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# Weight Training and Risk of 10 Common Types of Cancer

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## Abstract

**Introduction:** Ample data support that leisure time aerobic moderate to vigorous physical activity (MVPA) is associated with lower risk of at least seven types of cancer. However, the link between muscle-strengthening activities and cancer etiology is not well-understood. Our objective was to determine the association of weight lifting with incidence of 10 common cancer types.

**Methods:** We used multivariable Cox regression to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for association of weight lifting with incidence of 10 cancer types in the NIH-AARP Diet and Health Study follow-up. Weight lifting was modeled continuously and categorically. Dose-response relationships were evaluated using cubic restricted spline models. We explored whether associations varied by subgroups defined by sex, age, and body mass index (BMI) using the Wald test for homogeneity. We examined joint categories of MVPA and weight lifting in relation to cancer risk for significant associations.

**Results:** After adjusting for all covariates including MVPA, we observed a statistically significant lower risk of colon cancer ($P_{trend}$=0.003) in individuals who weight lifted; the HR and 95% CI associated with low and high weight lifting as compared with no weight lifting were 0.75(CI:0.66,0.87) and 0.78(CI:0.61,0.98) respectively. This relationship differed between men and women ($HR_{men}$=0.91; CI:0.84, 0.98; $HR_{women}$=1.00; CI:0.93, 1.08) ($P_{interaction}$=0.008). A lower risk of kidney cancer among weight lifters was observed but became non-significant after adjusting for MVPA ($P_{trend}$=0.06); resulting in a HR of 0.94 (CI:0.78,1.12) for low weight lifting and 0.80 (CI:0.59,1.11) for high weight lifting.

**Conclusion:** Participants who engaged in weight lifting had a significantly lower risk of colon cancer and a trend towards a lower risk of kidney cancer than participants who did not weight lift.

### Keywords

Resistance; strengthening; epidemiology; physical activity; colon

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CONFLICT OF INTEREST
The authors declare no conflicts of interests. The results of the present study do not constitute endorsement by ACSM, and these results are presented clearly, honestly and without fabrication, falsification, or inappropriate data manipulation.

## INTRODUCTION

The physical activity guidelines of the U.S. Department of Health and Human Services (USDHHS) recommend that adults perform muscle-strengthening activities, in addition to aerobic activity, at least two days per week for health benefits (1). Muscle-strengthening activities, like weight lifting, pull-ups, and resistance training, provide health benefits including but not limited to; bone and muscle development, improved cardiovascular health, reduced blood pressure and low-density lipoprotein cholesterol (2). Strong evidence indicates that aerobic activity is associated with lower risk of at least seven different types of cancer (3, 4); however, the link between strength training and cancer risk is virtually unstudied. As compared with aerobic training, muscle-strengthening activities stimulate greater development of lean muscle mass, which helps maintain glucose homeostasis (5), and could in turn lead to lower cancer risk (6). The USDHHS acknowledges that more research is needed on the effect of individual muscle-strengthening activities on cancer etiology (3).

To our knowledge, only one study has examined muscle-strengthening activities in relation to cancer risk, and one other examined strength training in relation to cancer mortality. The first study was a small case-control study that found no significant association between resistance training and risk of colon and rectal cancers; however, their measurements included some activities that the authors acknowledge may be of low resistance, possibly diluting effects (7). The second study found that strength training was associated with sharply lower risk of cancer-specific mortality, even after adjusting for time spent in aerobic physical activity; however, no details on individual cancers were available (8).

In the present study, we examined weight training in relation to risk of the 10 most common cancer types in the National Institutes of Health (NIH)-American Association of Retired Persons (AARP) Diet and Health Study. Our objectives were to determine the cancers associated with weight lifting and whether associations varied by sex, age and body mass index (BMI). We hypothesized that weight lifting will be associated with lower risks of at least some types of cancer, and that these associations will be independent of participation in leisure-time physical activity of a moderate to vigorous intensity (MVPA).

## MATERIALS AND METHODS

The NIH-AARP Diet and Health Study was established in 1995–1996, when an initial questionnaire regarding demographics, medical history, and dietary behaviors was mailed to AARP members, aged 50–71, residing in six US states (California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania) and two metropolitan areas (Atlanta, Georgia and Detroit, Michigan); 567,169 questionnaires were returned, resulting in an 18% response rate. In 2004–2005, a follow-up questionnaire was mailed to the remaining cohort participants to update information on lifestyle and included a more comprehensive assessment of physical activity. The follow-up questionnaire was completed by 313,363 participants.

In the current study, we excluded participants who moved out of the cancer registry catchment area prior to follow-up (n = 16,093), proxy respondents (n = 27,423), those who self-reported cancers prior to completion of the follow-up questionnaire including; ovarian (n = 1,405), endometrial (n = 2,166), prostate (n = 16,530), colorectal (n = 4,789), lung (n = 1,703), breast (n = 8,930), pancreas (n = 177), Non-Hodgkin's Lymphoma (n = 1635), and melanoma (n = 6,899), and participants with a cancer diagnosis prior to the follow-up questionnaire (n = 9,848). Participants with missing weight lifting information were also excluded (n = 10,507), resulting in a final analytic cohort of 215,122 individuals (121,001 men and 94,121 women). The NIH-AARP Diet and Health Study was approved by the Special Studies Institutional Review Board of the National Cancer Institute. Participants were informed in a supplemental letter with the baseline questionnaire and consented by completion and return of the questionnaires.

## Exposure Assessment

Our primary exposure was self-reported time spent per week on "weight training or lifting (include free weights and machines)", with 10 possible response options (none, 5 min, 15 min, 30 min, 1 hour, 1 hour + 30 min, 2–3 hours, 4–6 hours, 7–10 hours, more than 10 hours) in the follow up questionnaire. This was recoded into "no weight lifting", "low weight lifting" (5 minutes - 1.5 hours) and "high weight lifting" (2–10+ hours). While the current guidelines state that no specific amount of time is recommended for weight lifting (1), we chose to separate those who perform moderate amounts of weight lifting from those who do the most weight lifting.

Additional factors including body mass index (BMI; computed using self-reported height and weight), smoking, MVPA, and postmenopausal hormone use were also re-assessed in the 2004–2005 questionnaire. MVPA was modeled continuously based on the calculations of MET-hours per week of self-reported time spent in the following activities: jogging, tennis, golf, swimming, cycling, walking for exercise, and other aerobic activity. MVPA was categorized as low (less than 7.5 MET-hours per week) and high (greater than or equal to 7.5 MET-hours per week) for joint analysis (3). Sex, race/ethnicity, highest achieved education, alcohol intake, oral birth control use, age of menarche, age of menopause, and parity were assessed in the initial cohort questionnaire in 1995–1996.

## Outcome ascertainment

First incident primary cancers were identified by probabilistic linkage to cancer registries of the eight baseline recruitment states and three additional states (Arizona, Texas, and Nevada) where participants most commonly moved during follow-up. Our analysis focuses on the 10 types of cancer for which at least 500 cases occurred during follow-up. Cancer selection method and the specific ICD-O-3 codes used were the same as in a prior large pooled analysis of 26 types of cancer (4). The ICD-O-3 codes for the included cancers are: colon (C180-C189, C260), kidney (C649 and C659), bladder (C670-C679), breast (C500-C509), lung (C340-C349), Non-Hodgkin's lymphoma (C024, C098, C099, C111, C142, C379, C422, C770-C779), pancreatic (C250-C259), prostate (C619), rectum (C199, C209), and malignant melanoma (C440-C449).

Vital status was ascertained by linkage to the Social Security Administration Death Master File and response to mailings. Follow-up time was calculated from the date of return of the follow-up questionnaire until date of first cancer, death, move out of the registry area, or December 31, 2011, whichever occurred first.

### Statistical analysis

Cox proportional hazards models were used to estimate the associations of weight lifting with cancer risk. We examined weight lifting as a continuous variable (time per week) and as a categorical variable (none, low, high). Associations were examined using three different models. The multivariate model included age, sex, smoking status, BMI, alcohol consumption, education, and race/ethnicity. We examined a second model additionally adjusted for participation in MVPA, not counting time in weight lifting. For breast cancer, these models were additionally adjusted for postmenopausal hormone therapy use, oral contraceptive use, age at menarche, age at menopause, and parity. We also examined an age- and sex-adjusted model for all cancers in a supplementary analysis. Covariates were selected based on previous studies assessing physical activity and cancer risk (4, 9). If covariates had incomplete data, nonresponse was modeled using indicator variables. As a sensitivity analysis, we included family history of cancer as a covariate for all cancers, as well as history of hypertension for kidney cancer. These covariates were left out of the final analysis as they had little overall effect on the results. None of the hazard ratios changed by more than 0.01 except for the lung cancer high weight lifting group (HR: 0.90 to 0.95) and the kidney cancer high weight lifting group (HR: 0.80 to 0.83). All statistically significant associations were further explored for dose-response associations using cubic restricted spline models (10). Linearity of the dose-response relationship was evaluated using a likelihood ratio test comparing fit of a spline model selected by a stepwise regression procedure versus fit of a model that included only a linear term for weight lifting. We explored whether associations varied by subgroups defined by age, sex, and BMI using the Wald test for homogeneity. Subgroups for age were selected based on a prior analysis (4) and BMI subgroups were selected to correspond to the World Health Organization’s definition of overweight (BMI$\geq$ 25 kg/m$^2$) vs. normal weight (BMI$<$ 25 kg/m$^2$) (11). Significant associations were further examined using joint categories of MVPA and weight lifting in relation to cancer risk. Analyses were done in SAS 9.4.

## RESULTS

During up to 10 years of follow-up we ascertained 23,346 cases of total cancer (colon=1715, kidney=851, bladder=1836, breast=3288, lung=3480, Non-Hodgkin’s Lymphoma=1187, pancreas=795, prostate=7213, rectum=527, melanoma=2454). Approximately 25% of participants reported some weight lifting (Table 1). Comparing those who engaged in “high” weight lifting vs. “none”, a higher proportion were men (65.1% vs. 34.9%), had normal BMIs (37.1% vs. 1.2% underweight, 34.9% overweight, and 12.7% obese), white (92.7% vs. 2.8% black, 2.1% Hispanic and 1.6% Asian, Pacific Islander, American Indian, Alaskan Native) and/or were aged 65 years or older (74.6% vs. 25.4%). A lower proportion were current smokers (2.8% vs. 52.2% former and 35.5% never).

In multi-variable models (without MVPA adjustment), weight lifting was associated with a statistically significant lower risk of colon cancer ($P_{trend}$=0.003) and kidney cancer

($P_{trend}$=0.03) (Table 2). For colon cancer, the hazard ratios (HR) and 95% confidence intervals (CIs) associated with low and high weight lifting as compared with no weight lifting were 0.74 (CI: 0.64, 0.84) and 0.71 (CI: 0.57, 0.89) respectively. For kidney cancer, the HRs for the same contrasts were 0.93 (CI: 0.78, 1.12) and 0.78 (CI: 0.61, 0.98). For all other cancers, no statistically significant associations were observed.

To determine whether these associations were independent of those already established for MVPA, we further assessed associations after adjusting for all non-weight lifting MVPA. In these models, the magnitude of the association with lower risk attenuated somewhat but was still generally evident. For colon cancer, the HR comparing high vs. no weight lifting increased from 0.71 to 0.78 (CI: 0.61, 0.98) and the overall trend remained statistically significant ($P_{trend}$=0.05). For kidney cancer, the HR comparing high versus no weight lifting increased from 0.78 to 0.80 (CI: 0.59, 1.11; $P_{trend}$=0.06). For the other eight types of cancers, there were no statistically significant trends after adjusting for MVPA. We also evaluated models adjusted only for age and sex and noted that the magnitudes of hazard ratios were generally similar except that weight lifting was associated with lower risk of lung cancer ($P_{trend}$=0.004) [see Table, Supplemental Digital Content 1, Hazard ratio (HR) according to level of weight lifting by cancer type in age and sex-adjusted models in the NIH AARP Diet and Health Study]. Adding smoking status to the model attenuated this association so that it became non-significant.

We further explored the dose-response nature of the weight lifting-colon cancer association using a cubic restricted spline and found that the association was curvilinear. As compared with no weight lifting, participants who performed at least a low amount of weight lifting (5 minutes to 3 hours per week) had a markedly lower risk of colon cancer (HRs as low as 0.64), but there was no further reduction in risk at higher levels of lifting (Figure 1a). We also used this method to assess the weight-lifting kidney cancer association and observed a gradual decrease in risk (HRs as low as 0.70) and widening confidence band (Figure 1b).

To assess whether the association of weight lifting with risk of colon cancer varied by sex, age, and BMI we performed subgroup analyses, in which we observed that this association varied by sex and age (Table 3). For men, the HR of colon cancer for any weight lifting, compared with none was 0.91 (95% CI: 0.84, 0.98), whereas for women the HR was 1.00 (95% CI: 0.93, 1.08) ($P_{interaction}$=0.008). For participants younger than 65 years, the HR of colon cancer for any amount of weight lifting, as compared with no weight lifting was 0.78 (95% CI: 0.63, 0.95). For participants 65 years and older, the HR was 0.96 (95% CI: 0.91, 1.02) ($P_{interaction}$=0.04). There was no statistically significant effect modification by BMI. For all other cancers, including kidney cancer, we observed no statistically significant interactions for any of the three factors examined (see Table, Supplemental Digital Content 2, Hazard ratios of all cancers in relation to weight lifting, comparing any vs no weight lifting according to sex, age and BMI in the NIH AARP Diet and Health Study).

To determine independent effects of both MVPA and weight lifting on colon cancer risk, we assessed the HRs associated with their joint categories (Table 4). We found that there was little reduction in risk of colon cancer with high levels of MVPA unless also accompanied by weight lifting. Each joint category of weight lifting and physical activity was associated with a lower HR in men (HRs: 0.61–0.87) than in women (HRs: 0.83–1.01).

## DISCUSSION

In a large national cohort study, participants who engaged in weight lifting had a statistically significantly lower risk of colon cancer and a nearly statistically significant lower risk of kidney cancer than participants who did not lift weights. To our knowledge, this study is the first prospective study to examine weight lifting or resistance activities in relation to risk of any cancer. Current guidelines recommend weight training and other resistance activities based on the evidence that they improve blood pressure, overall physical function, and reduce the risk of falls in older adults (3). Our findings that resistance training is associated with lower risk of colon cancer and possibly kidney cancer extend on these findings by suggesting its benefits may also apply to lowering cancer risk.

To our understanding, one case control study has examined weight/resistance training in relation to risk of incident cancer, specifically colon and rectal cancers (7), and one other examined cancer mortality (8). In the case control study, the authors reported adjusted odds ratios and 95% confidence intervals for colon and rectal cancers of 0.70 (CI: 0.45, 1.11) and 1.16 (0.71, 1.87) respectively. Our findings for colon cancer were similar in magnitude, but unlike the prior study, statistically significant. This most likely reflects the larger sample size (1715 versus 552 cases in prior study) and the higher prevalence of resistance training in the current study (approximately 25% versus fewer than 7% “definitely” performing resistance training during their lifetime in the prior study). The findings for rectal cancer differed from our own but had wide confidence intervals that preclude meaningful comparisons. In the prior study, participants were not asked specifically about resistance training, and were instead asked to list different activities they participated in over the course of their lifetime, resulting in some unclear exposure statuses. One large pooled analysis has demonstrated that strength training, as measured by time spent at a gym using machines or free weights, is associated with a 31% lower risk of cancer mortality (8). However, cancer mortality is a complex composite of both incidence of cancer and survivorship, and disentangling which of these components is affected most by physical activity requires additional data. Moreover, this study did not provide a granular assessment of risk according to type of cancer, potentially masking any heterogeneity of association by cancer type.

Our finding that weight lifting is associated with lower colon cancer risk parallel those for MVPA, which show strong evidence of a protective effect against colon cancer as determined by the Physical Activity Guidelines Advisory Committee (3). In a pooled analysis of 1.44 million people, Moore et al. found a significant association ($P_{trend}$=<0.001) between leisure time physical activity and decreased risk of colon cancer (HR: 0.84 CI: 0.77, 0.91) (4). Similarly, a meta-analysis of physical activity and cancer risk showed that those who engaged in the highest versus lowest categories of leisure time physical activity had a significantly reduced colon cancer risk (RR=0.81, 95% CI: 0.75, 0.88) (12).

When we examined joint categories of weight lifting and non-lifting MVPA in relation to risk of colon cancer, we found that the weight lifting association predominated, with markedly lower risk among weight lifters and little further reduction with the addition of other MVPA. We also observed differences among men and women, though these results require further exploration to determine their implications.

Of the 10 cancer types examined in this study, weight lifting was significantly associated with colon cancer only, which differs from aerobic physical activity's reported benefits for many different cancer types. This could reflect that, despite the large overall sample size of the NIH-AARP study, the case numbers for some types of cancer were still modest, at least relative to those of large-scale meta-analyses of aerobic physical activity. Additionally, strength training's narrow effects may be explained by differences in biological mechanisms between the two exercise modalities. Strength training promotes greater muscle gain and strength, and is especially important for maintaining glucose homeostasis (5), an important contributor to increased colon cancer risk (13). At the molecular level, strength training is a major activator of mTOR (6, 14) a well-known regulator of cell growth and metabolism often dysregulated during cancer progression (15). Chronic strength training is also associated with lowered blood pressure (16), lending biological plausibility to our observed associations for kidney cancer. Further research into these underlying mechanisms is needed before definitive conclusions can be reached about the biology underlying strength training and cancer associations.

The primary strength of our study is that it is the first prospective study to assess the relationship of weight lifting to risk of incident cancer. Our data provide a foundation for future studies to build upon. Another strength is our large sample size, which afforded us the statistical power needed to detect inverse associations of moderate magnitude. Our study also includes several limitations. Our data are self-reported and therefore susceptible to some degree of measurement error (17). We had no information on the amount of weight, number of repetitions, or the overall intensity of participants' workouts. We also lacked information on weight lifting over the life course, which may also be pertinent to cancer risk. Since our criteria included studying cancers with at least 500 cases, we were not able to study the associations for less common cancers among this population. We did not have access to hysterectomy data at this timepoint, which prevented us from exploring the association between weight lifting and endometrial cancer. It is estimated that by the age of 60, one-third of all women will have a hysterectomy (18). Since women who have had this procedure cannot become endometrial cancer cases, they need to be excluded from the population to obtain valid results. Obesity is associated with both colon and kidney cancers and could confound our results to some degree. However, we adjusted for BMI, which should mitigate this issue. Moreover, when we compared the results of models that did and did not adjust for BMI, we observed little difference, suggesting that excess BMI is unlikely to be a major confounder. Lastly, our population was predominately white and aged 60–70 years.

In conclusion, weight lifting was associated with lower risk of colon cancer, and possibly kidney cancer. These findings underscore the importance of resistance activity for health, including possibly for prevention of these cancers.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.


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a

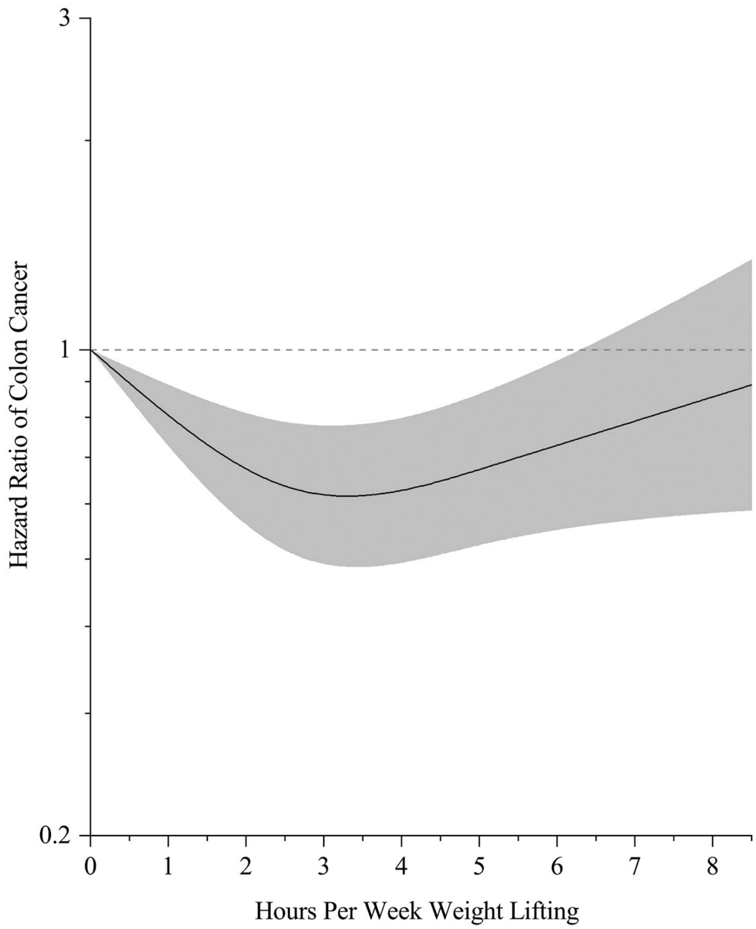


**Figure 1a.**

Cubic restricted spline of association of colon cancer with weight lifting[a]

[a] adjusted for age, sex, BMI, smoking status, race, education, alcohol intake, moderate and vigorous leisure time physical activity not including weight lifting (MVPA)

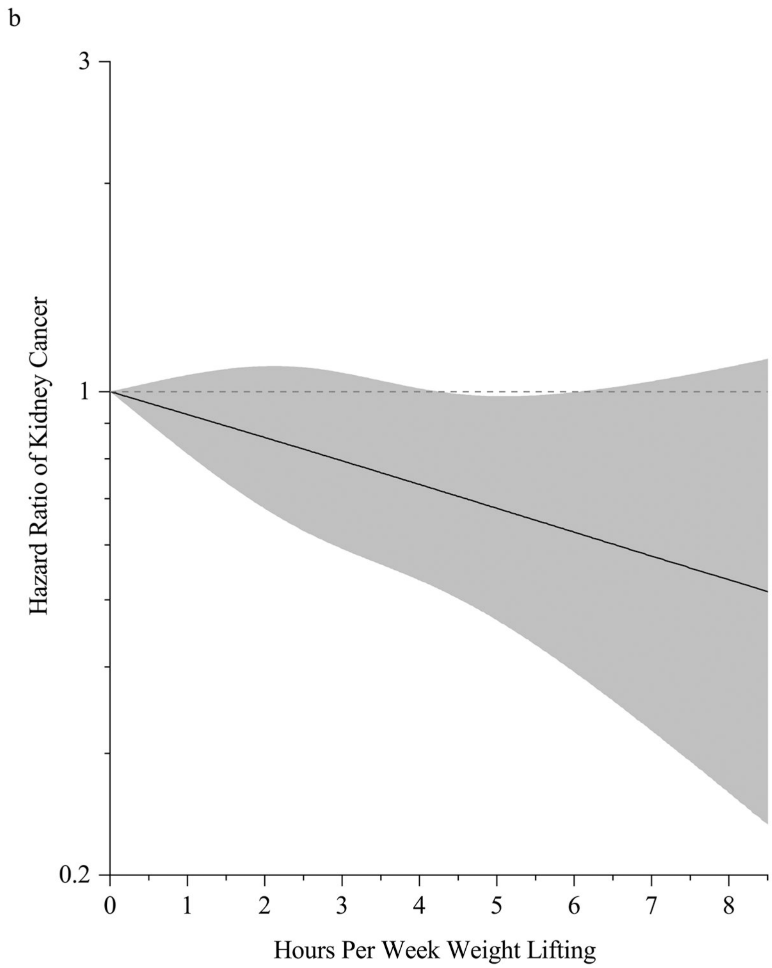


**Figure 1b.**

Cubic restricted spline of association of kidney cancer with weight lifting[a]

[a] adjusted for age, sex, BMI, smoking status, race, education, alcohol intake, moderate and vigorous leisure time physical activity not including weight lifting (MVPA)

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**Table 1.**

Participant characteristics in the NIH AARP Diet and Health Study according to level of weight lifting[a,b].

| | No Weight Lifting (n=158,898) % | Low Weight Lifting (n=42,153) % | High Weight Lifting (n=14,071) % |
|---|---|---|---|
| Age | | | |
| <65 | 19.7 | 23.2 | 25.4 |
| ≥65 | 80.3 | 76.8 | 74.6 |
| Sex | | | |
| Male | 54.5 | 59.9 | 65.1 |
| Female | 45.5 | 40.1 | 34.9 |
| Race | | | |
| White | 92.0 | 92.8 | 92.7 |
| Black | 3.7 | 2.9 | 2.8 |
| Hispanic | 1.7 | 1.7 | 2.1 |
| Other[c] | 1.5 | 1.8 | 1.6 |
| BMI (kg/m$^2$) | | | |
| Underweight (<18.5) | 1.3 | 1.3 | 1.2 |
| Normal (18.5–24.9) | 27.4 | 35.5 | 37.1 |
| Overweight (25–29.9) | 35.4 | 34.3 | 34.9 |
| Obese (30+) | 22.4 | 13.8 | 12.7 |
| Smoking | | | |
| Current | 6.7 | 3.0 | 2.8 |
| Former | 46.2 | 50.3 | 52.2 |
| Never | 37.8 | 37.5 | 35.5 |
| Education | | | |
| Less than High School | 4.5 | 1.8 | 2.0 |
| 12 years or Completed High School | 19.9 | 10.8 | 10.7 |
| Post-High School Training | 10.3 | 7.4 | 7.3 |
| Some College | 23.4 | 21.2 | 21.6 |
| College Graduate/Postgraduate | 39.5 | 56.9 | 56.5 |
| Age at Menarche | | | |
| 10 or younger | 6.7 | 6.3 | 6.7 |
| 11–12 | 42.1 | 42.4 | 41.8 |
| 13–14 | 41.4 | 42.5 | 41.7 |
| 15+ | 9.0 | 8.1 | 9.2 |
| Age at Menopause | | | |
| Less than 40 | 17.1 | 12.8 | 13.1 |
| 40–44 | 15.4 | 12.9 | 13.6 |
| 45–49 | 23.9 | 23.2 | 23.3 |
| 50–54 | 31.3 | 35.2 | 33.2 |
| 55+ | 6.8 | 7.6 | 7.7 |
| Still menstruating | 4.5 | 7.2 | 8.3 |

| | No Weight Lifting (n=158,898) % | Low Weight Lifting (n=42,153) % | High Weight Lifting (n=14,071) % |
|---|---|---|---|
| Oral Contraceptive Use | | | |
| Never | 59.6 | 51.7 | 50.4 |
| 1–4 years | 17.3 | 20.3 | 21.2 |
| 5–9 years | 12.2 | 14.9 | 14.5 |
| 10+ years | 9.7 | 11.8 | 13.1 |
| Age at first child, number of live births | | | |
| Nulliparous | 14.5 | 16.0 | 16.1 |
| <25 and 1 child | 4.8 | 4.1 | 5.1 |
| <25 and 2 children | 16.0 | 16.4 | 16.1 |
| <25 and 3+children | 39.0 | 33.5 | 33.3 |
| 25+ and 1 child | 5.3 | 5.8 | 5.9 |
| 25+ and 2 children | 9.6 | 12.3 | 12.4 |
| 25+ and 3+ children | 8.9 | 10.1 | 9.3 |
| Postmenopausal Hormone Use | | | |
| No | 36.5 | 25.4 | 24.6 |
| Yes, within past 10 years | 40.5 | 54.0 | 55.4 |
| Yes, more than 10 years ago | 16.0 | 13.8 | 13.5 |

[a] no=0 minutes, low=5 minutes-1.5 hours a week, high=2–10+ hours a week

[b] sex, race, education, age at menarche, age at menopause, oral contraceptive use, age at first child, and number of live births are taken from the baseline questionnaire 1995–1996; age, BMI, smoking, postmenopausal hormone use are taken from the follow-up questionnaire 2004–2005

[c] Asian, Pacific Islander, American Indian, Alaskan Native

**Table 2.**

Hazard ratios according to level of weight lifting[a] by cancer type in the NIH AARP Diet and Health Study[b]

| | Level of Weight Lifting | | | |
|---|---|---|---|---|
| | None | Low | High | $P_{trend}$ |
| Colon | | | | |
| No. of cases | 1379 | 255 | 81 | |
| Hazard ratio[c] | 1.00 | 0.74 | 0.71 | 0.003 |
| 95% confidence interval | | 0.64, 0.84 | 0.57, 0.89 | |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 0.75 | 0.78 | 0.05 |
| 95% confidence interval | | 0.66, 0.87 | 0.61, 0.98 | |
| Kidney | | | | |
| No. of cases | 649 | 157 | 45 | |
| Hazard ratio[c] | 1.00 | 0.93 | 0.78 | 0.03 |
| 95% confidence interval | | 0.78, 1.12 | 0.57, 1.05 | |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 0.94 | 0.80 | 0.06 |
| 95% confidence interval | | 0.78, 1.12 | 0.59, 1.11 | |
| Bladder | | | | |
| No. of cases | 1369 | 347 | 120 | |
| Hazard ratio[c] | 1.00 | 0.97 | 0.98 | 0.71 |
| 95% confidence interval | | 0.86, 1.09 | 0.81, 1.19 | |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 0.97 | 0.98 | 0.70 |
| 95% confidence interval | | 0.86, 1.10 | 0.81, 1.19 | |
| Breast[e] | | | | |
| No. of cases | 2508 | 614 | 166 | |
| Hazard ratio[c] | 1.00 | 1.00 | 0.92 | 0.09 |
| 95% confidence interval | | 0.91, 1.09 | 0.78, 1.08 | |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 1.02 | 0.99 | 0.51 |
| 95% confidence interval | | 0.93, 1.11 | 0.83, 1.17 | |
| Lung | | | | |
| No. of cases | 2761 | 543 | 176 | |
| Hazard ratio[c] | 1.00 | 0.88 | 0.86 | 0.38 |
| 95% confidence interval | | 0.80, 0.97 | 0.74, 1.01 | |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 0.91 | 0.90 | 0.30 |
| 95% confidence interval | | 0.82, 1.00 | 0.81, 1.12 | |
| Non-Hodgkin's Lymphoma | | | | |
| No. of cases | 894 | 217 | 76 | |
| Hazard ratio[c] | 1.00 | 0.90 | 0.95 | 0.97 |
| 95% confidence interval | | 0.78, 1.05 | 0.75, 1.20 | |

| | Level of Weight Lifting | | | |
|---|---|---|---|---|
| | None | Low | High | $P_{trend}$ |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 0.90 | 0.96 | 0.84 |
| 95% confidence interval | | 0.78, 1.05 | 0.75, 1.23 | |
| Pancreas | | | | |
| No. of cases | 578 | 170 | 47 | |
| Hazard ratio[c] | 1.00 | 1.14 | 0.95 | 0.64 |
| 95% confidence interval | | 0.95, 1.35 | 0.70, 1.28 | |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 1.15 | 0.98 | 0.46 |
| 95% confidence interval | | 0.96, 1.37 | 0.71, 1.34 | |
| Prostate | | | | |
| No. of cases | 5003 | 1595 | 615 | |
| Hazard ratio[c] | 1.00 | 1.04 | 1.10 | 0.06 |
| 95% confidence interval | | 0.99, 1.10 | 1.01, 1.19 | |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 1.03 | 1.05 | 0.65 |
| 95% confidence interval | | 0.97, 1.09 | 0.96, 1.15 | |
| Rectum | | | | |
| No. of cases | 427 | 69 | 31 | |
| Hazard ratio[c] | 1.00 | 0.65 | 0.87 | 0.54 |
| 95% confidence interval | | 0.50, 0.84 | 0.60, 1.26 | |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 0.68 | 1.01 | 0.59 |
| 95% confidence interval | | 0.52, 0.88 | 0.69, 1.48 | |
| Melanoma | | | | |
| No. of cases | 1658 | 599 | 197 | |
| Hazard ratio[c] | 1.00 | 1.23 | 1.18 | 0.19 |
| 95% confidence interval | | 1.12, 1.35 | 1.02, 1.37 | |
| Hazard ratio, MVPA adjusted[d] | 1.00 | 1.18 | 1.03 | 0.13 |
| 95% confidence interval | | 1.07, 1.30 | 0.88, 1.20 | |

[a]no=0 minutes, low=5 minutes-1.5 hours a week, high=2–10+ hours a week

[b]presented in the order of level of evidence linking physical activity to cancer risk as dictated by the Physical Activity Guidelines Advisory Committee(3)

[c]adjusted for age, sex, BMI, smoking status, race, education, alcohol intake

[d]adjusted for age, sex, BMI, smoking status, race, education, alcohol intake, moderate and vigorous leisure time physical activity not including weight lifting (MVPA)

[e]additionally adjusted for oral birth control use, age of menarche, age of menopause, post-menopausal hormone use, and parity

**Table 3.**

Hazard ratios of colon cancer in relation to weight lifting, comparing any vs. no weight lifting according to sex, age, and BMI[a]

| | HR | 95% Confidence Interval | $P_{interaction}$ |
|---|---|---|---|
| All Participants | 0.95 | 0.90, 1.00 | N/A |
| Sex | | | |
| Male | 0.91 | 0.84, 0.98 | 0.008 |
| Female | 1.00 | 0.93, 1.08 | |
| Age at start of follow-up | | | |
| <65 years | 0.78 | 0.63, 0.95 | 0.04 |
| ≥65 years | 0.96 | 0.91, 1.02 | |
| Body mass index | | | |
| <25 kg/m$^2$ | 0.98 | 0.90, 1.07 | 0.43 |
| ≥25 kg/m$^2$ | 0.94 | 0.87, 1.01 | |

[a]adjusted for age, sex, BMI, smoking status, race, education, alcohol intake, moderate and vigorous leisure time physical activity

**Table 4.**

Hazard ratios and 95% Confidence intervals for the joint effects analysis of colon cancer risk by any vs no weight lifting and low vs high leisure time moderate to vigorous physical activity[a,b]

| | **No Weight Lifting Low Activity** | **No Weight Lifting High Activity** | **Any Weight Lifting Low Activity** | **Any Weight Lifting High Activity** |
|---|---|---|---|---|
| All Participants | 1.00 (ref) | 0.93 (0.83, 1.03) | 0.77 (0.57, 1.03) | 0.69 (0.60, 0.80) |
| Men | 1.00 (ref) | 0.87 (0.76, 1.00) | 0.69 (0.47, 1.02) | 0.61 (0.50, 0.73) |
| Women | 1.00 (ref) | 1.01 (0.85, 1.19) | 0.88 (0.55, 1.41) | 0.83 (0.66, 1.04) |

[a]low activity = less than 7.5 MET-hours per week; high activity = greater than or equal to 7.5 MET-hours per week

[b]adjusted for age, sex, BMI, smoking status, race, education, alcohol intake