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Light-Intensity Activity Attenuates Functional Decline in Older Cancer Survivors

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Abstract

While moderate-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-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) aged 65 and older who participated in a 1-year, 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 (HLLPA): 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 3 measures of physical function (all p-values <0.005), after adjustment for age, sex, BMI, comorbidity, symptoms, and MVPA. Associations were stronger for HLLPA than for LLPA. Compared with survivors who decreased or remained stable in MVPA and HLLPA at the post-intervention follow-up, those who increased in HLLPA, but decreased or remained stable in MVPA, reported higher physical function scores (LSMeans (95% CI): SF-36 physical function subscale: -5.58 (-7.96, -3.20) vs. -2.54 (-5.83, 0.75), p=0.14; basic lower

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

extremity function: -2.00 (-3.45, -0.55) vs. 0.28 (-1.72, 2.28), $p=0.07$; advanced lower extremity function: -2.58 (-4.00, -1.15) vs. 0.44 (-1.52, 2.40), $p=0.01$).

Conclusion—Our findings suggest that increasing light-intensity activities, especially HLP, 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.

Keywords

physical activity; physical function; neoplasms; survivorship

INTRODUCTION

By 2022 there will be 18 million cancer survivors living in the U.S., and two-thirds will be over 60 years of age (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 two-fold increased risk of having one or more functional limitations; however, the risk is five-fold 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-aged 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, varies by study. However, most of 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 resting energy expenditure (1). With resting (sitting quietly) energy expenditure defined as 1 MET, a 4-MET activity expends four times the energy of rest while 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 minutes 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 cardio-

metabolic 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 minutes/week of MVPA), prolonged periods of sitting are associated with an adverse cardio-metabolic 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 has 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 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 non-exercise 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-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 if 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.

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 were 1) ≥ 65 years of age, 2) ≥ 5 years post-diagnosis from breast, prostate, or colorectal

cancer, 3) overweight or obese (25 BMI (kg/m²) 40), 4) <150 minutes/week 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 delayed intervention arms. At 1-year follow-up, the intervention was discontinued in the immediate intervention group and delivered to the delayed (wait-listed) 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 minutes every other day), 2) endurance exercise (30 minutes every day), 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/week).

Outcomes and Measures

Outcomes were assessed at baseline, and at one-year and two-year 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 (hours a week) of 41 activities, ranging from sedentary to vigorous-intensity, performed in a typical week during the past four weeks. Duration was collected as continuous data rather than as categories of hours per week in order 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. and the 2000 Compendium of Physical Activities (1, 35), and accounts for the probable reduced exertion among older adults (65 years) 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 α 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 3 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 r 0.73) and objective measures of physical performance (400 meter walk, Short Physical Performance Battery) (31), and very high reliability (intraclass correlation coefficients (ICC): 0.91 to 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-hour 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 pre- and post-intervention data (Figure 1; pre/post: Study baseline/1-year follow-up and 1-year follow-up/2-year follow-up for the immediate and delayed intervention arms, respectively). MET hours/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 (HLLPA; 2.1-2.9 METs), similar to Hekler et al. (17)(see examples in Table 2). For each intensity variable, MET hours/week were divided into tertiles.

Demographic, lifestyle, and medical characteristics were compared across quartiles of total physical activity MET hours/week and evaluated using ANOVA for continuous variables and the chi-square test for categorical variables. For the cross-sectional analysis, Analysis of Covariance (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. Based on the results of our cross-sectional analysis, suggesting greater benefits for higher compared with lower light-intensity activities, the longitudinal analysis focused on HLLPA and MVPA. Pre- and post-intervention change in PA was dichotomized as decreased or remained stable (± 3 MET hours/week $\approx$ sedentary) as the referent group vs. increased in MET hours/week for HLLPA and MVPA. A composite variable of mutually exclusive groups was created combining the change status of both HLLPA and MVPA to include: increased HLLPA only, increased MVPA only, or increased HLLPA and MVPA. Because the results of the pre- and post-intervention 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 I error integrity, the significance level for the test for trend was set at 0.015 (0.05 / 3 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 years). 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 hours/week of MVPA at baseline, reported fewer hours/week at post-intervention follow-up, yet were still meeting the MVPA guidelines. A sensitivity analysis was conducted whereby these individuals were re-coded as increased/meeting MVPA guidelines, with or without an increase in HLP. Analyses were conducted using SAS 9.3 statistical software (SAS Institute, Inc.).

RESULTS

The study participants were 73.1 ± 5.1 years old (range 65 to 87 years), 8.6 ± 2.7 years since cancer diagnosis (range 5 to 26 years), 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 HLP (31-39%). Individuals with the greatest amount of total PA (MET hours/week) 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 prior to completing the post-intervention 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 scale (mean $\pm$ SD: 49.9 ± 14.1 vs. 53.6 ± 14.4 ; $p=0.01$).

The top four 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 of time (minutes/week) 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 HLP 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 adjustment for age, sex, BMI, comorbidity, symptoms, and moderate-vigorous intensity physical activity (Model 1). Posthoc analyses revealed significant differences in physical function (all measures) between the lowest (median[IQR]: 21.7 [14.4, 27.5] MET hours/week) and highest (median[IQR]: 77.6 [66.0, 96.7] MET hours/week) 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 hours/week, respectively) had significantly higher scores on the SF-36 PFS and the Advanced LEF subscales; 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-/post-intervention analysis included 514 participants who completed the year-long intervention. Upon completing the intervention, 38% percent 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 to 5.6 points on each of the physical function measures (Figure 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 to 2.9 points above pre-intervention levels, for a difference of 4.4 to 7.6 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 hours/week of MVPA at both pre- and post-intervention 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 to 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 to 4.7 points higher in upper compared with 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 four-year period is associated with a 10% higher mortality risk over the subsequent 3 years; whereas a decline of 2 points is considered too small to be clinically detectable. We noted a one-year 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 minute bouts, e.g., climbing stairs, short walks) that occur throughout the day are difficult to capture. Therefore, our assessment of physical activity may have under- or over-estimated 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 engagement 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 over age 65, 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 (100-1,040 counts/minute) and HLPa (1,041-1,951 counts/minute), independent of sedentary activity and MVPA (<100 and 1,952 counts/minute, respectively). The magnitude of the association was similar for HLPa and MVPA. Furthermore, using an isothermal substitution model (24), the effect of substituting 30 minutes/day 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 non-exercise 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 adjustment for all types of activities including sports/exercise (all MVPA; P_{trend} = 0.004). This suggests that either 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 HLP, 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 HLP, 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-hour post-challenge 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. reported that HLP (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) (5). Furthermore, the substitution of only 30 minutes/day of HLP for sedentary behavior resulted in a significant increase in psychosocial well-being. Thraen-Borowski et al. 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 (37). 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 over-reporting 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). Additionally, 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], HLP [0.68], MVPA [0.66]) and concurrent validity (compared with accelerometry) for HLP ($r=0.27$, $p<0.0001$) and MVPA ($r=0.37$, $p<0.0001$); though 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 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. Additionally, 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 non-exercise 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-day Sedentary and Light Intensity Physical Activity log (4), could provide context for the activities and patterns measured objectively. Additionally, 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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References

1. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Medicine and science in sports and exercise*. 2000; 32(9 Suppl):S498–516. [PubMed: 10993420]
2. American Cancer Society. *Cancer Treatment and Survivorship Facts & Figures 2012-2013*. Atlanta: American Cancer Society; 2012. p. 1-39.

3. Bankoski A, Harris TB, McClain JJ, et al. Sedentary activity associated with metabolic syndrome independent of physical activity. *Diabetes Care*. 2011; 34(2):497–503. [PubMed: 21270206]
4. Barwais FA, Cuddihy T, Washington T, Tomson ML, Brymer E. Development and Validation of a New Self-Report Instrument for Measuring Sedentary Behaviors and Light-Intensity Physical Activity in Adults. *J Phys Act Health*. 2013 In press.
5. Buman MP, Hekler EB, Haskell WL, et al. Objective light-intensity physical activity associations with rated health in older adults. *Am J Epidemiol*. 2010; 172(10):1155–65. [PubMed: 20843864]
6. Camhi SM, Sisson SB, Johnson WD, Katzmarzyk PT, Tudor-Locke C. Accelerometer-determined moderate intensity lifestyle activity and cardiometabolic health. *Prev Med*. 2011; 52(5):358–60. [PubMed: 21300082]
7. Deimling GT, Arendt JA, Kypriotakis G, Bowman KF. Functioning of older, long-term cancer survivors: the role of cancer and comorbidities. *Journal of the American Geriatrics Society*. 2009; 57(Suppl 2):S289–92. [PubMed: 20122020]
8. Dunstan DW, Thorp AA, Healy GN. Prolonged sitting: is it a distinct coronary heart disease risk factor? *Curr Opin Cardiol*. 2011; 26(5):412–9. [PubMed: 21785350]
9. Guenther PM, Reedy J, Krebs-Smith SM, Reeve BB. Evaluation of the Healthy Eating Index-2005. *J Am Diet Assoc*. 2008; 108(11):1854–64. [PubMed: 18954575]
10. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *N Engl J Med*. 1995; 332(9):556–61. [PubMed: 7838189]
11. Haley SM, Jette AM, Coster WJ, et al. Late Life Function and Disability Instrument: II. Development and evaluation of the function component. *J Gerontol A Biol Sci Med Sci*. 2002; 57(4):M217–22. [PubMed: 11909886]
12. Ham SA, Kruger J, Tudor-Locke C. Participation by US adults in sports, exercise, and recreational physical activities. *J Phys Act Health*. 2009; 6(1):6–14. [PubMed: 19211953]
13. Harada ND, Chiu V, King AC, Stewart AL. An evaluation of three self-report physical activity instruments for older adults. *Med Sci Sports Exerc*. 2001; 33(6):962–70. [PubMed: 11404662]
14. Healy GN, Dunstan DW, Salmon J, et al. Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. *Diabetes Care*. 2007; 30(6):1384–9. [PubMed: 17473059]
15. Healy GN, Matthews CE, Dunstan DW, Winkler EA, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. *Eur Heart J*. 2011; 32(5):590–7. [PubMed: 21224291]
16. Healy GN, Wijndaele K, Dunstan DW, et al. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care*. 2008; 31(2):369–71. [PubMed: 18000181]
17. Hekler EB, Buman MP, Haskell WL, et al. Reliability and validity of CHAMPS self-reported sedentary-to-vigorous intensity physical activity in older adults. *J Phys Act Health*. 2012; 9(2): 225–36. [PubMed: 22368222]
18. Hewitt M, Rowland JH, Yancik R. Cancer survivors in the United States: age, health, and disability. *J Gerontol A Biol Sci Med Sci*. 2003; 58(1):82–91. [PubMed: 12560417]
19. Johnson BL, Trentham-Dietz A, Koltyn KF, Colbert LH. Physical activity and function in older, long-term colorectal cancer survivors. *Cancer Causes Control*. 2009; 20(5):775–84. [PubMed: 19123055]
20. Kruger J, Ham SA, Sanker S. Physical inactivity during leisure time among older adults--Behavioral Risk Factor Surveillance System, 2005. *J Aging Phys Act*. 2008; 16(3):280–91. [PubMed: 18660551]
21. Lynch BM, Friedenreich CM, Winkler EA, et al. Associations of objectively assessed physical activity and sedentary time with biomarkers of breast cancer risk in postmenopausal women: findings from NHANES (2003-2006). *Breast Cancer Res Treat*. 2011; 130(1):183–94. [PubMed: 21553294]
22. Manns PJ, Dunstan DW, Owen N, Healy GN. Addressing the nonexercise part of the activity continuum: a more realistic and achievable approach to activity programming for adults with mobility disability? *Phys Ther*. 2012; 92(4):614–25. [PubMed: 22156025]

23. McHorney CA, Ware JE Jr, Rogers W, Raczek AE, Lu JF. The validity and relative precision of MOS short- and long-form health status scales and Dartmouth COOP charts. Results from the Medical Outcomes Study. *Med Care*. 1992; 30(5 Suppl):MS253–65. [PubMed: 1583937]
24. Mekary RA, Willett WC, Hu FB, Ding EL. Isotemporal substitution paradigm for physical activity epidemiology and weight change. *Am J Epidemiol*. 2009; 170(4):519–27. [PubMed: 19584129]
25. Miller PE, Mitchell DC, Harala PL, Pettit JM, Smiciklas-Wright H, Hartman TJ. Development and evaluation of a method for calculating the Healthy Eating Index-2005 using the Nutrition Data System for Research. *Public Health Nutr*. 2011; 14(2):306–13. [PubMed: 20576195]
26. Morey MC, Sloane R, Pieper CF, et al. Effect of physical activity guidelines on physical function in older adults. *J Am Geriatr Soc*. 2008; 56(10):1873–8. [PubMed: 18800990]
27. Morey MC, Snyder DC, Sloane R, et al. Effects of home-based diet and exercise on functional outcomes among older, overweight long-term cancer survivors: RENEW: a randomized controlled trial. *JAMA*. 2009; 301(18):1883–91. [PubMed: 19436015]
28. Pate RR, O'Neill JR, Lobelo F. The evolving definition of “sedentary”. *Exerc Sport Sci Rev*. 2008; 36(4):173–8. [PubMed: 18815485]
29. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 1995; 273(5):402–7. [PubMed: 7823386]
30. Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report, 2008. Washington, DC: U.S. Department of Health and Human Services; 2008. p. G6-1-G6-31.
31. Sayers SP, Jette AM, Haley SM, Heeren TC, Guralnik JM, Fielding RA. Validation of the Late-Life Function and Disability Instrument. *J Am Geriatr Soc*. 2004; 52(9):1554–9. [PubMed: 15341561]
32. Seguin R, Lamonte M, Tinker L, et al. Sedentary Behavior and Physical Function Decline in Older Women: Findings from the Women's Health Initiative. *J Aging Res*. 2012; 2012:271589. [PubMed: 22675631]
33. Snyder DC, Morey MC, Sloane R, et al. Reach out to ENhance Wellness in Older Cancer Survivors (RENEW): design, methods and recruitment challenges of a home-based exercise and diet intervention to improve physical function among long-term survivors of breast, prostate, and colorectal cancer. *Psychooncology*. 2009; 18(4):429–39. [PubMed: 19117329]
34. Stamatakis E, Hamer M, Dunstan DW. Screen-based entertainment time, all-cause mortality, and cardiovascular events: population-based study with ongoing mortality and hospital events follow-up. *J Am Coll Cardiol*. 2011; 57(3):292–9. [PubMed: 21232666]
35. Stewart AL, Mills KM, King AC, Haskell WL, Gillis D, Ritter PL. CHAMPS physical activity questionnaire for older adults: outcomes for interventions. *Med Sci Sports Exerc*. 2001; 33(7):1126–41. [PubMed: 11445760]
36. Studenski S, Perera S, Patel K, et al. Gait speed and survival in older adults. *JAMA*. 2011; 305(1):50–8. [PubMed: 21205966]
37. Thraen-Borowski KM, Trentham-Dietz A, Edwards DF, Koltyn KF, Colbert LH. Dose-response relationships between physical activity, social participation, and health-related quality of life in colorectal cancer survivors. *J Cancer Surviv*. 2013; 7(3):369–78. [PubMed: 23546822]
38. Tucker JM, Welk GJ, Beyler NK. Physical activity in U.S.: adults compliance with the Physical Activity Guidelines for Americans. *Am J Prev Med*. 2011; 40(4):454–61. [PubMed: 21406280]
39. Ware JE Jr, Bayliss MS, Rogers WH, Kosinski M, Tarlov AR. Differences in 4-year health outcomes for elderly and poor, chronically ill patients treated in HMO and fee-for-service systems. Results from the Medical Outcomes Study. *JAMA*. 1996; 276(13):1039–47. [PubMed: 8847764]
40. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Medical care*. 1992; 30(6):473–83. [PubMed: 1593914]

Figure 1.
RENEW wait-list controlled trial design

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 $\pm$ 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, $P < 0.05$.

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/w lower than baseline score; no change = ± 3 MET h/w of baseline score (definition of sedentary); increase: >3 MET h/w 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, $P < 0.05$.

Table 1

Selected characteristics of study participants by physical activity at baseline (N=641)

	Quartiles of Total MET-Hours per Week of Physical Activity				p-value*
	1	2	3	4	
Range	0 – 33.8	33.9 – 53.5	53.7 – 77.1	77.5 – 238.7	
	N (%)				
Sex					
Female	75 (21%)	86 (25%)	98 (28%)	90 (26%)	<0.05
Male	85 (29%)	74 (25%)	63 (22%)	70 (24%)	
Race-Ethnicity					
Other	24 (33%)	20 (28%)	8 (11%)	20 (28%)	0.18
Non-Hispanic White	136 (24%)	140 (25%)	153 (27%)	140 (25%)	
Education					
No college	83 (34%)	56 (23%)	62 (25%)	45 (18%)	<0.0001
Any college	77 (19%)	104 (26%)	99 (25%)	115 (29%)	
Income					
<\$50,000	123 (29%)	105 (24%)	102 (24%)	101 (23%)	0.008
\$50,000	37 (18%)	54 (26%)	59 (28%)	59 (28%)	
Treatment					
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%)	
	Mean (SD)				
Physical activity (MET h/w)					
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)	

Quartiles of Total MET-Hours per Week of Physical Activity					
Range	1 0 – 33.8	2 33.9 – 53.5	3 53.7 – 77.1	4 77.5 – 238.7	p-value*
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 (years)	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
Number of comorbidities	2.2 (1.3)	2.0 (1.2)	2.1 (1.2)	1.8 (1.2)	0.03
Number of symptoms	4.7 (3.5)	4.4 (3.2)	4.4 (3.1)	4.3 (3.3)	0.25
Fruit & vegetable serv./d	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	%β	Activity	MET Value	%β	Activity	MET Value	%β
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

^aMost frequently performed activity in each intensity level based on minutes per week.

^βPercentage of participants reporting any frequency of the activity at baseline.