## Title
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*Objective:* To determine if exercise reduces body weight and to examine the dose-response relationships between changes in exercise and changes in total and regional adiposity.
*Methods and Results:* Questionnaires on weekly running distance and adiposity from a large prospective study of 3,973 men and 1,444 women who quit running (detraining), 270 men and 146 women who started running (training) and 420 men and 153 women who remained sedentary during 7.4 years of follow-up. There were significant inverse relationships between change in the amount of vigorous exercise (km/wk run) and changes in weight and BMI in men (slope±SE:-0.039±0.005 kg and -0.012±0.002 $kg/m^2$ per km/wk, respectively) and older women (-0.060±0.018 kg and -0.022±0.007 $kg/m^2$ per km/wk) who quit running, and in initially sedentary men (-0.098±0.017 kg and -0.032±0.005 $kg/m^2$ per km/wk) and women (-0.062±0.023 kg and -0.021±0.008 kg/m2 per km/wk) who started running. Changes in waist circumference were also inversely related to changes in running distance in men who quit (-0.026±0.005 cm per km/wk) or started running (-0.078±0.017 cm per km/wk).
*Conclusions.* The initiation and cessation of vigorous exercise decrease and increase body weight and intra-abdominal fat, respectively, and these changes are proportional to the change in exercise dose.

Condensed abstract: Questionnaires at baseline and after 7.4 years of follow-up from 3,973 men and 1,444 women revealed significant inverse relationships between change in vigorous exercise (km/wk run) and changes in weight and BMI in men and older women who quit running, and in initially sedentary men and women who started running.
Keywords: Exercise, running, body mass index, regional adiposity, waist circumference.

Obesity is a pervasive condition. Sixty-five percent of U.S. adults were overweight in 2000 and 32% were obese {1}. Furthermore, the percentage of men and women with a body mass index (BMI)≥30 kg/$m^2$, the criteria for obese, is substantially greater than in 1976 to 1980 when it affected 14.5 of U.S. adults {1}. Obesity and increased body weight have important emotional, social and medical consequences. {2,3}. This trend has prompted a search for hygienic and other strategies to prevent and reverse weight gain. Exercise is one attractive preventive and therapeutic strategy not only for its effects on body weight, but because of beneficial effects on other cardiovascular risk factors including insulin resistance, lipoproteins, and blood pressure {4,5}. Nevertheless, most weight control experts maintain that exercise is primarily useful in maintaining weight loss achieved by caloric restriction, and not effective alone {6-11}.

Several systematic reviews have failed to establish a dose-response relationship between exercise training and weight loss {8,9}. In contrast, cross-sectional data have repeatedly demonstrated a significant dose-response relationship between higher levels of physical activity and lower body weight and body fat {12}. For example, we observed in over 100,000 runners that weekly running distance is inversely related to BMI (an index of total adiposity), body circumferences (indicators of regional adiposity), and bra cup size {13,14}. Although these cross-sectional analyses precisely describe the dose-response relationships between body fat and running distance in men and women who have exercised for years, they are unable to distinguish whether the leanness of exercisers is due to weight loss or due to lean men and women choosing to run longer distances, i.e., self selection bias {15}.

This report uses data from the National Runners' Health Study {13,14,16,17}, a large prospective cohort recruited between 1991 and 1995, to examine further the utility of exercise as a weight loss strategy and the dose response relationship between distance run and changes in body composition. Evidence for a dose-response relationship were obtained by comparing changes in weight in men and women who start or quit running to others who remain sedentary at both baseline and follow-up. The results provide strong evidence that changes in vigorous physical activity cause changes in weight that are proportional to the exercise dose.

## Methods

The current analyses are restricted to sedentary individuals who, on their own volition, began exercising vigorously, and vigorously active individuals who stop running due to choice or injury. Men and women who completed the questionnaire but reported being nonrunners at both surveys are also included.

The design and survey instruments for the National Runners' Health Survey have been described elsewhere {13,14,16,17}. In brief, a two-page questionnaire, distributed nationally at foot races and to subscribers of the nation's largest running magazine (Runners' World, Emmaus PA), solicited information on demographics, running history, weight history, diet, current and past cigarette use, prior history of heart attacks and cancer, and medications for blood pressure, thyroid, cholesterol or diabetes at baseline and 7.4 years later. Running distance was reported in miles per week, body circumference in inches, and body weight in pounds, and converted to kilometers, centimeters, and kilograms. No data were collected on energy intake. Runners were excluded if they smoked, followed strict vegetarian diets, or used thyroid medications at either survey because of their possible influence on adiposity. Follow-up questionnaires were obtained from seventy-eight percent of participants. The study protocol was approved by the University of California Berkeley Committee for the Protection of Human Subjects, and all subjects provided written informed consent.

Change in BMI was calculated as the change in weight in kilograms between the baseline and follow-up questionnaire divided by the square of the average height from the two questionnaires in meters. Self-reported waist and hip circumferences were elicited by the question "Please provide, to the best of your ability, your body circumference in inches" without further instruction. Bra-cup sizes were coded on a five-point scale from 1 (A cup), 2 (B cup), 3 (C cup), 4 (D cup), and 5 (E cup or larger). Self-reported height and weight from the questionnaire have been found previously to correlate strongly with their clinic measurements (unpublished correlation in 110 men were r=0.96 for both). Self-reported waist, hip, and chest circumferences are somewhat less precise as indicate their correlations with their clinic measurements (r=0.68,r=0.63, and r=0.77, respectively). The test-retest correlation for miles run per week on repeat questionnaires was 0.89.

*Statistical analyses:* Evidence for a dose-response relationship was obtained by comparing changes in weight in men and women who initiate (training subset) or cease running (detraining subset) to others who remain sedentary at both baseline and follow-up. The dose-response relationship between weight loss and increased exercise in those that start running was corroborated by a dose-response relationship between weight gain and decreased exercise in those that quit running.

Results are presented as mean±SE or slopes±SE except where noted. Cut points for running distance categories were made to ensure reasonable sample sizes within categories and were defined prior to analyses. Categorization of men and women by running distance does not account for energy expenditure by other vigorous activities, but running was the primary exercise modality for these subjects.

Standard multiple regression analyses were used to adjust changes in adiposity for duration of follow-up and age. Men and women who were inactive at both baseline and follow-up were included in the regression analyses of the training subset and detraining subset.

## Results

*Subject Groups:* Table 1 shows that there were 3,973 men and 1,444 women who ran at baseline but had quit running by follow-up (detraining subset) and 270 men and 146 women who were nonrunners at baseline and started running by follow-up (training subset). An additional 420 men and 153 women reported not running at both baseline and follow-up, who serve as a primary comparison group in much of the analyses to follow. Among the detraining subset, those having the largest decreases in running distance were younger than those running less, due almost entirely to the highest mileage men being two to three years younger, and had had longer follow-up times. Baseline running distance was inversely and significantly ($P<0.0001$) associated with all adiposity indices in both men and women. Among the training subset, men who ran longer distances at follow-up had narrower waists at baseline, but were not distinguished from other men in this subset by age, follow-up duration, or other indices of adiposity. Women of the training subset who ran further at follow-up were younger and leaner.

*The Effects of Exercise Cessation:* At baseline running distance was inversely and significantly ($P<0.0001$) associated with all adiposity indices in both men and women (Table 1). When these men quit running, they significantly increased their weight, BMI, and waist and chest circumference in proportion to the change in running distance (Table 2). These regression analyses are adjusted for mean age during the follow-up, and follow-up duration. Similarly, women ≥45 years that quit running increased their body weight, BMI, chest circumference and bra cup size also in proportion to the change in running distance. Interestingly, among the women, the increases in body weight, BMI, chest circumference, and bra cup size were over two standard errors larger in the older (< 45 years) than younger women, suggesting that exercise cessation has a significantly more deleterious effect on these parameters in older women. In addition to these exercise effects, the regression models show a general tendency for the men and women to gain weight over time (i.e., positive coefficients for follow-up duration) that diminished with age (i.e., the negative coefficient for age).

Figure 1 presents histograms of the mean increases in body weight, BMI and waist circumference by the decrease in running distance. Mean increases in body weight and BMI for men who reduced their running distances by 1-15 km/wk or more were significantly larger than the mean increases in men who were nonrunners at both baseline and follow-up. Each 16 km/wk reduction in running distance was associated with significant increases in body weight and BMI (one exception, the difference between 1-15 and 16-31 km/wk). Men who had reduced their weekly distance by 32 km/wk or more when they quit running had significantly greater increases in waist circumference than those who had smaller reduction in distance. Figure 2 shows that the mean increases in body weight, BMI and bra cup size in older women who had reduced their running distance by 40 km/wk or more when they quit were significantly greater than older women having smaller reductions in running.

*Training effects or exercise adoption.* Table 2 also presents the regression analyses for men and women who began running after baseline. The analyses also include those who remained sedentary for comparison. Older and younger women were analyzed together because of the small sample sizes and the absence of an indication that older women lost more weight.

The increase in running distance from being sedentary at baseline was proportional to the amount of weight loss in both men and women when adjusted for age and follow-up duration. Men's waist and chest circumferences also decreased significantly in relation to their increase in running distance. Figures 3 and 4 show that men and women who increased their running distance by 24 km/wk or greater gained significantly less weight than those who remained sedentary. Increases in body weight and BMI were also significantly less in runners who started running 1-23 km/wk when compared to those who remained sedentary (albeit P=0.06 for ΔBMI in men). Mean increases in waist circumferences were significantly less in men who started running than remaining sedentary. Initially sedentary women who began running appeared to decrease their bra cup size in proportion to their running distance (Figure 4), but this did not attain statistical significance.

## Discussion

These results in runners who became sedentary, nonrunners who became runners, and persistent nonrunners provide consistent evidence that exercise, in the mode of distance running, reduces body weight and adiposity. Furthermore, the magnitude of the change in weight and indices of adiposity are inversely related to change in running distance. The decrease in weight in men and women starting exercise was greater per km/wk run than the increase in weight with exercise cessation. The reasons for this are not clear, but may indicate that exercise training produces a low set point for body weight that is preserved to some extent even with exercise cessation. These results are important and supplement those obtained from interventional trials, because our large sample size permits a level of statistical power unattainable in most controlled clinical trials. Also, the fact that both exercise cessation and adoption increased and decreased body weight, respectively, strengthens the argument for exercise being causally related the change.

These results are consistent with our prior randomized controlled clinical trials demonstrating that sedentary men assigned to a one-year running program lost significantly more weight and body fat than men who remained sedentary {18,19}, and that running plus caloric restriction produced more weight loss exceeding that caloric restriction alone {20}. In those and the present results, change in running distance correlated directly with the change in body weight. Other randomized controlled trials also demonstrated significant weight loss in men using a variety of exercise training interventions including 16 weeks of training on cycle ergometers at 70% of maximum heart rate in older men {21}, and 12 weeks of walking or light jogging requiring an energy expenditure of 3500 kcal/wk {22} or 4900 kcal/wk {23}. In contrast, some studies including one requiring 90 min of vigorous exercise per week observed no weight reduction {24}. Both these randomized and other nonrandomized exercise training studies have been summarized {9} and suggest that exercise produces significant weight loss, but these reports include in total only about a thousand exercise trained subjects, a number far smaller than the sample size of the present report.

The current study also differs from previous studies by the long follow-up duration of 7.4 years or 385 weeks. Most exercise-training studies are less than 16 weeks duration, and few extend beyond a year {9}. Weight loss initially achieved by either diet or exercise is often not maintained over long-term follow-up {10}. The cause of this recidivism is not clear, but may relate to reversal of behavioral change {11}. Weight loss in short-term exercise training studies is directly related to energy expenditure and is approximately 85% of expected based on the estimated exercise energy deficit. Weight loss in studies lasting 20 to 60 weeks achieve only about 30% of the project loss and may not have a dose-response relationship to energy expenditure {9}. Nevertheless, given the large sample size in the present study, it is likely that exercise does indeed produce weight loss, in contrast to previous conclusions.

Waist circumference decreased in men who started running and increased in men who quit, and these changes were also highly significantly related to the change running distance. Waist circumference reflects abdominal obesity and is an easily obtainable estimate of intra-abdominal fat {25}. Intra abdominal fat is associated with multiple CAD risk factors including hypertension, insulin resistance, diabetes, and lipoprotein disorders as well as CAD itself and these relationships are independent of total body fat {28}. A recent review {9} found some {23, 27-29} but not all {30,31} studies suggest that exercise training reduces intra-abdominal fat. Neither this review nor clinical guidelines from the National Institutes of Health {8} could establish a dose-response relationship between physical activity and abdominal obesity. In contrast, the present results using a large sample size document a strong relationship between increasing exercise and reduced abdominal obesity and support a clear dose relationship.

In women, body weight increased with running cessation and decreased with the start of exercise training in a dose-dependent manner. Weight loss from exercise has also been demonstrated in various randomized controlled clinical trials by others {32-35}. We also found that chest and bra-cup size also increased in older women who stopped running in proportion to the decrease in running distance. These observations were not confirmed by a decrease in chest circumference and cup size in women initiating a running program possibly because of a small sample size and less statistical power. Our recent paper on the cross-sectional relationships between indices of adiposity and running distance in 41,582 female runners{13} showed that waist, hip and chest circumferences also declined significantly with running distance across all age groups, but the declines were 52-58% greater in older than younger women. Thus there may be a generally stronger effect of exercise on body weight in older women that would make their exercise-related changes in adiposity more easily detected then in younger women.

Currently, exercise is usually prescribed as an adjunct to dieting in creating and maintaining weight loss {6-9}. Persons who successfully maintain substantial weight loss usually engage in physical activity in addition to following low fat diets and monitoring food portions and body weight {36}. Meta-analyses suggests that adding exercise to dieting improves long term maintenance of weight loss {7} and at least one study suggests this may occur in a dose-dependent manner {37}, although others suggest the benefit is modest, and may not provide any additional benefit beyond increasing the total caloric deficit {11}. The present results suggest that vigorous exercise, such as running, can reduce body weight and body fat, independent of dietary change.

The main limitation of the present study is that running distance and anthropometric values are based on self-report. We have validated our methods against clinic measurements and repeat questionnaires (see Methods). Furthermore, vigorous intensity activity is generally reported more accurately than light and moderate activities such as walking {38}. Running is an attractive exercise to study by self-report because exercise energy expenditure can be estimated quite accurately by distance run alone {39}, and therefore may be more accurately assessed than activities that require both duration and intensity for their calculation. Despite the possible limitation of self-report, the present study is based on sample sizes unachievable with most clinical trials.

In conclusion, the present results using both exercise cessation and initiation suggest that exercise has direct effects on body weight and intra-abdominal fat. Such observations suggest that vigorous exercise may be underestimated for its ability to reduce body fatness independent of dietary interventions.

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---------- Bibliographies ----------

[1] Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999–2000. JAMA 2002; 288: 1723–1727.

[2] Seidell JC, Verschuren WM, van Leer EM, Kromhout D. Overweight, underweight, and mortality. A prospective study of 48 287 men and women. Arch Intern Med 1996; 156 (9): 958–963

[3] Shaper AG. Body weight: implications for the prevention of coronary heart disease, stroke, and diabetes mellitus in a cohort study of middle aged men. Br Med J 1997; 314 (7090): 1311–1317.

[4] Roberts CK, Barnard RJ. Effects of exercise and diet on chronic disease.J Appl Physiol. 2005;98:3-30.

[5] Williams PT. Physical fitness and activity as separate heart disease risk factors: a meta-analysis. Med Sci Sports Exerc. 2001;33:754-61.

[6] Saris WH, Blair SN, van Baak MA, Eaton SB, Davies PS, Di Pietro L, Fogelholm M, Rissanen A, Schoeller D, Swinburn B, Tremblay A, Westerterp KR, Wyatt H. How much physical activity is enough to prevent unhealthy weight gain? Outcome of the IASO 1st Stock Conference and consensus statement. Obes Rev. 2003;4:101-14.

[7] Avenell A, Brown TJ, McGee MA, Campbell MK, Grant AM, Broom J, Jung RT, Smith WC. What interventions should we add to weight reducing diets in adults with obesity? A systematic review of randomized controlled trials of adding drug therapy, exercise, behaviour therapy or combinations of these interventions. J Hum Nutr Diet. 2004;17:293-316.

[8] National Institutes of Health; National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. Obes Res 1998; 6 (Suppl 2): 51S–209S.

[9] Ross R, Janssen I. Is abdominal fat preferentially reduced in response to exercise-induced weight loss? Med Sci Sports Exerc1999; 31 (Suppl 11): S568–S572.

[10] Anderson JW, Kons EC, Frederich RC, Wood CL. Long-term weight loss maintenance: a meta-analysis of US studies. Am J Clin Nutr 2001; 74: 579–584.

[11] Curioni CC, Lourenco PM Long-term weight loss after diet and exercise:a systematic review. Inter J Obes advance online publication, 31 May 2005

[12] Di Pietro L, Dziura J, Blair SN. Estimated change in physical activity level (PAL) and prediction of 5-year weight change in men: the Aerobics Center Longitudinal Study. International Journal of Obesity. 2004. 28: 1541–1547.

[13] Williams PT, Satariano WA. Relationships of age and weekly running distance on body mass index and circumferences in 41,582 physically active women. Obes Res 2005 (in press)

[14] Williams PT. Pate RR. Age-related weight gain, and age-specific weight loss, in 60,617 physically active men studied cross-sectionally. Med Sci Sports Exer (in press)

[15] Voorrips LE, Meijers JHH, Sol P, Seidell JC, van Staveren WA. History of body weight and physical activity of elderly women differing in current physical activity. Int J Obes 1992; 16: 199-205.

[16] Williams PT, Wood PD, The effects of changing exercise levels on weight and age-related weight gain. Int J Obes Relat Metab Disord 2005 (In press)

[17] Williams PT. Evidence for the incompatibility of age-neutral overweight and age-neutral physical activity standards from runners. American Journal of Clinical Nutrition 1997; 65:1391-6

[18] Wood PD, Stefanick ML, Dreon DM, Frey-Hewitt B, Garay SC, Williams PT, Superko HR, Fortmann SP, Albers JJ, Vranizan KM, et al. Changes in plasma lipids and lipoproteins in overweight men during weight loss through dieting as compared with exercise. N Engl J Med. 1988;319:1173-9.

[19] Wood PD, Haskell WL, Blair SN, Williams PT, Krauss RM, Lindgren FT, Albers JJ, Ho PH, Farquhar JW. Increased exercise level and plasma lipoprotein concentrations: a one-year, randomized, controlled study in sedentary, middle-aged men. Metabolism. 1983;32:31-9.

[20] Wood PD, Stefanick ML, Williams PT, Haskell WL.The effects on plasma lipoproteins of a prudent weight-reducing diet, with or

without exercise, in overweight men and women. N Engl J Med. 1991;325:461-6.

[21] Posner JD, Gorman KM, Windsor-Landsberg L, Larsen J, Bleiman M, Shaw C, Rosenberg B, Knebl J. Low to moderate intensity endurance training in healthy older adults: physiological responses after four months. J Am Geriatr Soc. 1992;40:1-7.

[22] Sopko G, Leon AS, Jacobs DR Jr, Foster N, Moy J, Kuba K, Anderson JT, Casal D, McNally C, Frantz I. The effects of exercise and weight loss on plasma lipids in young obese men. Metabolism. 1985;34:227-36.

[23] Ross R, Dagnone D, Jones PJ, Smith H, Paddags A, Hudson R, Janssen I. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. A randomized, controlled trial. Ann Intern Med. 2000;133:92-103.

[24] Cox KL, Burke V, Morton AR, Beilin LJ, Puddey IB. Independent and additive effects of energy restriction and exercise on glucose and insulin concentrations in sedentary overweight men. 1: Am J Clin Nutr. 2004;80:308-16.

[25] Rankinen T, Kim SY, Perusse L, Despres JP, Bouchard C. The prediction of abdominal visceral fat level from body composition and anthropometry: ROC analysis. Int J Obes Relat Metab Disord. 1999;23:801-9.

[26] Carr MC, Brunzell JD. Abdominal obesity and dyslipidemia in the metabolic syndrome: importance of type 2 diabetes and familial combined hyperlipidemia in coronary artery disease risk. J Clin Endocrinol Metab. 2004;89:2601-7.

[27] Mourier A, Gautier JF, De Kerviler E, Bigard AX, Villette JM, Garnier JP, Duvallet A, Guezennec CY, Cathelineau G.

Mobilization of visceral adipose tissue related to the improvement in insulin sensitivity in response to physical training in NIDDM. Effects of branched-chain amino acid supplements. Diabetes Care 1997; 20: 385–391.

[28] Schwartz RS, Shuman WP, Larson V, Cain KC, Fellingham GW, Beard JC, Kahn SE, Stratton JR, Cerqueira MD, Abrass IB. The effect of intensive endurance exercise training on body fat distribution in young and older men. Metabolism 1991; 40: 545–551.

[29] Bouchard C, Tremblay A, Despres JP, Theriault G, Nadeau A, Lupien PJ, Moorjani S, Prudhomme D, Fournier G. The response to exercise with constant energy intake in identical twins. Obes Res 1994; 2: 400–410.

[30] DiPietro L, Seeman TE, Stachenfeld NS, Katz LD, Nadel ER. Moderate-intensity aerobic training improves glucose tolerance in aging independent of abdominal adiposity. J Am Geriatr Soc 1998; 46: 875–879.

[31] Despres JP, Pouliot MC, Moorjani S, Nadeau A, Tremblay A, Lupien PJ, Theriault G, Bouchard C. Loss of abdominal fat and metabolic response to exercise training in obese women. Am J Physiol 1991; 261: E159–E167.

[32] Hinkleman LL, Nieman DC. The effects of a walking program on body composition and serum lipids and lipoproteins in overweight women. J Sports Med Phys Fitness. 1993;33:49-58.

[33] Kohrt WM, Ehsani AA, Birge SJ Jr. Effects of exercise involving predominantly either joint-reaction or ground-reaction forces on bone mineral density in older women. J Bone Miner Res. 1997;12:1253-61.

[34] Binder EF, Birge SJ, Kohrt WM. Effects of endurance exercise and hormone replacement therapy on serum lipids in older women. J Am Geriatr Soc. 1996;44:331-2.

[35] Ready AE, Drinkwater DT, Ducas J, Fitzpatrick DW, Brereton DG, Oades SC. Walking program reduces elevated cholesterol in women postmenopause. Can J Cardiol. 1995;11:905-12.

[36] Wing RR, Hill JO. Successful weight loss maintenance. Annu Rev Nutr. 2001;21:323-41.

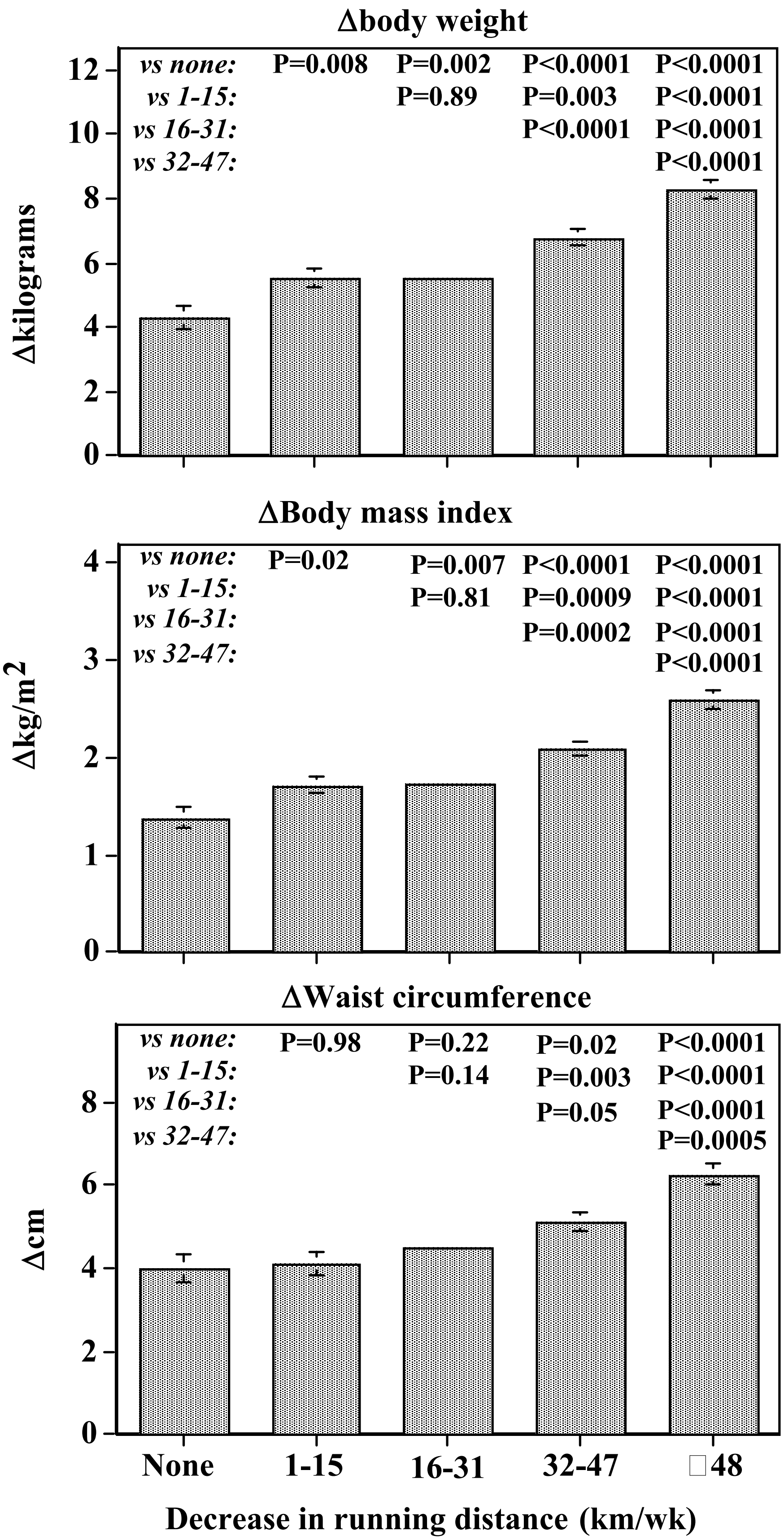
[37] Jakicic JM, Marcus BH, Gallagher KI, Napolitano M, Lang W. Effect of exercise duration and intensity on weight loss in overweight, sedentary women: a randomized trial. JAMA. 2003;290:1323-30.

[38] Jacobs DR Jr, Ainsworth BE, Hartman TJ, Leon AS. A simultaneous evaluation of 10 commonly used physical activity questionnaires. Med Sci Sports Exerc. 1993;25:81-91.

[39] ACSM’s guidelines for exercise testing and prescription. 5th edition Williams and Wilkins 1995, p278

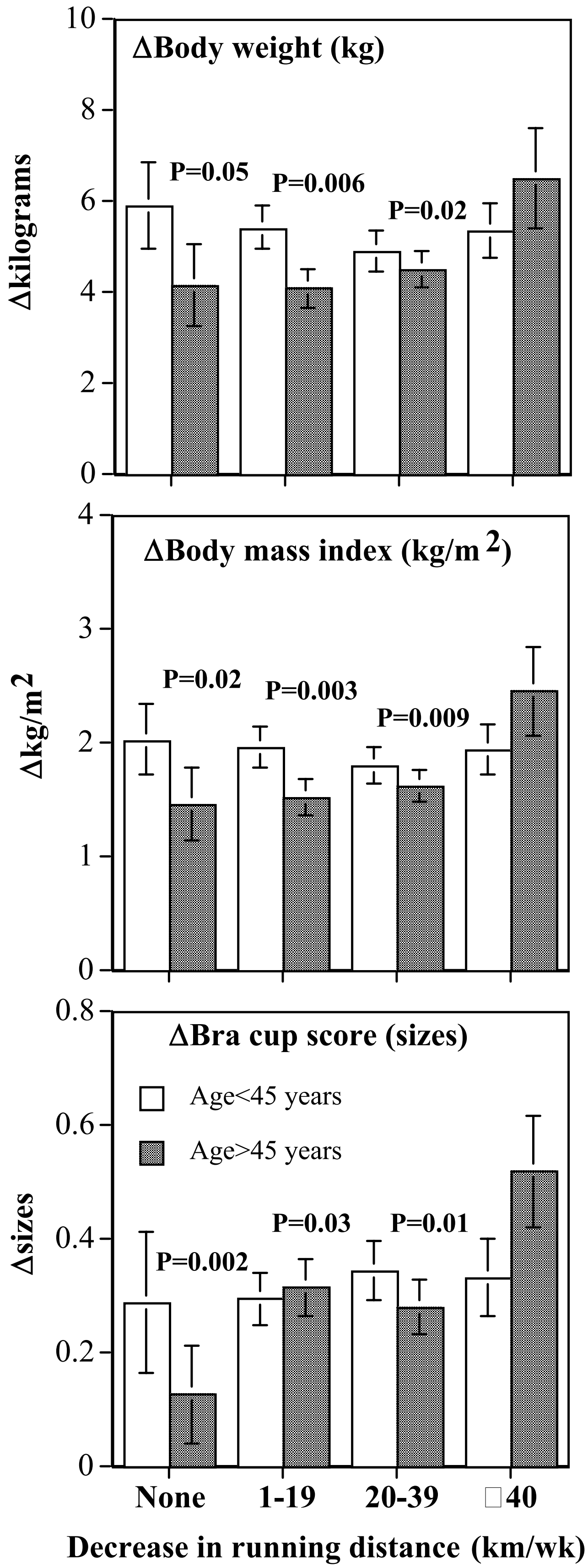
| Table 2. Regression analyses of changes in indicators of adiposity in 4,393 men and 1,597 women who detrained (quit running) or remained sedentary, and in 690 men and 299 women who trained (started running) or remained sedentary, during 7.4 years of follow-up. | | | | |
|---|---|---|---|---|
| | Regression coefficient±SE | | | |
| | Intercept | Age (years) | ΔFollow-up (years) | ΔRunning distance (km/wk) |
| **Detrained or remained sedentary** | | | | |
| ΔBody weight (kg) | | | | |
| Males | 7.435±0.785¶ | -0.171±0.010¶ | 0.652±0.066¶ | -0.039±0.005¶ |
| Females <45years | -3.014±2.062 | 0.097±0.045* | 0.658±0.151¶ | 0.008±0.014 |
| Females ≥45years | 12.088±3.041¶ | -0.224±0.050¶ | 0.243±0.173 | -0.060±0.018§ |
| ΔBMI (kg/m$^2$) | | | | |
| Males | 2.257±0.246¶ | -0.052±0.003¶ | 0.205±0.021¶ | -0.012±0.002¶ |
| Females <45years | -1.276±0.747 | 0.037±0.016* | 0.251±0.055¶ | 0.002±0.005 |
| Females ≥45years | 4.631±1.095¶ | -0.085±0.018¶ | 0.083±0.062 | -0.022±0.007§ |
| ΔWaist (cm) | | | | |
| Males | 3.834±0.750¶ | -0.073±0.01¶ | 0.431±0.063¶ | -0.026±0.005¶ |
| Females <45years | -0.510±2.442 | 0.012±0.054 | 0.616±0.175§ | -0.011±0.017 |
| Females ≥45years | 6.765±3.718 | -0.133±0.061* | 0.556±0.208† | -0.009±0.022 |
| ΔHip (cm) | | | | |
| Males | 3.312±1.561* | -0.075±0.019¶ | 0.363±0.136† | -0.011±0.011 |
| Females <45years | -3.648±2.410 | 0.032±0.053 | 0.807±0.171¶ | 0.005±0.016 |
| Females ≥45years | 6.393±3.392 | -0.096±0.056 | 0.127±0.187 | -0.028±0.019 |
| ΔChest (cm) | | | | |
| Males | 3.045±0.931¶ | -0.096±0.012¶ | 0.505±0.078¶ | -0.024±0.006¶ |
| Females <45years | -3.005±1.744 | 0.057±0.038 | 0.534±0.126¶ | -0.007±0.012 |
| Females ≥45years | 3.618±2.649 | -0.110±0.044† | 0.455±0.147† | -0.043±0.016† |
| ΔBra cup (size) | | | | |
| Females <45years | -0.149±0.227 | 0.005±0.005 | 0.038±0.017* | 0.000±0.002 |
| Females ≥45years | 0.086±0.330 | -0.007±0.005 | 0.057±0.019† | -0.006±0.002† |
| **Trained or remained sedentary** | | | | |
| ΔBody weight (kg) | | | | |
| Males | 5.88±1.948† | -0.136±0.023¶ | 0.571±0.186† | -0.098±0.017¶ |
| Females | 5.376±2.959 | -0.075±0.045 | 0.228±0.269 | -0.062±0.023† |
| ΔBMI (kg/m$^2$) | | | | |
| Males | 1.738±0.615† | -0.042±0.007¶ | 0.194±0.059§ | -0.032±0.005¶ |
| Females | 1.246±1.015 | -0.022±0.015 | 0.143±0.092 | -0.021±0.008† |
| ΔWaist (cm) | | | | |
| Males | 4.778±1.922* | -0.077±0.023§ | 0.3±0.183 | -0.078±0.017¶ |
| Females | 2.941±3.715 | -0.029±0.057 | 0.121±0.346 | 0.019±0.031 |
| ΔHip (cm) | | | | |
| Males | 0.235±3.416 | -0.034±0.039 | 0.426±0.344 | -0.011±0.03 |

| | | | | |
|---|---|---|---|---|
| Females | 7.61±4.141 | -0.061±0.065 | -0.408±0.385 | -0.028±0.034 |
| ΔChest (cm) | | | | |
| Males | 5.294±2.394* | -0.083±0.028† | 0.152±0.236 | -0.039±0.02* |
| Females | 1.418±2.735 | -0.004±0.041 | -0.011±0.252 | -0.023±0.022 |
| ΔBra cup (size) | | | | |
| Females | 0.462±0.405 | -0.003±0.006 | -0.016±0.038 | -0.004±0.003 |
| Significance levels from multiple regression analyses are coded * P<0.05; † P<0.01; § P<0.001; and ¶ P<0.0001 | | | | |



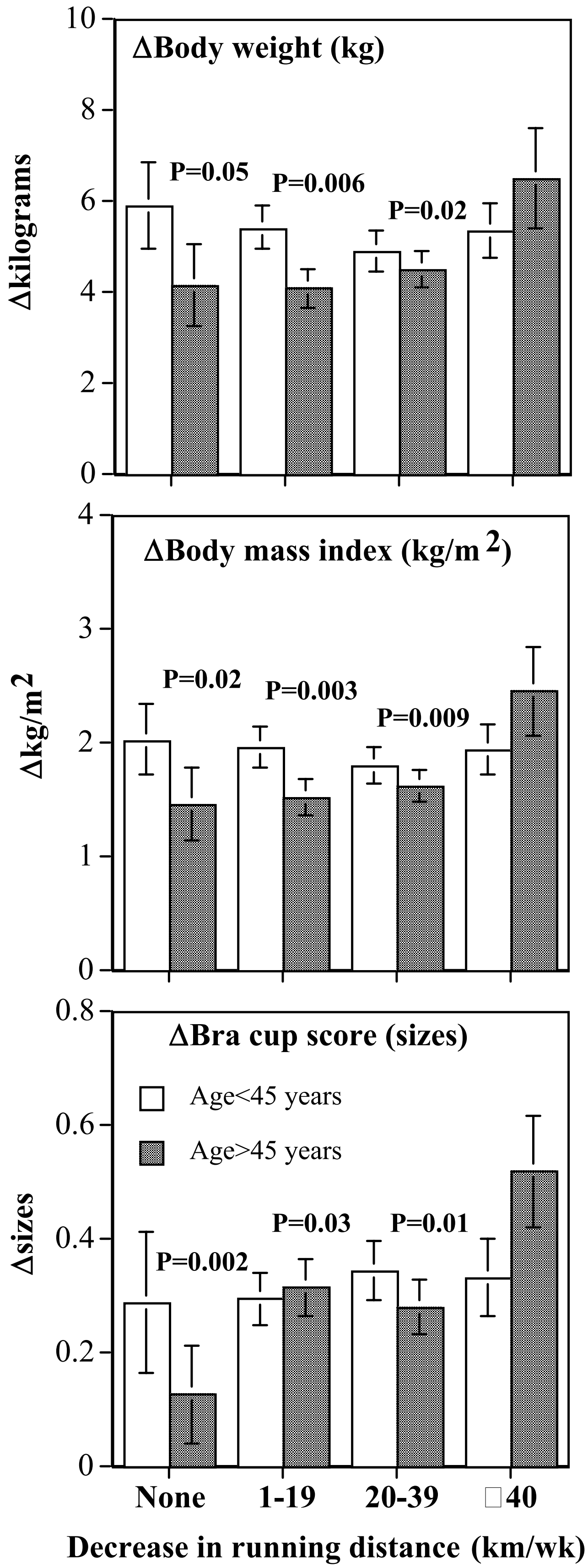
Δbody weight
vs none: P=0.008 P=0.002 P<0.0001 P<0.0001
vs 1-15: P=0.89 P=0.003 P<0.0001
vs 16-31: P<0.0001 P<0.0001
vs 32-47: P<0.0001
Δkilograms
0
2
4
6
8
10
12
ΔBody mass index
vs none: P=0.02 P=0.007 P<0.0001 P<0.0001
vs 1-15: P=0.81 P=0.0009 P<0.0001
vs 16-31: P=0.0002 P<0.0001
vs 32-47: P<0.0001
Δkg/m2
0
1
2
3
4
ΔWaist circumference
vs none: P=0.98 P=0.22 P=0.02 P<0.0001
vs 1-15: P=0.14 P=0.003 P<0.0001
vs 16-31: P=0.05 P<0.0001
vs 32-47: P=0.0005
Δcm
0
2
4
6
8
None
1-15
16-31
32-47
□48
Decrease in running distance (km/wk)

Figure 1. *Detraining or running cessation.* Mean changes in body weight, body mass index and waist circumference by decrease in running distance in 4,393 men who reported they quit running (N=3,793) or had remained sedentary (Decrease=None, N=420). Significance levels provided above the bars correspond to comparisons with categories of decreased running distance by two-sample t-test (e.g., P=0.008 is the probability that men who reduced their distance by 1-15 km/wk when they quit had the same mean increase in body weight as men who were sedentary at both baseline and follow-up, i.e. 0 km/wk change).



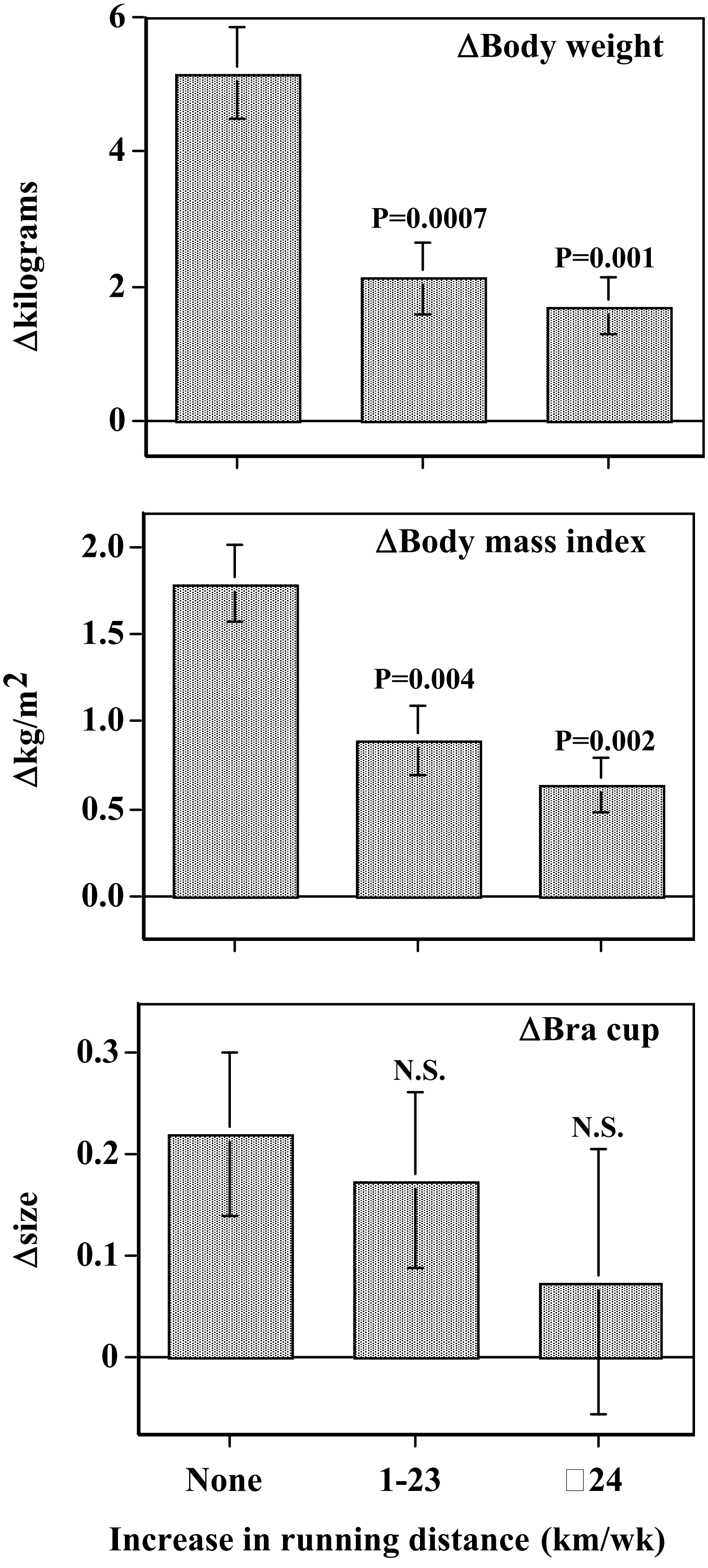
ΔBody weight (kg)
Δkilograms
P=0.05
P=0.006
P=0.02
ΔBody mass index (kg/m 2)
Δkg/m2
P=0.02
P=0.003
P=0.009
ΔBra cup score (sizes)
Age<45 years
Age>45 years
Δsizes
P=0.002
P=0.03
P=0.01
None
1-19
20-39
40
Decrease in running distance (km/wk)

Figure 2. *Detraining or running cessation.* Mean changes in body weight, body mass index and bra cup size by decrease in running distance in women who reported they quit running (N=1,444) or had remained sedentary (Decrease=None, N=153). Significance levels provided above the bars correspond to comparisons with the mean changed for women who ran over 40 km/wk at baseline by two-sample t-test (e.g., P=0.05 is the probability that women who remained sedentary had the same mean increase in body weight as women who decreased their distance by over 40 km/wk). Other comparisons did not achieve statistical significance.



ΔBody weight (kg)
Δkilograms
P=0.05
P=0.006
P=0.02
0
2
4
6
8
10
ΔBody mass index (kg/m2)
Δkg/m2
P=0.02
P=0.003
P=0.009
0
1
2
3
4
ΔBra cup score (sizes)
Age<45 years
Age>45 years
Δsizes
P=0.002
P=0.03
P=0.01
0
0.2
0.4
0.6
0.8
None
1-19
20-39
40
Decrease in running distance (km/wk)

Figure 3. *Training or running initiation*. Mean changes in body weight, body mass index and waist circumference by increase in running distance in initially sedentary men who remained sedentary (Increase=None, N=420) or began running (N=270). Significance levels provided above the bars correspond to comparisons with the mean changed for men who remained sedentary (*) or increased their distance by 1-23 km/wk (†).



ΔBody weight
Δkilograms
6
4
2
0
P=0.0007
P=0.001
ΔBody mass index
Δkg/m2
2.0
1.5
1.0
0.5
0.0
P=0.004
P=0.002
ΔBra cup
Δsize
0.3
0.2
0.1
0
N.S.
N.S.
None
1-23
□24
Increase in running distance (km/wk)

Figure 4. *Training or running initiation* Mean changes in body weight, body mass index and bra cup size by increase in running distance in initially sedentary women who remained sedentary (Increase=None, N=153) or began running (N=146). Significance levels provided above the bars correspond to comparisons with the mean changed for women who remained sedentary.