Light-Intensity Activity Attenuates Functional Decline in Older Cancer Survivors

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ABSTRACT

BLAIR, C. K., M. C. MOREY, R. A. DESMOND, H. J. COHEN, R. SLOANE, D. C. SNYDER, and W. DEMARK-WAHNEFRIED. Light-Intensity Activity Attenuates Functional Decline in Older Cancer Survivors. *Med. Sci. Sports Exerc.*, Vol. 46, No. 7, pp. 1375–1383, 2014. While moderate- to vigorous-intensity physical activities (MVPA) confer the greatest health benefits, evidence suggests that light-intensity activities are also beneficial, particularly for older adults and individuals with moderate to severe comorbidities. **Purpose**: To examine cross-sectional and longitudinal associations between light-intensity activity and physical function in older cancer survivors at increased risk for age- and treatment-related comorbidities, including accelerated functional decline. **Methods**: The analysis included data from 641 breast, prostate, and colorectal cancer survivors (54% female) age 65 yr and older who participated in a 1-yr home-based diet and exercise intervention designed to reduce the rate of physical function decline. ANCOVA was used to compare means of physical function across levels of PA intensity (low–light [LLPA]: 1.5–2.0 METs; high–light [HLPA]: 2.1–2.9 METs; MVPA: ≥3.0 METs). **Results**: In cross-sectional analyses, increasing tertiles of light-intensity activity were associated with higher scores for all three measures of physical function (all P values <0.005), after adjusting for age, sex, body mass index, comorbidity, symptoms, and MVPA. Associations were stronger for HLPA than for LLPA. Compared with survivors who had decreased MVPA or maintained stable MVPA and HLPA at the postintervention follow-up, those who had increased HLPA, but had decreased MVPA or maintained stable MVPA, reported higher physical function scores (LS means [95% confidence interval]: SF-36 Physical Function Subscale: −5.58 [−7.96 to −3.20] vs −2.54 [−5.83 to 0.75], P = 0.14; Basic Lower Extremity Function: −2.00 [−3.45 to −0.55] vs 0.28 [−1.72 to 2.28], P = 0.07; Advanced Lower Extremity Function: −2.58 [−4.00 to −1.15] vs 0.44 [−1.52 to 2.40], P = 0.01). **Conclusions**: Our findings suggest that increasing light-intensity activities, especially HLPA, may be a viable approach to reducing the rate of physical function decline in individuals who are unable or reluctant to initiate or maintain adequate levels of moderate-intensity activities. **Key Words:** PHYSICAL ACTIVITY, PHYSICAL FUNCTION, NEOPLASMS, SURVIVORSHIP

EPIDEMIOLOGY

By 2022, there will be 18 million cancer survivors living in the United States, and two-thirds will be older than 60 years (2). Given the late age of onset for many adult cancers, survivors are faced with both age- and treatment-related morbidity that increases their risk for physical functional impairment as well as additional comorbidities, including cardiovascular disease, diabetes, and osteoporosis, which further exacerbate the risk for functional limitations (7,18). Compared with individuals without a history of cancer, cancer survivors have a twofold increased risk of having one or more functional limitations; however, the risk is fivefold in the presence of comorbid conditions (18). Given the numerous adverse consequences of functional impairment, including mobility limitations, increased number of falls and hospital or nursing home admissions, diminished quality of life, premature death, and substantial financial costs (10,36), the importance of identifying and implementing strategies to delay or mitigate the trajectory of functional decline cannot be overstated.

Evidence from observational studies indicates that middle-age and older adults who engage in regular physical activity have a 30% reduced risk of developing moderate to severe functional limitations compared with inactive adults (30). Furthermore, among older adults with existing functional limitations, regular physical activity improves functional ability (30). The frequency, duration, intensity, and type of activity considered sufficient for better physical health, including physical function, vary by study. However, most of

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the research has focused on quantifying moderate-to-vigorous physical activity (MVPA; e.g., fast walking, aerobics, tennis), which is defined as ≥3 METs. A metabolic equivalent (MET) is a multiple of REE (1). With resting (sitting quietly) energy expenditure defined as 1 MET, a 4-MET activity expends four times the energy of rest, whereas a 6-MET activity expends six times the energy of rest. Current guidelines for general health, and often used in research on physical function, recommend ≥150 min of MVPA per week (30). Despite the known benefits of MVPA, including, lower rates of all-cause mortality, coronary heart disease, type 2 diabetes, hypertension, stroke, metabolic syndrome, and colon and breast cancer (30), a suboptimal percentage of adults, including cancer survivors, meet the recommended goal (20,26,38).

Recent research suggests that sedentary behavior, defined as prolonged sitting or reclining with minimal energy expenditure (≤1.5 METs) (1,8), has adverse effects on health, even among individuals who meet the recommended goals for MVPA (15,21,32). Sedentary/sitting time has been associated with increased risk of cardiovascular disease and cardiometabolic risk factors, all-cause and cardiovascular mortality, and decreased physical function (15,32,34). Even among physically active adults who meet or exceed the recommended activity levels (150 $min \cdot wk^{-1}$ of MVPA), prolonged periods of sitting are associated with an adverse cardiometabolic profile. The ubiquitous nature of sedentary behavior in our society (time spent sitting at work, while commuting, and during recreational time) and evidence of the associated independent deleterious effects on health have resulted in a growing interest among researchers in the potential of reducing sedentary activity by increasing light-intensity activity.

While MVPA confers the greatest health benefits, emerging evidence suggests that light–intensity physical activity (LPA; 1.5–3 METs), especially activities at the upper end of this category, are also beneficial. LPA includes activities resulting in less energy expenditure than MVPA, such as activities performed while seated or standing, with no or minimal upper body movement (low–light activities; e.g., playing board games, arts, and crafts) as well as activities involving a combination of standing , ambulatory movement, and upper body movement (high–light activities; e.g., walking at a leisurely pace [slower than 2 mph], light housework [e.g., sweeping or washing dishes], golfing with a cart, and gardening [e.g., watering plants]). Evidence from observational studies suggests that LPA, independent of MVPA, is associated with better physical health (5), including biomarkers of cardiometabolic health (6,14,16), and better psychosocial well-being (5,37). To date, only one study has evaluated the association between LPA and physical function among cancer survivors (19). In this cross-sectional study, LPA was no longer associated with physical function after adjustment for MVPA.

Light-intensity and nonexercise activities (i.e., activities that result in energy expenditure but are not planned or structured to improve physical fitness, e.g., leisurely walking, gardening) are more common in older adults and individuals with moderate to severe comorbidities (12,22) and thus may provide a more successful strategy for promoting physical activity in this population, especially for individuals who are unable or reluctant to initiate or maintain adequate levels of MVPA. The objective of this secondary analysis was to determine whether LPA is associated with better physical function in elderly cancer survivors, independent of MVPA. We evaluated the cross-sectional and longitudinal association between LPA and physical function in a home-based diet and exercise intervention among older, overweight, and physically inactive survivors of breast, prostate, and colorectal cancers.

EPIDEMIOLOGY

METHODS

Study design and participants. The methods and main outcomes for the RENEW trial have been published elsewhere (27,33). Briefly, this was a randomized controlled trial designed to evaluate whether a year-long diet and exercise intervention delivered via tailored print materials and telephone counseling was effective in improving physical functioning in older long-term cancer survivors. Cancer cases were primarily identified from the North Carolina Central Cancer Registry; a smaller proportion of cases (0.5%) were self-referred to the study. Subjects were eligible if they meet the following: 1) ≥65 yr of age; 2) ≥5 yr after diagnosis from breast, prostate, or colorectal cancer; 3) overweight or obese (25 ≤ body mass index [BMI; $kg \cdot m^{-2}$] ≤ 40), 4) <150 $min \cdot wk^{-1}$ of moderate-intensity strength training and endurance exercise; 5) had no contraindications to unsupervised exercise; and 6) English speaking and writing, without severe speaking or hearing impairments. Between 2005 and 2007, 641 eligible subjects were block randomized by sex, race, and cancer type to either the immediate or the delayed intervention arms. At 1-yr follow-up, the intervention was discontinued in the immediate intervention group and was delivered to the delayed (waitlisted) intervention group. The protocol was approved by the Duke University Institutional Review Board and the North Carolina Central Cancer Registry. Written informed consent was obtained from all study participants.

Intervention. The details of the intervention were previously described (27,33). Briefly, the RENEW intervention consisted of a personalized workbook with recommendations for a healthy, calorie-restricted diet and moderate-intensity exercise. The year-long intervention also included telephone counseling (15 sessions) and automated prompts (n = 8) as well as quarterly progress reports. Participants received a pedometer, resistance exercise bands, a poster with lower-extremity strength training exercises, the Portion Doctor table guide to food portioning, the T-Factor 2000 fat gram book, and food and activity record logs. The intervention goals included 1) strength training (15 min every other day), 2) endurance exercise (30 $min \cdot d^{-1}$), 3) seven (women)/nine (men) daily servings of fruits and vegetables, 4) saturated fat ≤10% of energy intake, and 5) reduced caloric intake to promote a slow rate of weight loss (≤0.5 $kg \cdot wk^{-1}$).

Outcomes and measures. Outcomes were assessed at baseline and at 1-yr and 2-yr follow-up via telephone interviews. Self-reported physical activity was collected using the Community Health Activities Model Program for Seniors (CHAMPS) questionnaire, which is a valid and reliable tool for assessing activities specific to older adults (13,35). Subjects reported the frequency and duration ($h{\cdot}wk^{-1}$) of 41 activities, ranging from sedentary to vigorous intensity, performed in a typical week during the past 4 wk. Duration was collected as continuous data rather than as categories of hours per week to detect modest improvements. Each CHAMPS activity was assigned a MET value according to Hekler et al. (17), which was based on Stewart et al. (35) and the 2000 Compendium of Physical Activities (1), and accounts for the probable reduced exertion among older adults (≥65 yr) compared with the general adult population.

Physical function was collected via self-report using the Physical Function Subscale (10 items) of the Short-Form 36 Health Status Survey (SF-36), which is valid and reliable for use in healthy and chronically ill adults. This subscale has excellent internal consistency ($0.89 \leq \alpha \leq 0.92$), published norms, and is sensitive to change (23,40). Given the role of lower-body strength in maintaining mobility and independence (10), the Basic and Advanced Lower Extremity Function subscales of the Late Life Function and Disability Index also were used to assess physical function (11). Participants reported the level of difficulty associated with performing basic (e.g., washing dishes while standing, getting into and out of a car, going up and down a flight of stairs) and advanced (e.g., going up and down three flights of stairs, walking 1 mile, running ½ mile or more) functional activities. Studies have shown significant moderate correlations between both Lower Extremity Function subscales ($0.63 \leq r \leq 0.73$) and objective measures of physical performance (400-m walk, Short Physical Performance Battery) (31), and very high reliability (intraclass correlation coefficients [ICC] = 0.91–0.98).

Additional data collected via telephone interviews included height and weight, six common medical conditions (arthritis or rheumatism, hypertension, heart problems, circulatory problems, osteoporosis, and cataracts), 22 symptoms (e.g., chest pain, shortness of breath, muscle weakness), and cancer treatment. Dietary intake was assessed via two 24-h recalls at each time point using the Nutrition Data System for Research software (Version 2006; Nutrition Coordinating Center, Minneapolis, MN). Diet quality was calculated using the Healthy Eating Index 2005 (HEI) (9) by summing 12 component scores (e.g., fruit, vegetables, whole grains, meats, and beans) according to previously described methods (25).

Statistical analyses. This secondary data analysis included data on 641 participants with study baseline data for the cross-sectional analysis. The longitudinal analysis included 514 participants with preintervention and postintervention data (Fig. 1; pre/post: study baseline/1-yr follow-up and 1-yr follow-up/2-yr follow-up for the immediate and delayed intervention arms, respectively). MET-hours per week were calculated for LPA (1.5–2.9 METs) and MVPA (≥3 METs). Given the range of energy expenditure for LPA along with preliminary evidence suggesting that activities at the higher end of this category are associated with better physical health and well-being (5), LPA was further defined as low–light (LLPA; 1.5–2.0 METs) and high–light (HLPA; 2.1–2.9 METs), similar to Hekler et al. (17) (see examples in Table 2). For each intensity variable, MET-hours per week were divided into tertiles.

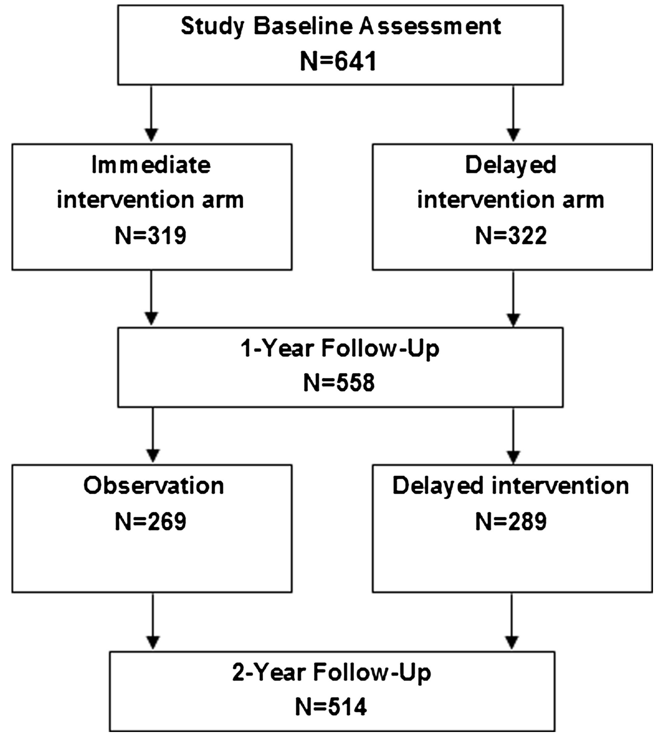

FIGURE 1—RENEW waitlist controlled trial design.

Demographic, lifestyle, and medical characteristics were compared across quartiles of total physical activity MET-hours per week and were evaluated using ANOVA for continuous variables and the χ^2 test for categorical variables. For the cross-sectional analysis, ANCOVA was used to compare least square means of physical function across tertiles of each PA intensity. Models were adjusted for age (continuous), sex, BMI (continuous), number of comorbidities (continuous), number of symptoms (0–2, 3–5, 6+), and the other intensity PA variables. Additional variables, e.g., race, education, income, time since diagnosis, cancer treatment, fruit and vegetable servings per week, and HEI, were evaluated but not included in the final models because they did not substantially change the parameter estimates. On the basis of the results of our cross-sectional analysis, suggesting greater benefits for higher compared with lower light-intensity activities, the longitudinal analysis focused on HLPA and MVPA. Preintervention and postintervention change in PA was dichotomized as decreased or remained stable (±3 $MET{\cdot}h{\cdot}wk^{-1} \approx$ sedentary) as the referent group versus increased in MET-hours per week for HLPA and MVPA. A composite variable of mutually exclusive groups was created combining the change status of both HLPA and MVPA to include increased HLPA only, increased MVPA only, or increased HLPA and MVPA. Because the results of the preintervention and postintervention change on physical function were of similar magnitude for the immediate and delayed intervention groups, data were combined for the longitudinal analyses. To maintain type 1 error integrity, the significance level for the test for trend was set at 0.015 (0.05 divided by three outcomes). Pairwise comparisons were only performed if the trend test was significant. The significance level for pairwise comparisons was set at the traditional level of 0.05.

Stratified analyses were carried out to evaluate differences in the effect of LPA and MVPA on each of the three physical function outcomes by sex and age at baseline (65–72 vs 73–87 yr). Significance of an interaction was determined by an F test of the interaction term in the ANCOVA model. A small proportion of individuals who reported ≥2.5 h·wk^{-1} of MVPA at baseline reported fewer hours per week at the postintervention follow-up, yet they were still meeting the MVPA guidelines. A sensitivity analysis was conducted, whereby these individuals were recoded as increased/meeting MVPA guidelines, with or without an increase in HLPA. Analyses were conducted using SAS 9.3 statistical software (SAS Institute, Inc.).

RESULTS

The study participants were 73.1 ± 5.1 yr old (range = 65–87 yr), 8.6 ± 2.7 yr since cancer diagnosis (range = 5–26 yr), 54% female, and primarily non-Hispanic white (88.8%). They reported 2.0 ± 1.2 comorbidities and 4.4 ± 3.3 symptoms associated with a variety of health conditions, such as pain, shortness of breath, dizziness, etc. The majority of time spent in weekly physical activity was spent in LLPA (42%–49%), followed by HLPA (31%–39%). Individuals with the greatest amount of total PA (MET·h·wk^{-1}) at baseline were more likely to be younger, college educated, to report higher income and fewer comorbidities, and to have been diagnosed more recently (Table 1). Participants who dropped out before completing the postintervention assessment were more likely to report an income of less than \$50,000 per year ($P = 0.008$) and had a lower baseline score on the Advanced Lower Extremity Function (LEF) scale (49.9 ± 14.1 vs 53.6 ± 14.4, $P = 0.01$).

The top 4 physical activities for each intensity level for which the cancer survivors reported spending time are presented in Table 2. Among the LLPA, the greatest amount

TABLE 1. Selected characteristics of study participants by physical activity at baseline (n = 641).

	Quartiles of Total MET·h·wk^{-1} of Physical Activity				
	1	2	3	4	*P**
Range	**0–33.8**	**33.9–53.5**	**53.7–77.1**	**77. 5–238.7**	
Sex, *n* (%)					
Female	75 (21%)	86 (25%)	98 (28%)	90 (26%)	<0.05
Male	85 (29%)	74 (25%)	63 (22%)	70 (24%)	
Race/ethnicity, *n* (%)					
Other	24 (33%)	20 (28%)	8 (11%)	20 (28%)	0.18
Non-Hispanic white	136 (24%)	140 (25%)	153 (27%)	140 (25%)	
Education, *n* (%)					
No college	83 (34%)	56 (23%)	62 (25%)	45 (18%)	<0.0001
Any college	77 (19%)	104 (26%)	99 (25%)	115 (29%)	
Income, *n* (%)					
<\$50,000	123 (29%)	105 (24%)	102 (24%)	101 (23%)	0.008
≥\$50,000	37 (18%)	54 (26%)	59 (28%)	59 (28%)	
Treatment, *n* (%)					
No chemo	121 (26%)	121 (26%)	112 (24%)	120 (25%)	0.61
Chemo	39 (23%)	39 (23%)	49 (29%)	40 (24%)	
No radiation	92 (26%)	79 (23%)	90 (26%)	87 (25%)	0.87
Radiation	68 (23%)	81 (28%)	71 (24%)	73 (25%)	
No hormone therapy	90 (24%)	91 (24%)	98 (26%)	93 (25%)	0.58
Hormone therapy	70 (26%)	69 (26%)	63 (23%)	67 (25%)	
No surgery	20 (28%)	21 (29%)	13 (18%)	18 (25%)	0.43
Surgery	140 (25%)	139 (24%)	148 (26%)	142 (25%)	
Physical activity (MET·h·wk^{-1}), mean ± SD					
Low–light	10.1 ± 6.4	20.8 ± 9.9	31.1 ± 14.2	53.1 ± 32.1	
High–light	7.9 ± 6.1	17.0 ± 10.0	24.6 ± 13.3	35.9 ± 23.0	
Moderate/vigorous	3.2 ± 4.7)	5.5 ± 6.6)	8.5 ± 9.4)	18.0 ± 26.8)	
Total	21.2 ± 8.9	43.4 ± 6.0	64.1 ± 6.9	107.0 ± 29.2	
Age (yr)	73.6 ± 5.0	73.6 ± 5.0	72.8 ± 5.3	72.4 ± 4.8	0.01
Years since diagnosis	9.0 ± 2.6	8.5 ± 2.6	8.4 ± 2.8	8.4 ± 2.6	0.04
BMI (kg·m^{-2})	29.4 ± 3.7	28.9 ± 3.6	29.3 ± 3.3	28.9 ± 3.2	0.39
No. comorbidities	2.2 ± 1.3	2.0 ± 1.2	2.1 ± 1.2	1.8 ± 1.2	0.03
No. symptoms	4.7 ± 3.5	4.4 ± 3.2	4.4 ± 3.1	4.3 ± 3.3	0.25
Fruit and vegetable servings per day	3.0 ± 1.7	3.1 ± 1.6	3.2 ± 1.7	3.1 ± 1.9	0.56
Healthy Eating Index-2005	59.0 ± 13.6	61.2 ± 13.4	59.9 ± 13.9	57.3 ± 13.8	0.19

* *P* value for categorical variables is for row mean scores from the Cochran-Mantel-Haenszel test; *P*-value for continuous variables is from the ANOVA test for trend.

TABLE 2. Most frequently performed physical activities by intensity level at study baseline.[a]

Low–Light Physical Activity (1.5–2.0 METs)			High–Light Physical Activity (2.1–2.9 METs)			Moderate–Vigorous Physical Activity (≥3 METs)		
Activity	MET Value	Pct.[b]	Activity	MET Value	Pct.[b]	Activity	MET Value	Pct.[b]
Use a computer	1.5	57	Light housework	2.5	81	Heavy gardening	4.0	21
Visit friends or family	1.8	84	Volunteer work	2.3	28	Walk or hike uphill	6.0	21
Attend church activities	1.5	76	Light gardening	2.3	43	Heavy housework	3.0	13
Do arts and crafts	1.7	29	Walk leisurely	2.5	51	Walk fast or briskly	3.5	16

[a]Most frequently performed activity in each intensity level based on minutes per week.
[b]Percentage of participants reporting any frequency of the activity at baseline.

of time (min·wk^{-1}) was spent using a computer; however, a greater percentage of participants reported (any frequency) visiting friends or family or attending church activities. Housework (light, heavy), gardening (light, heavy), and walking (leisurely, briskly) were among the most commonly reported HLPA and MVPA. The only vigorous activity reported at baseline was walking/hiking up hill.

Figure 2 illustrates the cross-sectional association between physical activity intensity and physical function. Increasing tertiles of baseline LPA were associated with higher scores for all three measures of baseline physical function (all trend test P values <0.005), after adjusting for age, sex, BMI, comorbidity, symptoms, and moderate- to vigorous-intensity physical activity (model 1). *Post hoc* analyses revealed significant differences in physical function (all measures) between the lowest (median [interquartile range {IQR}] = 21.7 [14.4–27.5] MET·h·wk^{-1}) and highest (median [IQR] = 77.6 [66.0–96.7] MET·h·wk^{-1}) LPA tertiles. The associations were stronger for high–light than for low–light intensity activities (model 2); however, the associations (trend tests) were no longer significant at the 0.015 level, except for HLPA and advanced LEF (P < 0.008). Compared to participants reporting no MVPA at baseline (first tertile), those in the second and third tertiles (median [IQR] = 4.0 [2.1–6.0] and 16.0 [11.3–24.7] MET·h·wk^{-1}, respectively) had significantly higher scores on the SF-36 Physical Function Subscale and the advanced LEF subscale; there was no significant association between MVPA and basic LEF (P = 0.11). There was no evidence of interaction by sex or age at diagnosis.

The pre/postintervention analysis included 514 participants who completed the year-long intervention. Upon completing the intervention, 38% of the cancer survivors either decreased or remained stable in both MVPA and HLPA (reference group). The referent group declined in physical functioning by 2.0–5.6 points on each of the physical function measures (Fig. 3). Compared to the reference group, survivors who increased in HLPA, but not MVPA, experienced either negligible change or attenuated decline in physical function scores (0.14 ≤ P values ≤ 0.01). For example, advanced LEF remained stable in this group (0.4 points) compared to a decrease of 2.6 points in the referent group (P = 0.01). Individuals who increased MVPA, regardless of change status in HLPA, had significantly higher function scores on each of the three measures. Individuals who increased both HLPA and MVPA increased their physical function scores by 2.0–2.9 points above preintervention levels, for a difference of 4.4–7.6

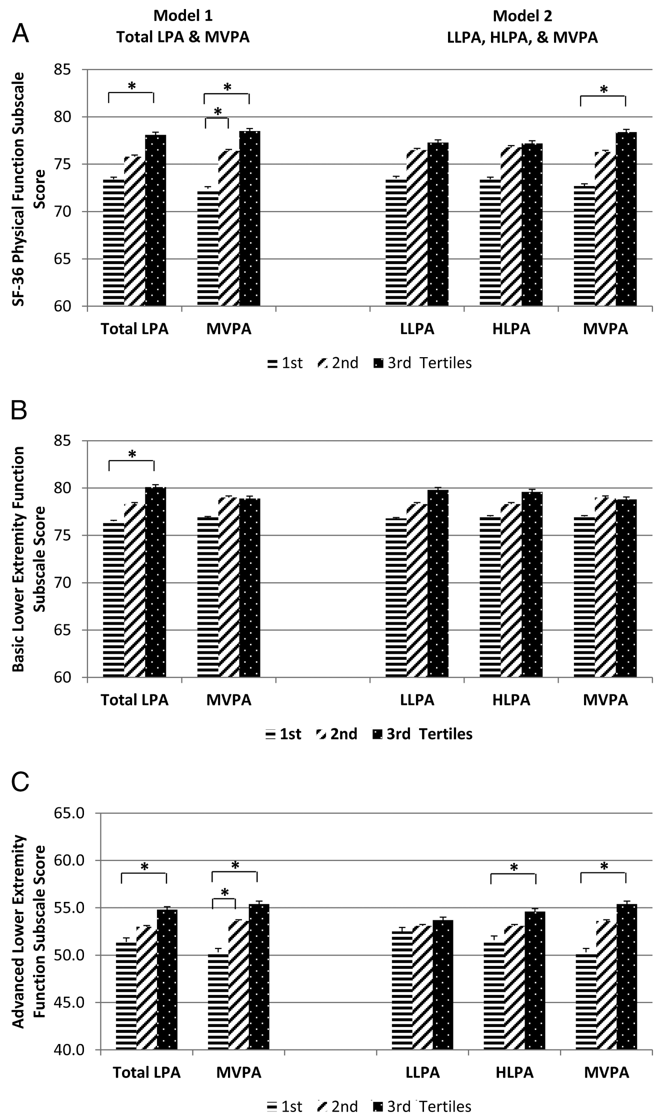

FIGURE 2—Cross-sectional association between physical activity intensity and physical function adjusted for age (continuous), sex, BMI (continuous), comorbidities (continuous), symptoms (0–2, 3–5, 6+), and other intensity PA variable(s). Data are presented as least square means ± SE. A. SF-36 Physical Function Subscale score; ANCOVA test for trend *P* value: Model 1: LPA = 0.004, MVPA = 0.0002; Model 2: LLPA = 0.020, HLPA = 0.021, MVPA = 0.0006. B. Basic Lower Extremity Function score; ANCOVA test for trend *P* value: Model 1: LPA = 0.004, MVPA = 0.11; Model 2: LLPA = 0.017, HLPA = 0.031, MVPA = 0.015. C. Advanced Lower Extremity Function score; ANCOVA test for trend *P* value: Model 1: LPA = 0.003, MVPA < 0.0001; Model 2: LLPA = 0.28, HLPA = 0.008, MVPA < 0.0001. *Post hoc analyses (only conducted for trend test *P* values ≤0.015) for difference between tertiles, *P* < 0.05.

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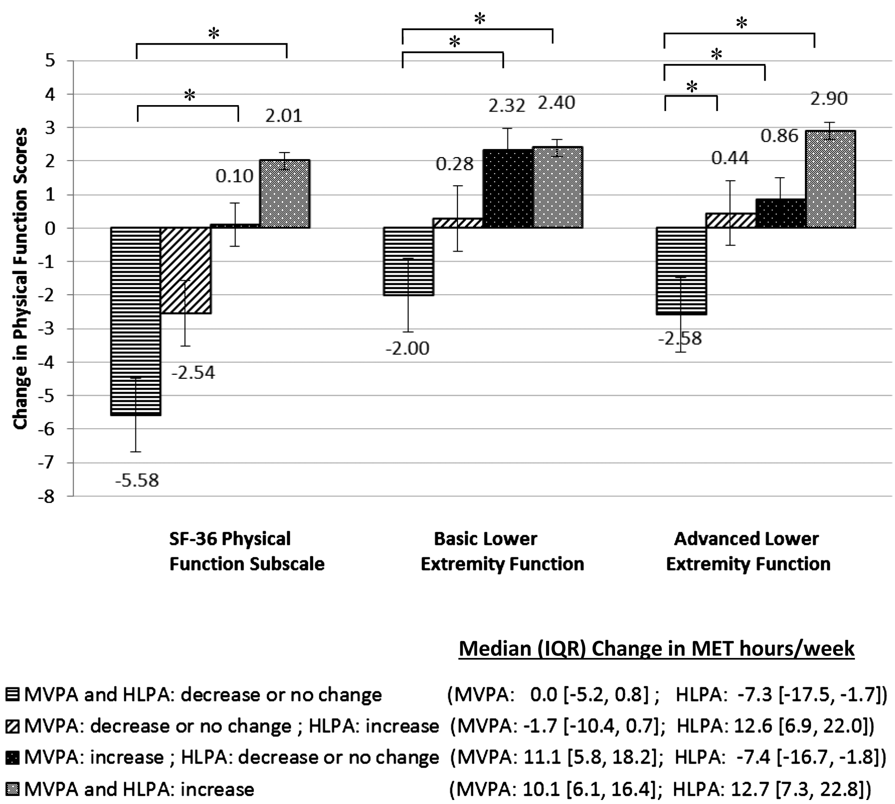

FIGURE 3—Association between change in physical activity and change in physical function adjusted for age (continuous), sex, BMI (continuous), comorbidities (continuous), symptoms (0–2, 3–5, 6+). Referent group: decreased or remained stable for both MVPA and HLPA. Definitions: decrease: >3 MET·h·wk^{-1} lower than baseline score; no change: ±3 MET·h·wk^{-1} of baseline score (definition of sedentary); increase: >3 MET·h·wk^{-1} above baseline score. ANCOVA test for trend *P* values for all three function measures <0.0001. **Post hoc* analyses comparing categories to the referent group, *P* < 0.05.

points higher than the reference group. There was no evidence of interaction by sex or age at diagnosis.

Since 11% of the cancer survivors who completed the intervention reported >2.5 h·wk^{-1} of MVPA at both preintervention and postintervention follow-up, but were categorized as decreased/remained stable in MVPA, we conducted a sensitivity analysis to examine the effect of moving these individuals to increased/met MVPA guidelines (upper two categories), with or without an increase in HLPA. This resulted in a slight attenuation of the difference in physical function scores between the group that increased in HLPA only, compared to the reference group (1.9–2.7 points higher), with the difference between groups for Advanced Lower Extremity Function remaining significant ($P < 0.05$; data not shown).

DISCUSSION

This is the first study to evaluate the cross-sectional and longitudinal associations between light-intensity (divided into low–light and high–light) physical activity and physical function in older, long-term, breast, prostate, and colorectal cancer survivors. Our results add to the expanding body of evidence that LPA, especially HLPA, is linked with beneficial health effects. In cross-sectional analyses, increasing tertiles of HLPA were associated with higher scores for all three measures of physical function (3.5–4.7 points higher in the upper compared with the lower tertile), independent of MVPA. In longitudinal analyses, survivors who increased in HLPA, but not MVPA, after the year-long intervention reported higher physical function scores (2–3 points) compared with survivors who decreased or remained stable in both intensity levels. To place this into a clinical context, a reduction of 6 points in the SF-36 physical summary score over a 4-yr period is associated with a 10% higher mortality risk over the subsequent 3 yr, whereas a decline of 2 points is considered too small to be clinically detectable. We noted a 1-yr decline of 5.6 points among individuals decreasing or maintaining reported levels of MVPA and HLPA, which stands in contrast to an attenuation of decline, i.e., −2.5 points, among individuals increasing their HLPA independent of MVPA over the same time frame (39).

While our results are encouraging, they must be interpreted with caution given the subjective assessment of physical activity. While the CHAMPS questionnaire was designed specifically to include activities commonly performed by older adults (35) and has acceptable 6-month concurrent validity (compared with accelerometry) for HLPA (r = 0.27, P < 0.0001) and MVPA (r = 0.37, P < 0.0001), there are only a select number of light physical activities that are included and no significant correlation between LLPA and accelerometry has been found (r = 0.06, P = 0.10) (17). Without objective measurement, many of the incidental activities (<10-min bouts, e.g., climbing stairs, short walks) that occur throughout the day are difficult to capture. Therefore, our assessment of physical activity may have underestimated or overestimated LPA in our study, thus limiting the generalizability of our results.

The landmark publication of Physical Activity and Health noted that the greatest physical activity health benefit occurred among individuals with the lowest baseline physical activity (29). From a clinical perspective, the largest health benefit would occur by moving sedentary individuals to a lifestyle of moderate physical activity. However, the research contributing to consensus statement was largely based on studies focusing on the higher doses of physical activity. Only recently have researchers begun investigating the lower end of the spectrum, i.e., the health impact of sedentary lifestyles versus habitual engagement in very light and light physical activity (28). Given the recent data suggesting that being sedentary is associated with adverse health outcomes independent of moderate physical activity (3), studies such as ours will provide important contributions to the potential health benefit of lower doses of physical activity. Thus, our intervention shifted some participants from being "sedentary" to being engaged in HLPA—a shift that likely contributed to the independent beneficial impact on physical function.

To our knowledge, only one other study distinguished between LLPA and HLPA when examining the association between LPA and physical health in older adults (5). While there are major differences between their analyses and ours, the results of Buman et al. provide support for the benefits of LPA, especially HLPA, on both physical health and psychosocial well-being. In a cross-sectional analysis of 862 adults older than 65 yr, Buman et al. reported significantly better physical health (composite variable including number of comorbidities and medications, general health rating, BMI, lower extremity function, and pain interference) associated with both LLPA (100–1040 counts per minute) and HLPA (1041–1951 counts per minute), independent of sedentary activity and MVPA (<100 and ≥1952 counts per minute, respectively). The magnitude of the association was similar for HLPA and MVPA. Furthermore, using an isotemporal substitution model (24), the effect of substituting 30 min·d^{-1} of HLPA or MVPA for either sedentary activity or LLPA resulted in similar increases in physical health; however, there were no significant substitution effects for exchanging HLPA for MVPA (5).

In contrast to the cross-sectional portion of our study results, a cross-sectional study of 843 older long-term male and female colorectal cancer survivors by Johnson et al. reported that LPA (CHAMPS items <3 METs) was no longer significantly associated with physical function (SF-36 Physical Function Subscale) after further adjustment for MVPA (CHAMPS items ≥3 METs) (P_{trend} across quartiles of LPA = 0.39) (19). However, in this previous study, strong, independent associations were found between nonexercise activities (P_{trend} across categories for housework [light and heavy] <0.0001, gardening [light and heavy] <0.0001) and walking (any pace; P_{trend} < 0.001), with higher levels of physical function after adjusting for all types of activities including sports/exercise (all MVPA; P_{trend} = 0.004). This suggests either that the cancer survivors reported performing more "heavy" (≥3 METs = MVPA), rather than "light" (<3 METs = LPA) housework and gardening activities, or that LLPA may have diluted any effect of HLPA, and thus separation of the two may be necessary to uncover potential associations.

While more research, particularly interventions and observational studies with longitudinal data, is needed to evaluate the effects of LPA, and especially HLPA, on physical function, research on other health outcomes provides additional preliminary evidence for beneficial effects of LPA. Cross-sectional studies using accelerometer data showed beneficial associations between time spent in LPA and biomarkers and indicators of cardiometabolic health, including 2-h postchallenge plasma glucose, waist circumference, clustered metabolic risk score, triglycerides, HDL-C, metabolic syndrome, and diabetes, independent of time spent in MVPA (6,14,16). Additional evidence for beneficial effects of LPA comes from cross-sectional studies evaluating the association with psychosocial well-being. Buman et al. (5) reported that HLPA (compared with LLPA and MVPA) had the strongest association with psychosocial well-being (composite variable including stress, life satisfaction, isolation, feeling depressed/blue, pain interference, lower-body physical function, and general health rating). Furthermore, the substitution of only 30 min·d^{-1} of HLPA for sedentary behavior resulted in a significant increase in psychosocial well-being. Thraen-Borowski et al. (37) also found higher levels of mental health (mental health components summary score of the SF-36) among elderly colorectal cancer survivors who engaged in greater weekly hours of social participation (CHAMPS LPA activities involving social participation) compared to those with less participation. Thus, there appears to be a growing list of potential benefits associated with this lower level of physical activity.

One of the primary limitations of this analysis was the subjective assessment of both physical activity and physical function. There is a possibility of overreporting on the CHAMPS questionnaire, especially with similar activities that vary in intensity (e.g., walking briskly vs walking/hiking up hill, heavy vs light gardening). In addition, light-intensity activities may be more difficult to recall. This questionnaire only included a few sedentary activities, and thus, we were unable to quantify and evaluate the effects of sedentary behavior on physical function. Nevertheless, the CHAMPS questionnaire has acceptable 6-month test–retest reliability (ICC: LLPA [0.70], HLPA [0.68], MVPA [0.66]) and concurrent validity (compared with accelerometry) for HLPA (r = 0.27, P < 0.0001) and MVPA (r = 0.37, P < 0.0001), although no significant correlation is found between LLPA and accelerometry (r = 0.06, P = 0.10) (17). Secondly, the intervention focused solely on increasing MVPA, which was done through strength training and endurance exercise. Nevertheless, due in part to the age and comorbidity level of

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our study population, the distribution of change in both moderate– and high–light intensity activities allowed us to compare combinations of the two activity intensity levels. This study also had several strengths, including a large sample size, inclusion of both males and females, as well as a broad spectrum of cancer survivors, and the evaluation of both low–light and high–light intensity activities. Moreover, our study is the first to report intervention effects of light-intensity physical activity and physical function.

Increasing HLPA may be a viable approach to reducing the rate of physical function decline and may be especially relevant among individuals who are unable or reluctant to initiate or maintain adequate levels of moderate-intensity activities. Older adults at risk for or with existing mobility or functional impairments could potentially benefit from interventions designed to increase HLPA, since many of these activities are activities of daily living (e.g., carrying items such as groceries, climbing stairs), which are measured in the SF-36 Physical Function and Advanced Lower Extremity Function Subscales. In addition, for older adults who are capable of but not meeting the MVPA guidelines, initially targeting HLPA may help lay the foundation for further improvements in activity duration or intensity.

Given the substantial personal, social, and economic costs associated with functional decline resulting in loss of independence, it is of great importance to design interventions to attenuate the rate of decline and prevent or delay severe functional impairment. Existing observational studies with longitudinal data for both LPA and MVPA can provide answers to the question of whether maintaining or increasing LPA is associated with better health. Future research involving PA should include the assessment of both exercise and nonexercise PA across the intensity continuum, including both objective and subjective measures. Activity monitors with both accelerometer and inclinometer (detects change in posture) functionality, such as the ActivPal3 (PAL Technologies LTD, Glasgow, UK), would enable accurate measurement of sedentary behavior, LPA, and MVPA. Recently developed subjective instruments specifically designed to capture sedentary and light activities, such as the 7-d Sedentary and Light Intensity Physical Activity log (4), could provide context for the activities and patterns measured objectively. In addition, research is needed to determine the effectiveness of exercise prescriptions to increase HLPA in terms of initiation, sustainability, as well as short- and long-term effects on physical functioning and other health outcomes.

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