2 km/d	0.74±0.10 [§]	1.13±0.27 [§]	1.24±0.27 [§]	
2-4 km/d	0.64±0.05 [§]	0.70±0.17 [§]	0.83±0.17 [§]	
4-6 km/d	0.47±0.05 [§]	0.31±0.16 [*]	0.75±0.16 [§]	
6-8 km/d	0.33±0.07 [§]	-0.06±0.26	0.64±0.25 [‡]	
8 km/d	0.42±0.06 [§]	-0.53±0.21 [‡]	0.31±0.21	
Interaction	$P<10^{-8}$	$P<10^{-9}$	$P=0.0002$	
Females				
<2 km/d	1.26±0.13 [§]	2.64±0.44 [§]	1.75±0.25 [§]	2.67±0.35 [§]
2-4 km/d	0.88±0.08 [§]	1.85±0.29 [§]	1.01±0.16 [§]	1.90±0.22 [§]
4-6 km/d	0.69±0.07 [§]	1.87±0.29 [§]	1.04±0.16 [§]	1.87±0.21 [§]
6-8 km/d	0.58±0.11 [§]	2.29±0.48 [§]	1.23±0.25 [§]	1.22±0.33 [‡]
8 km/d	0.57±0.09 [§]	0.81±0.40 [*]	0.85±0.22 [§]	1.31±0.30 [§]
Interaction	$P<10^{-15}$	$P=0.0004$	$P=10^{-5}$	$P<10^{-6}$
Fruit (pieces/d)				
Males				
<2 km/d	-0.28±0.04 [§]	-0.33±0.11 [‡]	-0.20±0.11	
2-4 km/d	-0.15±0.02 [§]	-0.08±0.06	-0.12±0.06	
4-6 km/d	-0.15±0.02 [§]	0.10±0.06	-0.06±0.06	
6-8 km/d	-0.12±0.02 [§]	0.04±0.08	0.11±0.08	
8 km/d	-0.07±0.02 [§]	0.23±0.06 [§]	-0.02±0.06	
Interaction	$P<10^{-12}$	$P<10^{-7}$	$P=0.03$	
Females				
<2 km/d	-0.16±0.05 [‡]	-0.07±0.15	0.06±0.09	-0.09±0.12
2-4 km/d	-0.04±0.02	0.03±0.09	-0.01±0.05	0.02±0.07
4-6 km/d	0.04±0.02	0.29±0.08 [‡]	0.08±0.05	0.16±0.06 [‡]
6-8 km/d	-0.01±0.03	0.14±0.12	0.00±0.07	0.14±0.09
8 km/d	-0.01±0.02	0.21±0.09 [*]	0.02±0.05	-0.10±0.07
Interaction	$P<10^{-6}$	$P=0.001$	<i>NS</i>	<i>NS</i>

* Adjusted for age and education. Significance levels coded: $P<0.05$,

[†]P<0.01,

[‡]P<0.001,

[§]P<0.0001.

Table 3

Multivariate regression to determine the linear combinations of reported intakes of meat and fruit that best predicts body mass index and circumferences in runners who averaged <2 km/d.

	Slopes $\pm$ SE	
	Meat (servings/day)	Fruit (pieces/day)
Males		
BMI (kg/m ²)	0.73 $\pm$ 0.10 ^{\$}	-0.27 $\pm$ 0.04 ^{\$}
Waist circumference (cm)	1.11 $\pm$ 0.27 ^{\$}	-0.31 $\pm$ 0.12 [†]
Chest circumference (cm)	1.25 $\pm$ 0.27 ^{\$}	-0.17 $\pm$ 0.12
Females		
BMI (kg/m ²)	1.28 $\pm$ 0.13 ^{\$}	-0.13 $\pm$ 0.05 [†]
Waist circumference (cm)	2.76 $\pm$ 0.44 ^{\$}	0.00 $\pm$ 0.15
Chest circumference (cm)	1.77 $\pm$ 0.25 ^{\$}	0.12 $\pm$ 0.09
Hip circumference (cm)	2.64 $\pm$ 0.35 ^{\$}	0.00 $\pm$ 0.12

* Adjusted for age and education. Significance levels coded: P<0.05,

[†]P<0.01,

[‡]P<0.001,

^{\$}P<0.0001