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Physical activity and the risk of becoming overweight or obese in middle aged and older women

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Abstract

Although public health campaigns stress leisure time physical activity (LTPA) as essential for obesity prevention, few epidemiological studies have focused on the association of specific types and intensities of LTPA and the clinical endpoints of overweight and obesity. Therefore, we prospectively assessed whether moderate and vigorous intensity as well as total LTPA were associated with the risk of becoming either overweight or obese using a prospective cohort design of 19,003 women enrolled in the Women’s Health Study. Women reported their participation in walking and LTPA at baseline. During a median follow-up of 11.6 years, 7865 women became overweight or obese. In multivariable-adjusted models that included demographic, lifestyle, and dietary factors, both vigorous intensity and total LTPA showed a modest inverse relationship with the development of overweight/obesity. The hazard ratios (HR) and 95% confidence interval (CI) for the highest categories of vigorous intensity LTPA (>2000 kilocalories/week) and total LTPA (>3000 kilocalories/week) compared to no LTPA were 0.79 (0.71–0.89) and 0.87 (0.78–0.96), respectively. In addition, a greater percentage of total LTPA spent performing vigorous intensity activities was associated with a lower risk of overweight/obesity (multivariable HR 0.93, 95% CI 0.87–0.98 for performing > 50% compared to < 50% of activity as vigorous). In conclusion, higher amounts of total LTPA should be encouraged to prevent obesity. Among those willing to participate in vigorous LTPA, and for whom such activities are not contraindicated, vigorous LPTA should be encouraged.

Introduction

The prevalence of obesity remains unacceptably high in the US and continues to rise worldwide.(1, 2) This has important public health implications given the known association between obesity and chronic diseases.(2) Although the initial response to the obesity epidemic often focused on treatment, there is growing recognition that prevention is key because biological mechanisms favor adaptation to a higher body mass once weight gain occurs.(3) In the modern world, environmental factors, including a decrease in leisure time physical activity (LTPA) and the consumption of a calorie-dense diet, have been major

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contributors to the mismatch between energy intake and expenditure, and the resulting high prevalence of obesity.

While an extensive epidemiological literature exists on the role of LTPA as a predictor of long-term weight change during adulthood,(4, 5) these studies have predominantly focused on total LTPA, but not specific intensities and types of LTPA. This additional information can provide concrete, clinically relevant information to patients who target their LTPA for obesity prevention. We therefore examined the association between the intensity and type of LTPA and the risk of becoming overweight or obese in a cohort of initially normal-weight, middle-aged and older US women during more than 10 years of follow-up.

Methods

Study Population

We analyzed data from the Women's Health Study (WHS), a completed, randomized clinical trial of low-dose aspirin and vitamin E in the primary prevention of cardiovascular disease (CVD) and cancer. A detailed description of WHS has been previously published.(6) Between November 1992 and July 1995, 39,876 US female health professionals aged ≥45 years without CVD or cancer (except non-melanoma skin cancer) were randomized into the study through 2004. Subjects for the present study were excluded if they were underweight, overweight, or obese, defined as a body mass index (BMI) <18.5 or ≥25 kg/m^2 (n=20,313), were diabetic (n=945), or were missing information on LTPA (n=213) at baseline. Women who reported CVD or cancer post-randomization with a pre-randomization diagnosis date (n=25) and women with missing information on BMI during follow-up (n=127) were also excluded. These exclusions resulted in a final sample size of 19,003 women.

Assessment of LTPA

On baseline questionnaires, participants were asked the average time spent per week on eight groups of recreational activities, including walking or hiking, jogging (slower than 10 minute miles), running (faster than 10 minute miles), bicycling (including use of stationary machines), aerobic exercise/aerobic dance/exercise machine use, lower intensity exercise (including yoga, stretching or toning), racquet sports (including tennis, squash, or racquetball), and lap swimming. Women also reported their usual pace of walking. Each group of activities was assigned a multiple of resting metabolic rate (MET) based on absolute intensity of the activity, which was then multiplied by the woman's body weight in kilograms and by the hours per week engaged in the activity to obtain the kilocalories per week expended in that activity.(7) We divided the activities into moderate intensity LTPA (3-<6 METS) and vigorous intensity LTPA (≥6 METS). Moderate intensity LTPA included walking, bicycling, and low-intensity exercise; vigorous intensity LTPA included running (≥10 minutes/mile), jogging (≤10 minutes/mile), aerobic dance or exercise machine use, racquet sports and lap swimming. We calculated the total LTPA, as well as moderate and vigorous intensity LTPA separately by summing the energy expenditure for corresponding activities.

The LTPA questions used in WHS were adapted from the College Alumni Health Study questionnaire, which has been validated using the double-labeled water method.(8) In contrast to the College Alumni questionnaire, the WHS questionnaire listed eight specific activities commonly carried out by women. The WHS questionnaire had a 2 year test-retest correlation coefficient of 0.59, and a correlation coefficient of 0.62 compared with activities diaries recorded every 4 weeks during the year prior to the administration of the questionnaire.(9)

Other Baseline Variables

On baseline mailed questionnaires, women also provided self-reports on age (in years), smoking (never, former, or current), parental history of myocardial infarction before the age of 60 years (yes/no), alcohol use (rarely/never, 1–3 drinks/month, 1–6 drinks/week, and ≥1 drink/day), history of hypertension (defined as either a physician diagnosis, a self-reported blood pressure ≥140/90, or use of antihypertensive medications), history of high cholesterol (defined as either a physician diagnosis, treatment or self-reported total cholesterol ≥240 mg/dL), diabetes (yes/no), menopausal status (premenopausal, postmenopausal or uncertain) and postmenopausal hormone use (never, former, current). BMI (in kg/m^2) was calculated from self reported height and weight. Participants also completed a 131-item validated semi-quantitative food frequency questionnaire (SFFQ) by reporting the frequency of consuming common portion sizes for each food item, on average, during the previous year. Nutrient intake was computed by multiplying the intake frequency of each unit of food by the nutrient content of the specified portion size according to food composition tables from the Harvard School of Public Health, Boston, MA.(10) Each nutrient reported was adjusted for total energy intake using the residual method.(11) All participants gave written informed consent, and the study protocol was approved by the institutional review board at Brigham and Women's Hospital, Boston, Massachusetts.

Outcome Ascertainment

Information on body weight was updated at the 24, 36, 60, 72, and 108-month follow-up questionnaires. In addition, 17 600 of 19 03 women (92.6%) with a normal BMI at baseline agreed to continue in an observational follow-up study and have BMI updated on three annual follow-up questionnaires. BMI was categorized into 3 groups according to the World Health Organization criteria: normal weight (18.5 to <25 kg/m^2), overweight (25 to <30 kg/m^2), and obese (≥30 kg/m^2).

Cases of women who become either overweight or obese (n=7865) were defined as women of normal weight at baseline who subsequently had a BMI ≥25 kg/m^2 at any follow-up time-point. The 'time-to-event' for each case that became overweight or obese was calculated as the estimated time when her BMI crossed the cutoff point by modeling a regression line from the last reported BMI of less than 25 to the first reported BMI of 25 or higher during follow-up. For women who remained normal weight, the time-of-censoring was calculated as the latest date when a normal BMI was reported. Incident cases of becoming obese were defined in a similar manner using a BMI of 30 as the cutoff point. Women who developed intermediate diabetes, the management of which typically involves weight control, were censored on the date of the diabetes diagnosis. In a similar population of female health professionals, self-reported weight was highly correlated with clinic-measured weight (Pearson r=0.97).(12)

Statistical Analysis

Moderate-intensity, vigorous-intensity and total LTPA were categorized separately. Categories were chosen to allow assessment of dose-dependent relationships. Baseline characteristics were compared across categories of total LTPA using χ^2 tests for proportions and ANOVA for means. For each category of LTPA, we computed the incidence rates of becoming overweight or obese. After checking the assumption of proportional hazards (all p >0.05) we used cox proportional hazards models to compute hazard ratios (HRs) with corresponding 95% confidence intervals (CIs). The initial model adjusted only for age (in years). The multivariable-adjusted model additionally controlled for smoking, alcohol use, hormone replacement therapy, menopausal status, randomization arm, total caloric intake, and dietary factors, including intake of saturated fat, low-fat dairy products, high-fat dairy products, red meat, poultry, whole grains, and fiber. The effect of baseline BMI (in kg/m^2)

was examined separately, as BMI is part of the defined outcome and may represent over-adjustment. Tests for linear trend were computed using median values within each category of LTPA as an ordinal variable. We also assessed potential confounding by adding hypertension and hypercholesterolemia into the model. We computed the ratio of vigorous/total LTPA to assess the risk of becoming overweight or obese in individuals performing ≥50% versus <50% of their LTPA as vigorous activity.

We also conducted several secondary analyses. Stratified analyses were conducted by baseline BMI (<22.5 kg/m^2 versus 22.5–25 kg/m^2). We restricted the analysis to non-smokers to reduce bias due to smoking. We also analyzed the association between individual activities, focusing on the most common LTPA, and the risk of becoming overweight or obese. Finally, we repeated the main analysis using updated LTPA assessments at 36, 72, and 96 months in a time-dependent Cox model. All analyses were completed using SAS version 9.2 (SAS Institute, Cary, NC). The significance level was set at 0.05. All authors had full access to the data and take responsibility for its integrity.

Results

Among the 19,003 women comprising the study population, the mean age was 54.5 ± 7.1 years. Table 1 compares the baseline characteristics by level of total LTPA. A significant association was found between increasing levels of total LTPA and age, dietary variables, smoking status, alcohol intake, hypertension, high cholesterol, and total daily caloric intake (all $p < 0.05$). Baseline BMI did not differ substantially with higher levels of either moderate or vigorous LTPA. During a median follow-up of 11.6 years, 7,865 new cases of either overweight or obesity developed.

For moderate LTPA, no association was found between increasing levels of LTPA and the risk of becoming overweight or obese in either age-adjusted or multivariable-adjusted models. There remained no association after addition of baseline BMI to the multivariable-adjusted model (Table 2).

For both vigorous and total LTPA, a significant graded decrease in the risk of becoming overweight or obese was observed with increasing levels of LTPA in the age-adjusted and multivariable-adjusted models. HRs (95% CI) for the highest categories of vigorous and total LTPA in the multivariable-adjusted model were 0.79, (0.71–0.89) (p, trend <0.0001) and 0.87 (0.78–0.96) (p, trend = 0.002), respectively. Additional adjustment for baseline BMI diminished the HRs for both vigorous and total LTPA to 0.95 and 0.92. The trend across categories remained significant for total (p, trend = 0.02), but not vigorous (p, trend = 0.3) LTPA (Table 2).

For all types of LTPA, additional adjustment for a history of hypertension or hypercholesterolemia did not significantly alter the HRs. Individuals who performed ≥50% of their total LTPA as vigorous-intensity activities had a modest lower risk of becoming overweight or obese after controlling for total LTPA. The HR (95% CI) for the multivariable-adjusted model was 0.93 (0.87–0.98).

In secondary analyses stratified by baseline BMI category (BMI <22.5 versus 22.5–25 kg/m^2), the risk of becoming overweight or obese was similar in women regardless of their baseline BMI category in both the age-adjusted and multivariable plus BMI adjusted models for all intensities of LTPA (all $p_{interaction} > 0.05$). The multivariable HRs (95% CI) for the highest amount of LTPA for moderate, vigorous and total LTPA were 0.86 (0.60–1.23), 0.82 (0.64–1.07), and 0.98 (0.78–1.23) for women with BMI <22.5 kg/m^2 and 0.96 (0.81–1.14), 1.00 (0.88–1.14) and 0.92 (0.81–1.03) for women with BMI of 22.5–25 kg/m^2. In sensitivity analyses that excluded LTPA due to walking at a pace <3 miles per hour (which requires <3

METS and is a light-intensity activity), the results were similar (data not shown). In analyses limited to non-smokers, the findings largely paralleled those from the main analyses for moderate and vigorous-intensity LTPA, but differed for total LTPA. Specifically, the inverse association between total LTPA and the risk of becoming overweight or obese was no longer present in the age and multivariable-adjusted models.

When we considered the risk of becoming obese alone as a separate outcome, the findings were largely similar to the main analysis for moderate and vigorous LTPA (Table 4). However, the significant inverse association seen with total LTPA in the main analysis was no longer present, perhaps due to a smaller number of incident cases of obesity in this subgroup analysis.

In separate analyses examining the association between specific LTPA activities and the risk of becoming overweight or obese, there was no association between higher levels of walking and the risk of becoming overweight or obese. For bicycling, a significant increase in risk was seen for the individual category of 500–1000 kilocalories per week in age-adjusted and multivariable–adjusted models, but this association was no longer present after additional adjustment for baseline BMI. An inverse association was found between higher levels of jogging and the risk of becoming overweight or obese in multivariable-adjusted models. This relation was no longer present after additional adjustment for BMI. For the category of aerobic dance and exercise machine use, a significant increase in the risk of overweight/obesity was found in the multivariable-adjusted model among those participants performing >1000 kilocalories weekly of activity, but this association was no longer present after adjustment for baseline BMI. In contrast, a significant inverse association was found between 500–1000 kilocalories of this type of activity and the risk of becoming overweight/obese even after adjustment for baseline BMI.

When we repeated our main analysis with updated assessments of LTPA at 36, 72 and 96 months, the findings were largely similar. In multivariable models, no association was found between higher levels of moderate LTPA and the risk of becoming overweight or obese whereas a significant graded decrease in the risk of becoming overweight or obese was observed with higher levels of vigorous and total LTPA. HRs (95% CI) for the highest categories of vigorous and total LTPA in the multivariable-adjusted model were 0.80 (0.71–0.90) (p, trend <0.0001) and 0.88 (0.79–0.97) (p, trend = 0.001), respectively. Additional adjustment for baseline BMI diminished the HRs for both vigorous and total LTPA to 0.95 and 0.92. The trend across categories remained significant for total (p, trend = 0.004) and vigorous (p, trend = 0.0002) LTPA. In time-dependent analysis examining individuals who performed ≥50% of their total LTPA as vigorous-intensity activities, the HR (95% CI) for the multivariable-adjusted model was 0.82 (0.77–0.88), and was attenuated, but remained significant after adjustment for baseline BMI 0.92 (0.86–0.99).

Discussion

This large, long-term, prospective cohort of middle-aged and older women provides insight into the relationship between both the quantity and intensity of LTPA and the risk of becoming overweight or obese. Specifically, we found a modest but significant inverse association between higher levels of both vigorous and total LTPA and the risk of becoming overweight or obese after multivariable adjustment. A similar association was not observed for moderate LTPA. In analysis of individual activities, jogging, a vigorous intensity activity, had an inverse association with the risk of becoming overweight or obese whereas moderate-intensity activities such as walking and bicycling did not. Overall, these findings suggest that higher total LTPA has an important but modest role in preventing the development of overweight and obesity. Expending a larger percentage of total LTPA devoted to vigorous activities, may have an incremental benefit, thus allowing individuals to target more vigorous-intensity LTPA if obesity prevention is their primary goal. The lack of an inverse association for moderate LTPA and the risk of developing obesity was somewhat surprising. This may reflect less precise reporting of moderate-intensity activities, the tendency of individuals to increase their level of moderate intensity LTPAs once they have begun to put on weight, or the fact that although moderate LTPA may still be associated with less weight gain over time, it may not prevent the development of the clinical cutpoints of overweight and obesity.

These findings add to the large body of literature on the association between LTPA and weight change, and uniquely examine the association between LTPA and the endpoint of becoming overweight or obese. The risk of becoming overweight or obese has been infrequently assessed in epidemiological studies.(13) These BMI "milestones" are clinically relevant as most studies examining the association between body weight and adverse health outcomes, including cardiovascular disease, diabetes and mortality, use overweight or obesity as the exposures of interest.

In addition, our analysis examined different intensities of LTPA. Most prior analyses of weight change have focused on total level of LTPA, and have differed in terms of the range of individuals' baseline BMI.(4, 14–17) These differences in study design may provide insight into the lack of association of moderate intensity LTPA and the development of overweight and obesity in our study. The largest previous study examining intensity of LTPA and weight change among women with normal BMI at baseline had findings similar to ours, specifically an association between high-intensity LTPA, but not moderate LTPA and weight gain.(16, 17) As in our study, this lack of association of moderate intensity LTPA and weight gain was counterintuitive. Differential reporting of moderate LTPA may contribute to these findings. Prior work with the Physical Activity index from the College Alumnus Questionnaire suggets that moderate intensity LTPA may be less accurately reported in questionnaires compared with vigorous or total LTPA.(18) Specifically, self-reported high intensity LTPA had higher correlations than moderate LTPA with direct reporting of similar intensities of LTPA. Another explanation for the lack of association of moderate LTPA and the risk of becoming overweight or obese is that moderate activity prevents some amount of weight gain, but not sufficient weight to prevent many individuals from crossing the threshold defines overweight or obesity. Findings from a large prospective study in Washington state that included women of all BMI's at baseline provide support for this theory.(17) In this analysis, higher amounts of low and moderate, in addition to high intensity, LTPA were associated with less weight gain. The largest benefit for low and moderate intensity LTPA was seen among women with BMI ≥25 kg/m^2. In conjunction with these prior studies, our findings support the additional insight provided by the use of the endpoints of overweight and obesity, which are used clinically and have been prospectively associated with the development of obesity-associated comorbidities.

Our findings using overweight and obesity as the endpoint compliment a recent study in the WHS that examined the amount of total LTPA and weight gain(19). Both analyses demonstrate the difficulty of maintaining a normal weight among middle-aged and older women and that relatively high levels of total LTPA are required to decrease weight gain. This contrasts with studies examining LTPA and the risk of other chronic health conditions including type 2 diabetes and coronary heart disease(20, 21) in which even relatively low levels of light- and moderate-intensity activities were beneficial. Taken together, these findings suggest that the health benefits attributed to LTPA for chronic disease prevention are not solely explained by a reduction in the risk of becoming overweight or obese. Our study expands on the previous WHS study by examining the intensity of LTPA. The inverse association we found between vigorous LTPA and the development of overweight/obesity may help explain the greater benefit seen with the highest levels of LTPA in the previous study. Presumably, women participating in vigorous intensity LTPA are more likely to achieve high amounts of total LTPA although this was not assessed.

Major strengths of our study include the large number of cases of overweight and obesity accrued over a long period of follow-up, allowing for sufficient statistical power to detect modest effects. Detailed information on both specific type and intensity of LTPA as well as important confounders strengthened the multivariable analysis. The repeated assessments of amount and intensity of LTPA allowed us to take into account changes in activity level during follow-up. Some potential limitations deserve comment. Both LTPA and weight were self-reported and therefore are subject to misclassification. However, the high validity and reliability of both of these variables has been demonstrated in similar populations(9, 12) although moderate-intensity LTPA may be less accurately reported than vigorous intensity LTPA. The relatively low average level of LTPA in our study population may have also limited our ability to detect a threshold effect for moderate LTPA. The ability of each individual to perform absolute MET level of activity may depend on fitness. However, we used absolute, as opposed to relative, METS, as it is more applicable to population-based, as opposed to individual targeted, LTPA recommendations. Finally, despite our detailed multivariable adjustment, we cannot exclude the possibility that self-reported LTPA may at least partially serve as a proxy for an overall healthy lifestyle.

In conclusion, our findings suggest a modest association between higher levels of both vigorous intensity and total LTPA and a lower risk of becoming overweight or obese. Performing a greater proportion of total LTPA as vigorous activity may also decrease the risk of becoming overweight or obese. While we did not observe similar findings with moderate-intensity LTPA, moderate intensity LTPA may still attenuate weight gain albeit perhaps not enough to prevent the development of overweight or obesity. Alternatively, the lack of association may be explained by less precise reporting of such activities. Moderate-intensity activities, such as brisk walking, should in no way be discouraged: a large body of evidence clearly supports a role of these activities in decreasing the risk of many chronic diseases.(22)

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References

1. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and Trends in Obesity Among US Adults, 1999–2008. JAMA. 2010; 303:235–241. [PubMed: 20071471]
2. Caterson ID, Hubbard V, Bray GA, et al. Prevention Conference VII: Obesity, a Worldwide Epidemic Related to Heart Disease and Stroke: Group III: Worldwide Comorbidities of Obesity. Circulation. 2004; 110:e476–e483. [PubMed: 15520332]
3. Leibel RL. Molecular physiology of weight regulation in mice and humans. Int J Obes. 2008; 32:S98–S108.
4. Wareham NJ, van Sluijs EMF, Ekelund U. Physical activity and obesity prevention: a review of the current evidence. Proceedings of the Nutrition Society. 2005; 64:229–247. [PubMed: 15960868]
5. Skidmore PML, Yarnell JWG. The obesity epidemic: prospects for prevention. QJM. 2004; 97:817–825. [PubMed: 15569814]

6. Ridker PM, Cook NR, Lee IM, et al. A Randomized Trial of Low-Dose Aspirin in the Primary Prevention of Cardiovascular Disease in Women. N Engl J Med. 2005; 352:1293–1304. [PubMed: 15753114]
7. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of Physical Activities: an update of activity codes and MET intensities. Medicine & Science in Sports & Exercise. 2000; 32(9):S498–S516. [PubMed: 10993420]
8. Lee, I-M.; Paffenbarger, RS, Jr. Design of present-day epidemiologic studies of physical activity and health. In: Lee, I-M., editor. Epidemiologic methods in physical activity studies. New York, NY: Oxford University Press; 2009. p. 100-123.
9. Wolf AM, Hunter DJ, Colditz GA, et al. Reproducibility and Validity of a Self-Administered Physical Activity Questionnaire. Int. J. Epidemiol. 1994; 23:991–999. [PubMed: 7860180]
10. Jones BR, Barrett-Connor E, Criqui MH, Holdbrook MJ. A community study of calorie and nutrient intake in drinkers and nondrinkers of alcohol. Am J Clin Nutr. 1982; 35:135–139. [PubMed: 7064869]
11. Rissanen A, Heliovaara M, Knekt P, Reunanen A, Aromaa A. Determinants of weight gain and overweight in adult Finns. Eur J Clin Nutr. 1991; 45:419–430. [PubMed: 1959514]
12. Rimm EB, Stampfer MJ, Colditz GA, Chute CG, Litin LB, Willett WC. Validity of Self-Reported Waist and Hip Circumferences in Men and Women. Epidemiology. 1990; 1:466–473. [PubMed: 2090285]
13. Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. Television Watching and Other Sedentary Behaviors in Relation to Risk of Obesity and Type 2 Diabetes Mellitus in Women. JAMA. 2003; 289:1785–1791. [PubMed: 12684356]
14. Fogelholm M, Kukkonen-Harjula K. Does physical activity prevent weight gain?; a systematic review. Obesity Reviews. 2000; 1:95–111. [PubMed: 12119991]
15. Kahn HS, Tatham LM, Rodriguez C, Calle EE, Thun MJ, Heath CW Jr. Stable behaviors associated with adults' 10-year change in body mass index and likelihood of gain at the waist. Am J Public Health. 1997; 87:747–754. [PubMed: 9184500]
16. Droyvold WB, Holmen J, Kruger O, Midthjell K. Leisure time physical activity and change in body mass index: an 11-year follow-up study of 9357 normal weight healthy women 20–49 years old. Journal of Women's Health (15409996). 2004; 13:55–62.
17. Littman AJ, Kristal AR, White E. Effects of physical activity intensity, frequency, and activity type on 10-y weight change in middle-aged men and women. Int J Obes Relat Metab Disord. 2005; 29:524–533.
18. Ainsworth BE, Leon AS, Richardson MT, Jacobs DR, Paffenbarger RS. Accuracy of the college alumnus physical activity questionnaire. Journal of Clinical Epidemiology. 1993; 46:1403–1411. [PubMed: 8263567]
19. Lee IM, Djousse L, Sesso HD, Wang L, Buring JE. Physical Activity and Weight Gain Prevention. JAMA. 303:1173–1179. [PubMed: 20332403]
20. Lee IM, Rexrode KM, Cook NR, Manson JE, Buring JE. Physical Activity and Coronary Heart Disease in Women: Is "No Pain, No Gain" Passe? JAMA. 2001; 285:1447–1454. [PubMed: 11255420]
21. Weinstein AR, Sesso HD, Lee IM, et al. The Joint Effects of Physical Activity and Body Mass Index on Coronary Heart Disease Risk in Women. Arch Intern Med. 2008; 168:884–890. [PubMed: 18443265]
22. Physical Activity Guidelines for Americans. Physical Activity Has Many Health Benefits. Committee US Department of Health and Human Services Physical Activity Guidelines; 2008. Chapter 2.

Table 1

Baseline characteristics of 19, 003 US women according to level of total leisure time physical activity (kilocalories/day)

	Level of Total Leisure Time Physical Activity					
	<500 kcal/week N=8088	**500–1000 kcal/week N=3963**	**1000–2000 kcal/week N=4354**	**2000–3000 kcal/week N=1446**	**>3000 kcal/week N=1152**	**p value**
Total daily leisure time physical activity, kcal/day	203.9 (149)	728.0 (146)	1419.3 (273)	2418.9 (282)	4456.9 (1673)	<0.0001
Age (mean, SD)	54.5 (7.2)	54.3 (7.0)	54.8 (7.2)	54.0 (6.8)	53.9 (6.8)	<0.0001
Baseline BMI, kg/m^2 (mean, SD)	22.5 (1.6)	22.4 (1.6)	22.4 (1.6)	22.4 (1.6)	22.4 (1.6)	0.07
High cholesterol (%)	26.4	25.4	24.5	20.5	20.9	<0.0001
Hypertension (%)	16.3	16.1	16.7	13.3	13.1	0.002
Postmenopausal (%)	53.7	53.6	54.7	52.0	51.7	0.62
Randomization Arm (%)	50.3	48.6	50.0	49.9	51.3	0.39
Smoking (%)						<0.0001
Never	50.0	53.3	51.5	48.0	49.7	
Former	31.0	35.8	39.0	43.8	43.7	
< 15 cigarettes / day	6.5	4.3	4.4	4.2	3.6	
> 15 cigarettes / day	12.5	6.6	5.0	4.0	3.0	
Alcohol (%)						<0.0001
Rarely / Never	42.2	36.4	34.2	31.9	33.3	
1–3 drinks / month	13.3	13.2	12.9	11.9	13.8	
1–6 drinks / week	31.8	37.7	39.2	41.2	38.8	
1+ drinks / day	12.7	12.7	13.7	15.0	14.1	
Hormone Therapy (%)						0.74
Never	46.5	45.4	46.4	43.5	47.8	
Former	9.5	8.7	8.9	9.1	7.5	
Current	44.2	45.9	44.7	46.4	44.7	
Dietary Factors						
Saturated fat, g/day	20.2 (4.9)	18.9 (4.6)	18.4 (4.6)	17.8 (4.9)	17.3 (4.8)	<0.0001
Fiber intake g/day	17.9 (5.7)	19.6 (5.8)	20.4 (6.1)	21.3 (6.5)	22.1 (7.1)	<0.0001

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Fruit and vegetables, servings/day	5.4 (3.3)	6.2 (3.0)	6.7 (4.0)	7.2 (3.7)	7.9 (4.5)	<0.0001
High-fat dairy products, g/day	0.79 (1.0)	0.72 (0.8)	0.71 (0.8)	0.72 (0.9)	0.71 (0.9)	<0.0001
Low-fat dairy products, g/day	1.04 (1.0)	1.24 (1.0)	1.30 (1.1)	1.34 (1.1)	1.47 (1.2)	<0.0001
Red meat intake, servings/day	0.75 (0.6)	0.64 (0.5)	0.60 (0.5)	0.54 (0.5)	0.52 (0.5)	<0.0001
Poultry intake, servings/day	0.40 (0.3)	0.42 (0.3)	0.43 (0.3)	0.45 (0.3)	0.48 (0.3)	<0.0001
Whole grain intake servings/day	1.23 (1.1)	1.46 (1.2)	1.56 (1.3)	1.63 (1.4)	1.66 (1.4)	<0.0001
Total daily caloric intake, kcal/day	1668.0 (521)	1706.3 (504)	1727.7 (503)	1739.9 (522)	1773.4 (555)	<0.0001

Table 2

Incidence rates and hazard ratios (95% confidence intervals) of overweight/obesity according to level of physical activity

Amount of Weekly Physical Activity	Cases	Crude Incidence Rate (cases/10,000 person years)	Age-adjusted	Multivariable Model§	Multivariable Model + BMI*
Moderate Physical Activity					
None	489	530.4	1.0	1.0	1.0
<1000 kilocalories	5108	457.3	0.88 (0.80–0.96)	0.89 (0.81–0.98)	0.92 (0.84–1.01)
1000–2000 kilocalories	1259	474.8	0.91 (0.82–1.01)	0.94 (0.84–1.05)	0.88 (0.79–0.99)
>2000 kilocalories	287	514.3	0.97 (0.84–1.13)	1.03 (0.88–1.19)	0.93 (0.80–1.09)
p for trend			0.2	0.07	0.3
Vigorous Physical Activity					
None	4216	498.9	1.0	1.0	1.0
<1000 kilocalories	2709	453.9	0.92 (0.87–0.96)	0.94 (0.90–0.99)	0.99 (0.94–1.04)
1000–2000 kilocalories	554	457.9	0.92 (0.84–1.00)	0.94 (0.86–1.02)	0.97 (0.88–1.06)
>2000 kilocalories	346	382.1	0.77 (0.69–0.86)	0.79 (0.71–0.89)	0.95 (0.85–1.07)
p for trend			<0.0001	<0.0001	0.3
Total Physical Activity					
<500 kilocalories	3492	507.4	1.0	1.0	1.0
500–1000 kilocalories	1578	441.3	0.88 (0.83–0.94)	0.92 (0.86–0.98)	0.91 (0.85–0.97)
1000–2000 kilocalories	1777	462.2	0.92 (0.87–0.98)	0.95 (0.90–1.01)	0.93 (0.88–0.99)
2000–3000 kilocalories	567	426.7	0.85 (0.78–0.93)	0.89 (0.81–0.98)	0.89 (0.81–0.97)
>3000 kilocalories	451	431.1	0.85 (0.77–0.94)	0.87 (0.78–0.96)	0.92 (0.83–1.02)
p for trend			<0.0001	0.002	0.02

§Multivariable Model adjusted for age, alcohol, smoking, hormone replacement therapy, postmenopausal status, randomization arm, total caloric intake and dietary factors (saturated fat, low-fat dairy, high-fat dairy, red meat, poultry, whole grain, and fiber intake)

*Baseline BMI

Table 3

Hazard ratios (95% confidence intervals) for incident obesity according to level of physical activity

Amount of Weekly Physical Activity	Cases	Crude Incidence Rate (cases/10,000 person years)	Age-adjusted	Multivariable Model[§]	Multivariable Model + BMI[*]
Moderate Physical Activity					
None	47	35.7	1.0	1.0	1.0
<1000 kilocalories	463	29.8	0.83 (0.61–1.12)	0.88 (0.64–1.20)	0.89 (0.65–1.22)
1000–2000 kilocalories	104	29.8	0.83 (0.59–1.17)	0.84 (0.58–1.21)	0.81 (0.56–1.17)
>2000 kilocalories	28	35.5	1.03 (0.64–1.64)	1.05 (0.64–1.71)	0.94 (0.58–1.54)
p for trend			0.67	0.86	0.63
Vigorous Physical Activity					
None	395	33.8	1.0	1.0	1.0
<1000 kilocalories	243	28.8	0.84 (0.72–0.99)	0.90 (0.77–1.07)	0.94 (0.79–1.10)
1000–2000 kilocalories	49	26.6	0.78 (0.58–1.05)	0.76 (0.55–1.04)	0.79 (0.58–1.08)
>2000 kilocalories	32	25.6	0.76 (0.53–1.09)	0.75 (0.51–1.10)	0.89 (0.61–1.31)
p for trend			0.05	0.05	0.25
Total Physical Activity					
<500 kilocalories	337	34.5	1.0	1.0	1.0
500–1000 kilocalories	131	26.6	0.77 (0.63–0.94)	0.80 (0.65–0.98)	0.78 (0.64–0.97)
1000–2000 kilocalories	154	29.4	0.85 (0.70–1.03)	0.85 (0.69–1.04)	0.83 (0.68–1.02)
2000–3000 kilocalories	57	31.6	0.93 (0.70–1.23)	0.93 (0.70–1.24)	0.95 (0.71–1.28)
>3000 kilocalories	40	27.5	0.80 (0.58–1.11)	0.74 (0.52–1.06)	0.81 (0.57–1.15)
p for trend			0.17	0.12	0.25

[§]Multivariable Model adjusted for age, alcohol, smoking, hormone replacement therapy, postmenopausal status, randomization arm, total caloric intake and dietary factors (saturated fat, low-fat dairy, high-fat dairy, red meat, poultry, whole grain, and fiber intake)

[*]Baseline BMI

Table 4

Incidence rates and hazard ratios (95% confidence intervals) of overweight/obesity according to level of specific physical activities

Amount of Weekly Physical Activity	Cases	Crude Incidence Rate (cases/10,000 person years)	Age-adjusted	Multivariable Model§	Multivariable Model§ + BMI*
Walking					
<500	4278	462.9	1.0	1.0	1.0
500–1000 kilocalories	1154	448.4	0.98 (0.92–1.04)	1.00 (0.93–1.07)	0.92 (0.86–0.99)
>1000 kilocalories	1005	481.2	1.04 (0.97–1.12)	1.05 (0.98–1.13)	0.95 (0.89–1.02)
p for trend			0.4	0.2	0.09
Bicycling					
None	5377	476.3	1.0	1.0	1.0
<500 kilocalories	2045	450.8	0.95 (0.91–1.00)	0.96 (0.91–1.02)	0.96 (0.91–1.01)
500–1000 kilocalories	314	562.6	1.15 (1.02–1.29)	1.15 (1.02–1.29)	0.94 (0.84–1.06)
>1000 kilocalories	129	443.2	0.94 (0.79–1.11)	0.96 (0.80–1.16)	1.07 (0.89–1.28)
p for trend			0.9	0.6	0.8
Jogging					
None	7065	485.9	1.0	1.0	1.0
<500 kilocalories	567	382.2	0.81 (0.74–0.88)	0.81 (0.74–0.89)	0.95 (0.87–1.04)
500–1000 kilocalories	116	313.2	0.67 (0.56–0.80)	0.67 (0.56–0.82)	0.96 (0.80–1.17)
>1000 kilocalories	113	355.0	0.74 (0.61–0.89)	0.77 (0.63–0.93)	0.88 (0.72–1.06)
p for trend			<0.0001	<0.0001	0.15
Aerobic dance/Exercise machines					
None	5168	471.2	1.0	1.0	1.0
<500 kilocalories	1540	483.3	1.02 (0.96–1.08)	1.04 (0.98–1.10)	1.05 (0.99–1.12)
500–1000 kilocalories	738	411.4	0.87 (0.81–0.94)	0.89 (0.82–0.96)	0.91 (0.84–0.98)
>1000 kilocalories	419	615.9	1.25 (1.14–1.39)	1.27 (1.15–1.41)	1.05 (0.95–1.17)
p for trend			0.07	0.02	0.8

§ adjusted for age, alcohol, smoking, hormone replacement therapy, postmenopausal status, randomization arm, total caloric intake and dietary factors (saturated fat, low-fat dairy, high-fat dairy, red meat, poultry, whole grain, and fiber intake)

* Baseline BMI