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RESEARCH

Changes in physical activity since cancer diagnosis and associations with health-related quality of life: a study of adults living with advanced cancer

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Abstract

Purpose Physical activity (PA) is associated with better quality of life for cancer survivors; however, less is known about this association among individuals with advanced cancer. This study assesses whether changes in PA following an advanced cancer diagnosis are associated with health-related quality of life (HRQoL) outcomes.

Methods Data were collected from 247 participants in a survey of adults with advanced cancer who visited the University of Wisconsin Carbone Cancer Center (January 2021–2023). PA since cancer diagnosis was assessed using a validated, self-reported tool. HRQoL was assessed using the Functional Assessment of Cancer Therapy – General and Patient-Reported Outcomes Measurement Information System measures of physical function, fatigue, and pain interference. We used generalized linear models to assess relationships between PA and HRQoL.

Results Most adults with advanced cancer were insufficiently active (53%), and reported a lot less activity (41%) after diagnosis, followed by a little less activity (33%), and the same/more activity (26%). Compared to the other activity groups, those who reported a lot less activity had the worst HRQoL scores, including lower HRQoL ($\bar{x}=70.3$ vs. $\bar{x}=82.6$, 90.7) and physical function ($\bar{x}=40.3$ vs. $\bar{x}=47.3$, 52.5), and higher fatigue ($\bar{x}=59.3$ vs. $\bar{x}=51.4$, 42.3) and pain interference ($\bar{x}=55.5$ vs. $\bar{x}=48.8$, 45.6).

Conclusions Adults with advanced cancer who report PA reductions have worse HRQoL, higher pain and fatigue, and lower physical function than those engaging in the same/more PA since their diagnosis. Future interventions focused on improving HRQoL among adults with advanced cancer should incorporate light-intensity PA to reduce declines following diagnosis.

Keywords Physical activity · Advanced cancer · Quality of life · Pain · Fatigue · Physical function

Introduction

The American Cancer Society (ACS) describes the term 'advanced cancer' as referring to cancers that are unlikely to be cured [1, 2]. Many adults are living considerably longer (i.e., five or more years) after an advanced cancer diagnosis due to modern advances in treatments for cancer [3–5]. However, living longer with advanced cancer is associated with an increase in complex needs, like physical and mental health challenges, that are not well

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understood [3, 6]. Physical activity is known to provide physical and mental health benefits for cancer survivors [7], but more research is needed to understand how physical activity influences quality of life among adults living with advanced cancer specifically.

Physical activity is promoted as an important component of survivorship for cancer survivors due to its multitude of physical and mental health benefits [3, 7, 8]. Evidence suggests that increased physical activity for adults living with advanced cancer enhances quality of life, decreases fatigue, and improves aerobic fitness and lower-body strength associated with exercise [8–13]. Unfortunately, most adults living with advanced cancer do not meet the national physical activity recommendations for cancer survivors of 150 min per week of moderate-vigorous physical activity and muscle-strengthening activities on two or more days per week, likely due to intense initial treatments that contribute to long-term toxicities and the need for ongoing treatment(s) [3, 7]. For instance, a study by Knowlton et al. (2020) found only 34% of patients with advanced cancer in their sample met the national physical activity guidelines [14]. A recent randomized control trial pilot study of a walking intervention among people with recurrent or advanced/metastatic cancer, CanWalk, was found to be acceptable and well-tolerated, suggesting the potential benefits of activities like walking for the advanced cancer population [15]. The National Cancer Institute (NCI) recognizes the growing need to better characterize the physical activity levels, including aerobic and strength-based activity, among this population of adults living with advanced cancers [3].

Research suggests that those living with advanced cancer experience varying degrees of health declines, particularly with physical issues such as increasing fatigue and pain [3, 6]. In addition, many cancer survivors face diverse functional limitations due to their cancer and/or its treatment, leading to potential increases in pain, fatigue, neuropathy, and sleep disruptions [16]. These functional limitations and health declines may reduce overall quality of life and increase emotional challenges (e.g., trouble coping with their illness) [16, 17]. Due to the compounding effects of living with advanced cancer and undergoing intense cyclic treatment(s), adults living with advanced cancer need interventions designed to alleviate their ongoing quality of life concerns [3]. Assessing how changes in physical activity may be associated with quality of life across several important domains may serve as a foundation to design interventions that best support this growing population of adults living with advanced cancer.

The purpose of this study is to: (1) evaluate changes in physical activity since diagnosis among adults living with advanced cancer; (2) measure physical activity levels and intensity, including both aerobic and strength-based activities; and (3) assess the relationship between physical activity and important health-related quality of life domains.

Methods

Study design and population

Our team identified the incidence rates and 5-year distant survival rate percentages for a variety of cancers using recently available data from the National Cancer Institute's (NCI) Surveillance, Epidemiology, and End Results (SEER)*Explorer Application [18]. We selected three of the most common cancer types (stage 4 breast, prostate, and colorectal cancer). We also included patients diagnosed with stage 3 and 4 lymphoma (non-Hodgkin's and Hodgkin's) and myeloma because these hematologic malignancies have high 5-year survival rates of approximately 67%, 84%, and 59%, respectively [18].

Eligibility criteria included the following: cancer type and stage [stage 4 breast, prostate, or colorectal cancer; stage 3 or 4 lymphoma (non-Hodgkin's and Hodgkin's); or myeloma], 18–80 years of age as of January 2023, date of eligible diagnosis (January 2021-January 2023), valid mailing address, alive at the time of contact, and English speaking. The study aimed to capture those who received care at the University of Wisconsin's Carbone Cancer Center (UWCCC) within two years of their cancer diagnosis date (January 2021-January 2023) because they were able to recount recent treatment(s) and had a valid mailing address. A list of patients and their contact information was provided by the Clinical and Health Informatics Institute (CHI2) team at the University of Wisconsin-Madison's Institute for Clinical and Translational Research. This study was approved as minimal risk by the University of Wisconsin-Madison's Minimal Risk Institutional Review Board (Protocol #2022–0966) and by the UWCCC's Protocol Review and Monitoring Committee (Protocol UW22103).

Data collection

We modified an approach by Dillman et al. to minimize participant burden and limit the amount of contact between the participants and the study team [19]. We recruited participants by mailing a pre-survey postcard to our list of patients in March 2023 (Online Resource 1), notifying them that a survey about their health (but not mentioning cancer specifically) would arrive in two weeks. The postcard included contact information for the study team, allowing patients to opt out of receiving the survey for any reason. Two weeks after the postcards were mailed, we mailed the survey to eligible patients who had not opted out, which included questions related to physical activity,

quality of life, and demographic and clinical characteristics, along with a small incentive ($2). Five weeks after the first survey was mailed, we sent a second copy of the survey to eligible patients who had not opted out or returned their survey.

We collected surveys from April 3, 2023-July 31, 2023. Among the eligible patients ($n=683$), $n=9$ (1%) opted out, $n=3$ (0.4%) returned a blank survey, $n=393$ (58%) did not respond, and $n=278$ (41%) returned a completed survey. We took a subset of our eligible patients who had complete data on the Functional Assessment of Cancer Therapy – General (FACT-G), and demographic and clinical variables to use as our analytic ($n=247$, 89%).

Survey measures

We collected data on changes in physical activity since diagnosis by asking participants to compare their physical activity level before their cancer diagnosis to how much physical activity they are doing currently. Participants responded using the 5-point Likert scale: a lot less activity, a little less activity, about the same amount of activity, a little more activity, and a lot more activity. We collected aerobic activity data using a modified Godin-Shepard Leisure-Time Physical Activity Questionnaire (GSLTPQ) [20, 21] to ask about the number of times an activity was completed in the past seven days, with three designated intensities: light, moderate, and strenuous/vigorous. We also included questions about average time (in minutes) spent in one session for each intensity category. We collected muscle-strengthening activity data using a modified Muscle-Strength Exercise Questionnaire (MSEQ) to ask about the types and durations of muscle-strengthening activities completed in the past seven days [22].

We assessed health-related quality of life (HRQoL) using the FACT-G which includes four subscales: physical well-being (7 questions), social/family well-being (7 questions), emotional well-being (6 questions), and functional well-being (7 questions) [23, 24]. Participants responded using the 5-point Likert scale, ranging from 0 (not at all) to 4 (very much) for each question. We used the Patient-Reported Outcomes Measurement Information System (PROMIS) to measure three important domains of health-related quality of life: physical function, fatigue, and pain interference. These measures were selected due to their direct relationship with physical activity and could be influenced by a physical activity intervention, thereby impacting quality of life. We used the available PROMIS short-form instruments to minimize the patient's response burden [25–33]. Participants responded using the 5-point Likert scale, ranging from 0 (normal) to 4 (severe impairment) for each question to obtain raw scores. We then converted PROMIS raw scores to *T* scores using the short form conversion tables for each domain. For clinical reference, physical function scores range from: severe impairment (<30), moderate impairment (30–40), mild impairment (40–45), to normal (≥ 45); fatigue scores range from severe impairment (≥ 75), moderate impairment (55–74), mild impairment (50–54), to normal (<50); and pain interference scores range from severe impairment (≥ 70), moderate impairment (60–69), mild impairment (50–59), to normal (<50) [32, 33]. Higher scores reflect more of the domain being measured (i.e., higher score = higher physical function, fatigue, or pain interference).

We derived cancer type from the electronic health record and collected comorbidity data using the Functional Comorbidity Index (FCI) [34]. We collected demographic and other clinical characteristics (e.g., current treatments received) using questions developed for this survey.

Data preparation

We double-entered data into REDCap (Research Electronic Data Capture, a secure platform for data storage) and reviewed it for quality and completeness using REDCap's data comparison tool [35]. We categorized physical activity data by light, moderate, and strenuous, and included all three activity intensities in the Leisure Score Index (LSI) calculation. Weekly frequencies of each intensity category were multiplied by their metabolic equivalents of task (MET) value (light = 3, moderate = 5, strenuous = 9) to get an overall LSI value. We categorized physical activity using the LSI cut points for active ($LSI \geq 24$), moderately active ($14 \leq LSI < 24$), and insufficiently active ($LSI < 14$). We also calculated activity in the past seven days by multiplying the MET value and corresponding minutes reported (light, moderate-strenuous, and total). We did the same calculation for muscle-strengthening activity by multiplying the number of times in each type of activity by the number of minutes reported in the past seven days. Respondents who did not report any aerobic or muscle-strengthening activities were given a value of 0 for the corresponding activity.

We calculated the FACT-G scores for respondents who answered at least 80% of the questions (at least 22 of the 27 questions must be answered), we summed questions across the four subscales (physical, social/family, emotional, and functional) to create a total FACT-G score ranging from 0–108. We calculated the PROMIS *T* scores only if all four questions for each PROMIS measure were answered. Lastly, we calculated the overall functional comorbidity index (FCI) score by counting the number of self-reported "yes" responses to the list of 18 comorbidities, categorized from zero comorbidities to three or more comorbidities.

Statistical analysis

We calculated descriptive statistics, including the mean ($\bar{x}$) and standard deviation (SD) of continuous variables and the frequencies of categorical variables. We used analysis of variance (ANOVA) tests to assess differences in mean scores of the FACT-G and its four subscales and mean *T* scores of PROMIS measures (i.e., physical function, fatigue, and pain interference) by category of change in physical activity since diagnosis (a lot less activity, a little less activity, about the same amount of activity, a little more activity, and a lot more activity). Due to the low sample size of respondents reporting a little more activity ($n=5$, 2.0%) or a lot more activity ($n=16$, 6.4%) since their diagnosis, we tested two category combinations: a 4-category measure and a 3-category measure. The 4-category measure combined those categories together, creating the category "a little or a lot more activity " ($n=21$, 8.4%), while the 3-category measure combined this new category with "same amount of activity" ($n=44$, 17.8%; combined $n=65$, 26.2%). We conducted sensitivity analyses to assess if our results differed using the 4- versus 3-category measure for activity change. There were no significant or clinically meaningful differences in results; therefore, we used the 3-category measure for activity change in our analysis.

We used linear regression models to assess the relationship between categories of change in physical activity since diagnosis and health-related quality of life, measured by continuous mean FACT-G score, FACT-G subscale scores, and PROMIS scores. Covariates were decided a priori based on established and hypothesized relations between exposures and outcomes. Categorical covariates included: current physical activity level (LSI category: insufficiently active, moderately active, active); current age (<60 years, 60–70 years, 70+years); gender (man, woman); marital status (married or living with partner, separated, divorced, widowed, or single); education level (high school or less, some college or associate's degree, Bachelor's degree or higher); employment status (full or part time, not employed, retired, not employed, other); urbanicity (rural, suburban, urban); and clinical characteristics (cancer type: breast, colorectal, prostate, myeloma, lymphoma); current treatment status (on treatment, not on treatment); and FCI score (none, 1 comorbidity, 2 comorbidities, or 3 or more comorbidities). All analyses were conducted in SAS 9.4 (Cary, NC). Distribution plots were made using ggplot in R (R version 4.3.2).

Results

Sample characteristics

Adults living with advanced cancer in our sample ($n=247$) were on average 66 ± 10 years of age, with 60% identifying as men (Table 1). Our respondents identified as married or living with a partner (75%), retired (62%), and residing in rural areas (35%), urban areas (25%), and suburban areas (40%). For clinical characteristics, respondents identified their cancer types as advanced prostate cancer (32%), myeloma (23%), advanced lymphoma (16%), advanced breast cancer (18%), and advanced colorectal cancer (11%). Most respondents were currently undergoing treatment (80%), and nearly half had received treatment within the two weeks before the survey (47%). Only 18% of our sample reported no comorbidities.

Changes in physical activity since diagnosis

From the adults sampled, we found 41% ($n=100$) were "a lot less active", 33% ($n=82$) were "a little less active", and 26% ($n=65$) were "the same or more active" compared to before their cancer diagnosis (Table 1). Adults reporting "a lot less activity" since their diagnosis were less likely to be college-educated compared to the other two activity groups (40% vs. 60% and 51%, respectively; $p=0.02$). They were also more likely to be receiving chemotherapy, immunotherapy, or hormonal therapy (77% vs. 80% and 58%, respectively; $p=0.006$) and to be currently on treatment (86% vs. 85% and 65%, respectively; $p=0.001$). Adults who were "a lot less active" were most likely to be considered insufficiently active/sedentary by the LSI when compared to the other two activity groups (76% vs. 46% and 25%; $p=<0.0001$) and they had lower health-related quality of life (FACT-G) mean scores ($\bar{x}=70.3$ vs. 82.6 and 90.7; $p<0.0001$) than the other two activity groups.

Assessment of physical activity levels

Only 6% of our respondents were meeting the national physical activity moderate-vigorous activity guideline; however, more respondents (27%) were meeting the muscle-strengthening activity guideline (Table 2). Most respondents reported engaging in light-intensity aerobic activity ($n=153$, 62%) compared to moderate-intensity ($n=97$, 39%) and/or strenuous-intensity aerobic activity ($n=36$, 15%). On average, respondents engaged in light aerobic activity for 100.0 min (±216.5 SD) in the week prior to the survey, and combined moderate and strenuous activity for 24.6 min (±93.7 SD) in the week prior to the survey. Average times spent in muscle-strengthening activities in the week prior to the survey were similar across the four types of activity. Those engaging in any strength activity on one or more days in the week prior to the survey reported using resistance bands or free weights ($n=45$; 18%) the most, followed by body weight exercises ($n=32$; 13%), weight machines ($n=24$; 10%), and holistic exercises ($n=17$; 7%).

Table 1 Demographic, clinical, and physical activity characteristics of individuals with advanced cancer (diagnosed between 2021 and 2023) separated by changes in physical activity since diagnosis. Significance is determined by P-value ≤ 0.05

Characteristics	Sample	A lot less activity	A little less activity	The same or more activity	*P*-value
	n (%) or Mean (SD)				
	n = 247	*n* = 100 (41)	*n* = 82 (33)	*n* = 65 (26)	
Demographics					
Current Age—Mean (SD)	66.3 (10.3)	66.6 (9.9)	66.5 (10.3)	65.4 (10.9)	0.76
Age Group					0.86
< 60 years old	52 (21)	20 (20)	16 (20)	16 (25)	
60 to 70 years old	86 (35)	34 (34)	28 (34)	24 (37)	
> 70 years old	109 (44)	46 (46)	38 (46)	25 (38)	
Gender					0.95
Woman	99 (40)	41 (41)	33 (40)	25 (38)	
Man	148 (60)	59 (59)	49 (60)	40 (62)	
Marital Status					0.17
Married or living with partner	185 (75)	69 (69)	63 (77)	53 (82)	
Not married or living with partner	62 (25)	31 (31)	19 (23)	12 (18)	
Education Level					0.02
High school or less	52 (21)	22 (22)	19 (23)	11 (17)	
Some college/associate's degree	73 (30)	38 (38)	14 (17)	21 (32)	
Bachelor's degree or higher	122 (49)	40 (40)	49 (60)	33 (51)	
Employment Status					0.07
Full or part-time	65 (26)	20 (20)	20 (24)	25 (39)	
Not employed, retired	153 (62)	65 (65)	52 (64)	36 (55)	
Not employed, other	29 (12)	15 (15)	10 (12)	4 (6)	
Urbanicity					0.88
Urban	61 (25)	24 (24)	20 (24)	17 (26)	
Suburban	99 (40)	41 (41)	30 (37)	28 (43)	
Rural	87 (35)	35 (35)	32 (39)	20 (31)	
Clinical Characteristics					
Cancer Type					0.24
Breast	45 (18)	22 (22)	14 (17)	9 (14)	
Colorectal	27 (11)	10 (10)	7 (9)	10 (15)	
Myeloma	57 (23)	26 (26)	21 (26)	10 (15)	
Prostate	79 (32)	30 (30)	29 (35)	20 (31)	
Lymphoma	39 (16)	12 (12)	11 (13)	16 (25)	
Current Treatment Type[a]					
Chemo/Immune/Hormone therapy[b]	181 (73)	77 (77)	66 (80)	38 (58)	0.006
Radiation therapy[b]	21 (9)	12 (12)	5 (6)	4 (6)	0.27
Surgery (< 6 months ago)[b]	14 (6)	7 (7)	4 (5)	3 (5)	0.75
Bone marrow or stem cell transplant (< 6 months ago)[b]	6 (2)	3 (3)	3 (4)	0 (0)	0.32
Other[b]	22 (9)	10 (10)	7 (9)	5 (8)	0.87
Current Treatment Status					0.001
On treatment	198 (80)	86 (86)	70 (85)	42 (65)	
Not on treatment	49 (20)	14 (14)	12 (15)	23 (35)	
Functional Comorbidity Index Category					0.11
No comorbidities	45 (18)	13 (13)	12 (14)	20 (31)	
1 comorbidity	48 (19)	21 (21)	17 (21)	10 (15)	
2 comorbidities	52 (21)	20 (20)	18 (22)	14 (22)	
3 or more comorbidities	102 (41)	46 (46)	35 (43)	21 (32)	
FACT-G Score—Mean (SD)	79.7 (15.5)	70.3 (16.4)	82.6 (11.8)	90.7 (12.6)	< .0001

Table 1 (continued)

Characteristics	Sample	A lot less activity	A little less activity	The same or more activity	*P*-value
	n (%) or Mean (SD)				
	n = 247	*n* = 100 (41)	*n* = 82 (33)	*n* = 65 (26)	
Physical Activity					
Leisure Score Index (LSI) Category					< .0001
Insufficiently active/sedentary	130 (53)	76 (76)	38 (46)	16 (25)	
Moderately active	52 (21)	18 (18)	17 (21)	17 (26)	
Active	65 (26)	6 (6)	27 (33)	32 (49)	
Meeting Moderate-Vigorous Activity (MVPA) Guideline					0.0008[c]
Yes	15 (6)	1 (1)	4 (5)	10 (15)	
No	232 (94)	99 (99)	78 (95)	55 (85)	
Meeting Strength Activity Guideline					< .0001
Yes	67 (27)	14 (14)	22 (27)	31 (48)	
No	180 (73)	86 (86)	60 (73)	34 (52)	

[a]Respondents could select more than one treatment type, so these data reflect the number who checked each treatment box and do not add up to 100%

[b]Percentages out of column total and not mutually exclusive (e.g. In the "a lot less active" category 77/100 were on chemo v 33/100 not on chemo)

[c]P-value calculated by Fisher exact test

FACT-G (Functional Assessment of Cancer Therapy-General)

Association between changes in physical activity and health-related quality of life

Differences in FACT-G mean scores

Adults who engaged in "the same or more activity" since diagnosis had the highest overall health-related quality of life (FACT-G) mean score, 90.7 (95% CI: 87.3, 94.2; $p < 0.0001$), while those who engaged in "a little less activity" and "a lot less activity" had a mean score of 82.6 (95% CI: 79.5, 85.6; $p < 0.0001$) and 70.3 (95% CI: 67.5, 73.1; $p < 0.0001$), respectively (Fig. 1). Across the FACT-G subscales, the greatest differences in mean scores were observed for physical well-being and functional well-being. For physical well-being, adults who engaged in "a lot less activity" had the lowest mean scores ($\bar{x} = 18.6$; 95% CI: 17.8, 19.5; $p < 0.0001$), which were clinically meaningful (i.e., a 5-point difference in FACT-G total score and a 2-point difference in subscale scores [36]) compared to those who were "a little less active" ($\bar{x} = 23.2$; 95% CI: 22.3, 24.2; $p < 0.0001$) and those reporting "the same or more activity" ($\bar{x} = 25.7$; 95% CI: 24.7, 26.8; $p < 0.0001$). For functional well-being, adults who engaged in "a lot less activity" had the lowest mean scores, which were clinically meaningful ($\bar{x} = 15.3$; 95% CI: 14.3, 16.4; $p < 0.0001$) compared to those who were "a little less activity" ($\bar{x} = 19.2$; 95% CI: 18.1, 20.3; $p < 0.0001$) and those reporting "the same or more activity" ($\bar{x} = 22.8$; 95% CI: 21.5, 24.1; $p < 0.0001$). While differences in mean scores by activity group emerged across the social well-being and emotional well-being subscales, clinically meaningful differences in scores were only present when comparing those engaging in "the same or more activity" to those engaging in "a lot less activity" since diagnosis across those domains.

FACT-G linear regression

We found an association between a larger reported decrease in physical activity since diagnosis and a lower overall health-related quality of life (FACT-G) score (Table 3). After adjustment for physical activity level, clinical, and demographic characteristics, adults who reported being "a lot less active" had a score 17.21 points lower (95% CI: −21.96, −12.46; $p < 0.0001$) than those who were "the same or more active." Adults who reported being "a little less active" had a score 6.05 points lower (95% CI: −10.59, −1.50; $p < 0.0001$) than those who were "the same or more active." The greatest differences in scores across the FACT-G subscales were observed for physical well-being and functional well-being scores. Adults who were "a lot less active" had a physical well-being score 6.07 points lower (95% CI: −7.54, −4.59; $p < 0.0001$) and a functional well-being score 6.22 points lower (95% CI: −8.03, −4.42; $p < 0.0001$) than those who were "the same or more active" since diagnosis.

Table 2 Self-reported amount and duration of physical activity types and intensities in times and minutes per week of adults living with advanced cancer (diagnosed between 2021 and 2023) by Leisure Score Index (LSI) category. P-value is of analysis of variance (ANOVA) to assess whether differences exist between the mean values of the three activity groups. Significance is determined by P-value ≤ 0.05

Activity Type	Overall ($n=247$)		Insufficiently Active ($n=130$)		Moderately Active ($n=52$)		Active ($n=65$)		*P*-value
Number of Times in Past 7 Days	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	
Light Activity	153 (62)	4.1 (3.7)	66 (51)	2.4 (1.1)	41 (79)	4.2 (2.1)	46 (71)	6.6 (5.5)	< .0001
Moderate Activity	97 (39)	3.7 (2.6)	15 (12)	1.3 (0.5)	27 (52)	2.5 (1.0)	55 (85)	5.0 (2.7)	< .0001
Strenuous Activity	36 (15)	3.3 (2.0)	0	0	8 (15)	1.4 (0.5)	28 (43)	3.8 (1.9)	0.001
Minutes per Session in Past 7 Days									
Light Activity[a]	152 (62)	45 (66)	66 (51)	45 (83)	41 (79)	46 (59)	45 (69)	42 (40)	0.97
Moderate Activity	97 (39)	39 (33)	15 (12)	36 (23)	27 (52)	32 (18)	55 (85)	44 (40)	0.25
Strenuous Activity	36 (15)	34 (22)	0	0	8 (15)	25 (19)	28 (43)	36 (23)	0.21
Number of Times in Past 7 Days									
Use weight machines	24 (10)	3.0 (1.1)	4 (3)	2.3 (1.0)	4 (8)	2.3 (1.3)	16 (25)	3.3 (1.0)	0.08
Body weight exercises	32 (13)	3.4 (2.1)	5 (4)	4.4 (2.4)	7 (13)	2.1 (2.4)	20 (31)	3.7 (2.0)	0.15
Use resistance bands or free weights	45 (18)	3.7 (1.9)	12 (9)	3.4 (1.6)	8 (15)	3.8 (2.8)	25 (038)	3.8 (1.7)	0.87
Holistic exercises	17 (7)	3.2 (2.3)	2 (2)	4.0 (4.2)	7 (13)	3.3 (1.9)	8 (12)	3.0 (2.6)	0.88
Minutes Per Session in Past 7 Days									
Use weight machines	24 (10)	42 (50)	4 (3)	10.0 (0)	4 (8)	40.6 (33.9)	16 (25)	50.5 (57.0)	0.36
Body weight exercises[b]	31 (13)	24 (16)	5 (4)	25.0 (20.6)	7 (13)	25.4 (17.0)	19 (29)	22.5 (15.7)	0.91
Use resistance bands or free weights[c]	41 (17)	20 (14)	12 (9)	15.6 (11.4)	8 (15)	21.3 (17.1)	21 (32)	22.7 (14.7)	0.39
Holistic exercises[d]	14 (6)	39 (31)	1 (1)	30.0 (.)	6 (13)	53.3 (39.8)	7 (11)	27.1 (19.1)	0.33
Aerobic Activity in Past 7 Days									
Light Activity	100.0 (216.5)		55.7 (174.1)		146.5 (300.4)		151.2 (196.9)		0.0030
Moderate and Vigorous Activity	24.6 (93.7)		0 (0)		5.7 (21.9)		88.8 (166.3)		< .0001
Total Combined Activity	124.5 (247.2)		55.7 (174.1)		152.2 (298.8)		240.0 (280.9)		< .0001
Strength Activity in Past 7 Days									
Use weight machines	12.1 (56.7)		0.7 (4.2)		6.8 (30.0)		39.0 (102.9)		< .0001
Body weight exercises	11.5 (47.9)		4.7 (33.4)		11.2 (58.7)		25.5 (59.3)		0.0159
Use resistance bands or free weights	11.9 (39.9)		4.5 (17.1)		15.0 (61.5)		24.3 (47.5)		0.0038
Holistic exercises	7.1 (39.5)		1.6 (18.4)		19.7 (72.1)		7.8 (31.4)		0.0194

[a]Missing $n=1$; [b]Missing $n=1$; [c]Missing $n=4$; [d]Missing $n=3$

Insufficiently active (Leisure Score Index (LSI) < 14), moderately active (14 ≤ LSI < 24), active (LSI ≥ 24), light activity (number of times and minutes in light activity in past 7 days from Godin-Shepard Leisure-Time Physical Activity Questionnaire (GSLTPQ)), moderate activity (number of times and minutes in past 7 days in moderate activity from GSLTPQ), strenuous activity (number of times and minutes in past 7 days in strenuous activity from GSLTPQ)

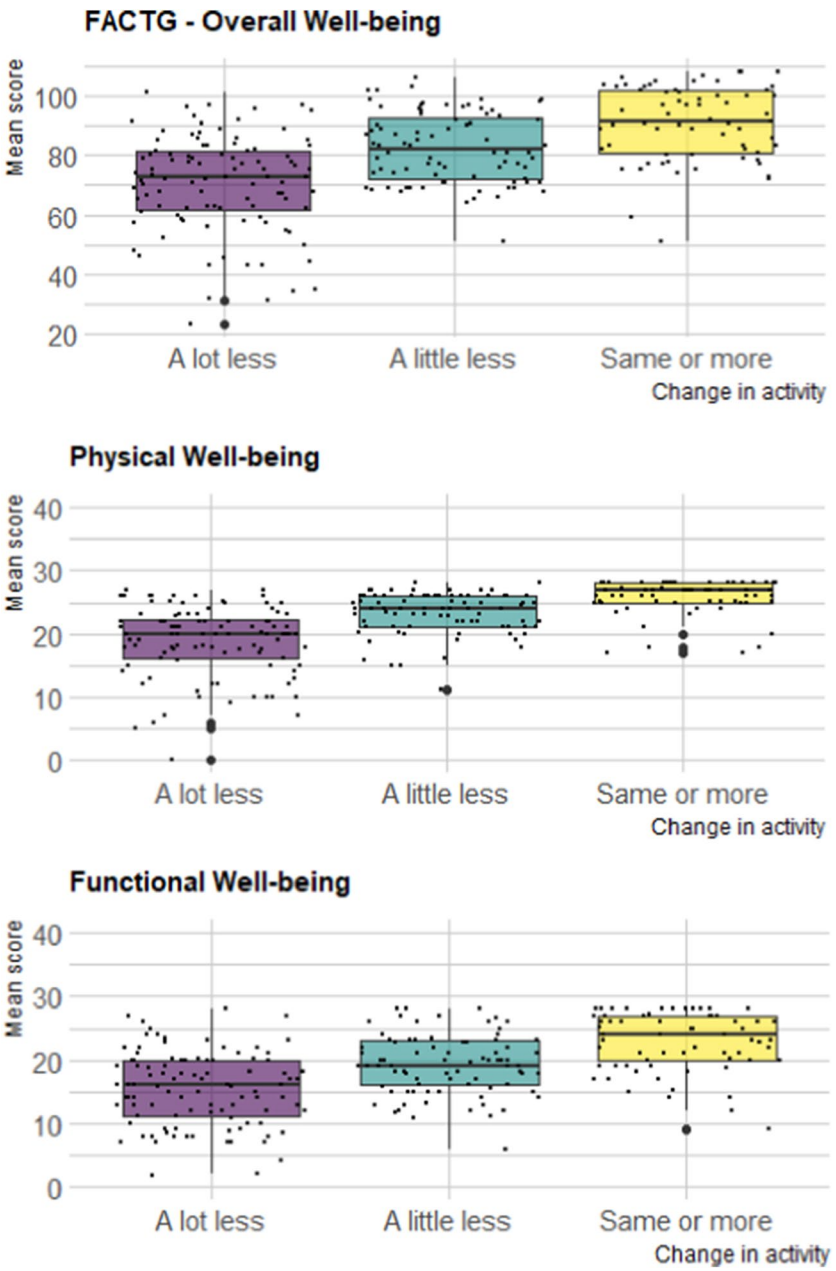

Fig. 1 Distribution of health-related quality of life operationalized by mean FACT-G overall and subscale scores (physical well-being and functional well-being) by changes in physical activity among adults living with advanced cancer (diagnosed between 2021 and 2023). *Note:* FACT-G (Functional Assessment of Cancer Therapy – General); Sample sizes and means, 95% confidence intervals of means, F-test values, and p-values are displayed in Supplementary Table S1. P-values were generated using analysis of variance (ANOVA) tests to assess whether differences exist between the mean scores of the three groups. Significance is determined by P-value ≤ 0.05

Differences in PROMIS mean scores

Adults who were "a lot less active" since diagnosis reported lower PROMIS physical function scores and higher fatigue and pain interference scores compared to those who were "a little less active" or "the same or more active" (Fig. 2). Adults who were "a lot less active" since diagnosis had a physical function mean score of 40.3 (95% CI: 38.8, 41.8; $p < 0.0001$), which was clinically meaningful (i.e., a 3-point difference in score (31,37)) compared to "a little less active" ($\bar{x} = 47.3$; 95% CI: 45.6, 48.9; $p < 0.0001$) and "the same or more active" adults ($\bar{x} = 52.5$; 95% CI: 50.6, 54.3; $p < 0.0001$). Those who were "a lot less active" had a physical function mean score corresponding to moderate impairment (30–40), while the other two activity group's scores were within normal limits (≥ 45). Adults who were "the same or more active" since diagnosis reported the lowest fatigue scores compared to adults reporting "a little less" or "a lot less" activity since diagnosis. Fatigue scores ranged from moderate impairment (55–74) among those "a lot less active" since diagnosis, 59.3 (95% CI: 57.5, 61.1; $p < 0.0001$) mild impairment (50–54) for those "a little less active", 51.4 (95% CI: 49.4, 53.5; $p < 0.0001$), and

Table 3 Association between changes in physical activity and health-related quality of life (FACT-G) among adults living with advanced cancer (diagnosed between 2021 and 2023) ($n = 247$). Linear regression models were adjusted for physical activity level, education, gender, age (categorical), marital status, cancer type, functional comorbidity index score (categorical), on treatment status, and urbanicity. Significance is determined by P-value ≤ 0.05

	Model: Overall FACT-G			Model: Physical			Model: Social			Model: Emotional			Model: Functional		
Parameter	Beta Estimate	95% CI	P-value	Beta Estimate	95% CI	P-value	Beta Estimate	95% CI	P-value	Beta Estimate	95% CI	P-value	Beta Estimate	95% CI	P-value
Activity Change *(ref = Same or more active)*			< .0001			< .0001			0.01			0.003			< .0001
A little less active	−6.05	(−10.59, −1.50)		−1.71	(−3.12, −0.31)		−0.40	(−2.16, 1.36)		−1.21	(−2.58, 0.17)		−2.72	(−4.46, −0.99)	
A lot less active	−17.21	(−21.96, −12.46)		−6.07	(−7.54, −4.59)		−2.42	(−4.26, −0.59)		−2.49	(−3.93, −1.06)		−6.22	(−8.03, −4.42)	
Activity Level (ref = Insufficiently active)			0.02			0.11			0.02			0.76			0.10
Active	2.36	(−2.35, 7.07)		0.84	(−0.62, 2.30)		0.84	(−0.98, 2.67)		0.19	(−1.24, 1.6)		0.48	(−1.31, 2.28)	
Moderately active	6.26	(1.80, 10.71)		1.47	(0.09, 2.85)		2.44	(0.72, 4.17)		0.51	(−0.84, 1.86)		1.84	(0.14, 3.53)	

FACT-G (Functional Assessment of Cancer Therapy – General), 95% CI (95% confidence interval), ref = Reference group; P-value is for the Type III tests of fixed effects of multiple linear regression models. Activity change categories represent self-reported current level of physical activity compared to physical activity prior to their cancer diagnosis (1) a little less activity, (2) a lot less activity, (3) the same activity/a little more or a lot more activity

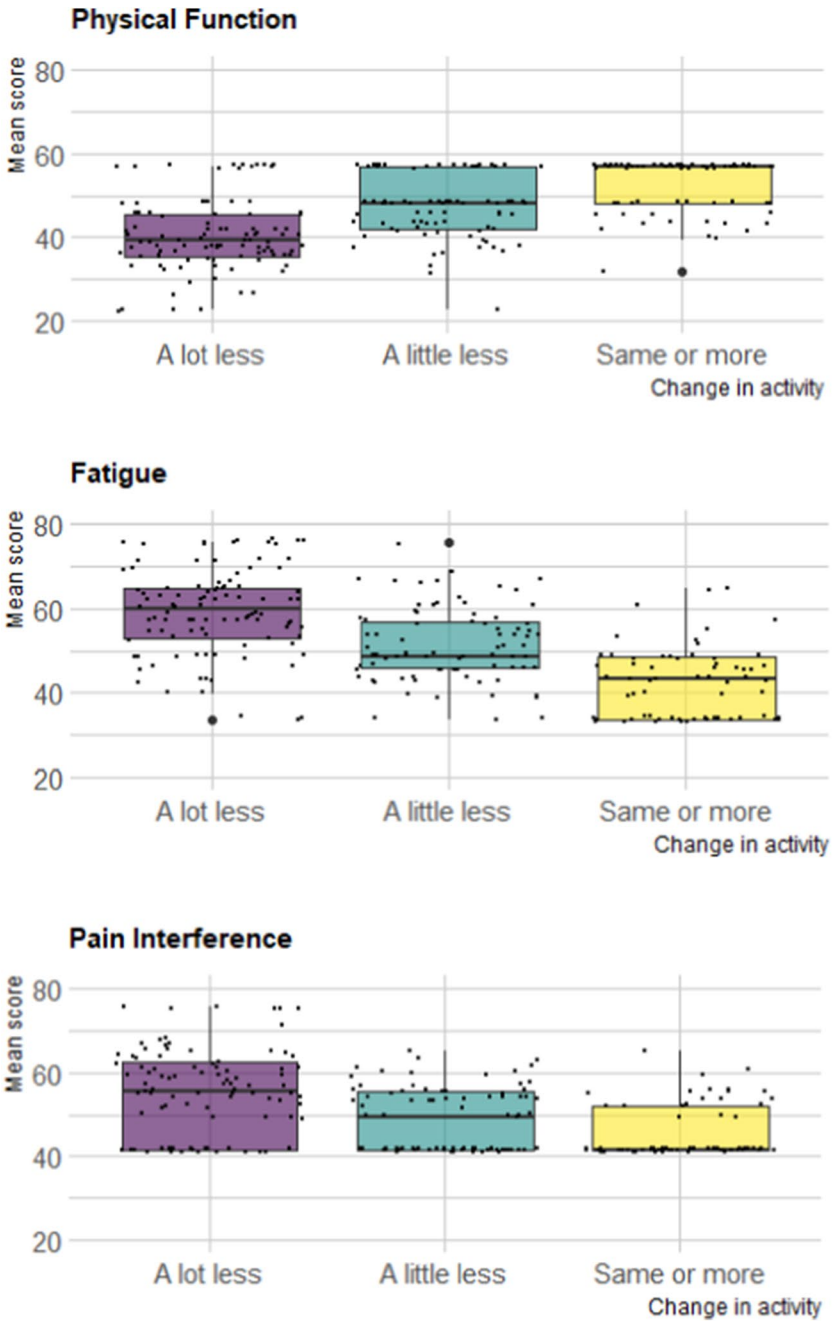

Fig. 2 Distribution of health-related quality of life as operationalized by mean PROMIS scores by changes in physical activity since diagnosis among adults living with advanced cancer (diagnosed between 2021 and 2023). *Note:* PROMIS (Patient-Reported Outcomes Measurement Information System); Sample sizes and means, 95% confidence intervals of means, F-values, and p-values are displayed in Supplementary Table S1. P-values were generated using analysis of variance (ANOVA) tests to assess whether differences exist between the mean scores of the three groups. Significance is determined by P-value ≤ 0.05

within normal limits (< 50) for those "the same or more active", 42.3 (95% CI: 40.0, 44.6; $p < 0.0001$). Adults who were "the same or more active" since diagnosis also reported the lowest pain interference scores, 45.6 (95% CI: 43.5, 47.6; $p < 0.0001$), compared to "a little less active", 48.8 (95% CI: 47.0, 50.7; $p < 0.0001$), or "a lot less active" adults, 55.5 (95% CI: 53.8, 57.2; $p < 0.0001$); those "a lot less active" had mild impairment (50–59) of pain interference, while the other two groups were within normal limits (< 50).

PROMIS linear regression

We found an association between worse (i.e., more impairment) physical function, fatigue, and pain interference scores for those "a lot less active" or "a little less active" compared to those who were "the same or more active" since diagnosis, after adjustment for physical activity level, clinical, and demographic characteristics (Table 4). Adults who reported being "a lot less active" and "a little less active" had physical function scores of 8.88 (95% CI: −11.46, −6.29; $p < 0.0001$)

Table 4 Association between changes in physical activity and health-related quality of life (PROMIS) domains of physical function, fatigue, and pain interference among adults living with advanced cancer (diagnosed between 2021 and 2023). Linear regression models were adjusted for physical activity level, education, gender, age (categorical), marital status, cancer type, functional comorbidity index score (categorical), on treatment status, and urbanicity. Significance is determined by P-value ≤ 0.05

	Model: Physical Function ($n=245$)			Model: Fatigue ($n=244$)			Model: Pain Interference ($n=243$)		
Parameter	Beta Estimate	95% CI	P-value	Beta Estimate	95% CI	P-value	Beta Estimate	95% CI	P-value
Activity Change *(ref = Same or more active)*			< .0001			< .0001			< .0001
A little less active	−3.14	(−5.62, −0.65)		7.88	(4.69, 11.07)		1.99	(−0.94, 4.91)	
A lot less active	−8.88	(−11.46, −6.29)		14.83	(11.52, 18.14)		8.54	(5.49, 11.58)	
Activity Level *(ref = Insufficiently active)*			0.006			0.14			0.04
Active	2.67	(0.12, 5.22)		−2.67	(−5.95, 0.61)		0.70	(−2.33, 3.72)	
Moderately active	3.78	(1.37, 6.19)		−2.71	(−5.82, 0.40)		−3.09	(−5.95, −0.23)	

PROMIS (Patient-reported outcome measurement information system), 95% CI (95% confidence interval), ref = Reference group; P-value is for the Type III tests of fixed effects of multiple linear regression models. Activity change categories represent self-reported current level of physical activity compared to physical activity prior to their cancer diagnosis (1) a little less activity, (2) a lot less activity, (3) the same activity/a little more or a lot more activity

and 3.14 points lower (95% CI: −5.62, −0.65; $p < 0.0001$), respectively, compared to those who were "the same or more active". Adults who reported being "a lot less active" and "a little less active" had fatigue scores of 14.83 (95% CI: 11.52, 18.14; $p < 0.0001$) and 7.88 points higher (95% CI: 4.69, 11.07; $p < 0.0001$), respectively, compared to those "the same or more active". Adults who reported being "a lot less active" and "a little less active" had pain scores of 8.54 (95% CI: 5.49, 11.58; $p < 0.0001$) and 1.99 points higher (95% CI: −0.94, 4.91; $p < 0.0001$), respectively, compared to those "the same or more active" since diagnosis.

Discussion

Our study assessed current physical activity levels and changes in physical activity since cancer diagnosis with health-related quality of life among a US-based sample of adults living with advanced cancer. We found that 53% of adults living with advanced cancer were considered insufficiently active using the LSI cutoffs, and while only 6% of our sample was meeting the MVPA guideline of 150 min or more per week, 27% of respondents were meeting the strength guideline. A study conducted by Bail et al. (2022) of metastatic cancer patients in Alabama found higher levels of moderate-vigorous intensity minutes per week, but lower levels of light-intensity minutes per week among their sample [38]. However, they did not assess strength-based activity separately, which could have led to different estimates of physical activity engagement. Assessing three intensities of aerobic activity and types of strength-based activities, using two validated instruments, is a strength of our analysis and demonstrates important trends in activity engagement among adults with advanced cancer.

We observed a decline in physical activity since diagnosis for 74% of respondents, which we found to be associated with worse health-related quality of life. Although our respondents had a mean FACT-G score (79.7) similar to a reference study of adults with and without cancer (the mean FACT-G score for adults with cancer was 80.9 and without cancer was 80.1) [36], clinically meaningful differences emerged by changes in physical activity since diagnosis. The group in our sample most similar to the reference study FACT-G mean scores by Brucker et al. (2005) of adults with cancer (all stages) was the group engaging in "a little less activity" (82.6) with clinically meaningful differences among the other activity groups [36]. Our findings using the PROMIS measures closely align with a study by Jensen et al. (2017) which found similar deficits in their sample of patients with stage IV cancer compared to our sample of adults engaging in "a lot less activity" [37]. We found similar levels of physical function (40.3 v J: 41.1) and pain interference (55.5 v J: 55.2), but lower levels of fatigue (59.3 v J: 55.8) in our sample of adults engaging in a lot less activity [37]. They also found levels of impairment worsened in those with stage IV cancer compared to the other cancer stages [37].

Clinically meaningful differences are useful when comparing health-related quality of life scores because these are the differences in outcomes that matter to patients. Our study of adults living with advanced cancer had an overall mean FACT-G score of 80, which was similar to a US-based cancer survivor sample that included multiple cancer types and stages and had an overall mean score of 81 [36], suggesting

a lack of a clinically meaningful difference in scores of our sample compared to these reference populations. However, we found an association between greater reductions in physical activity and lower health-related quality of life scores, which ranged from 17.21 points lower for those "a lot less active" and 6.05 points lower for those "a little less active" compared to those reporting "the same or more active," demonstrating clinically meaningful differences in health-related quality of life between the activity groups.

Recommendations by the American Cancer Society (ACS) and the American College of Sports Medicine (ACSM) encourage those living with cancer to move more and sit less, because even a little activity is better than none [7, 8]. Our study found that adults with advanced cancer who were moderately active or active reported higher health-related quality of life compared to those who were insufficiently active. These findings support the ACS and ACSM recommendations and underscore the importance of engaging in physical activity after diagnosis. Given our findings, future research aimed at improving the health-related quality of life of adults living with advanced cancer should focus on regularly assessing patients' functional status and finding ways to improve their physical function, reduce fatigue, and manage pain. An important future research direction is to determine feasible and acceptable interventions to encourage physical activity post-diagnosis. Interventions should be designed to incorporate light-intensity activities, including muscle-strengthening activities, to serve as an initial target for improving physical activity, as these activities are likely to be more accessible for adults living with advanced cancer.

Strengths and Limitations

The strengths of our study included a specific focus on the understudied population of adults living with advanced cancer. We included those with diverse cancer types (including both solid tumors and hematologic malignancies), facilitating a range of perspectives within the advanced cancer population. In addition, our study used well-validated measures of health-related quality of life and physical activity.

The limitations of our study included the cross-sectional nature of our data, which limited the evaluation of physical activity in real-time and changes in health-related quality of life over time. The self-reported physical activity data, as opposed to accelerometers or other wearables, may have led to an overestimation of physical activity levels among respondents. However, a study of physical activity in breast cancer survivors found a strong correlation between accelerometry and self-report data using the GSLTPAQ, with a mean difference in moderate-vigorous activity estimates of less than 5 min [21]. In addition, they found those over the age of 60 underestimated their self-reported activity. We also had potential for two types of bias: (1) healthy responder bias, as respondents were likely healthier than the average advanced cancer patient, and (2) recall bias, since data collection (collected at a single time point) relied on respondents recalling changes in activity since before their diagnosis. Finally, our study was restricted to one cancer center in the Midwest, limiting the generalizability of our results.

Conclusions

Adults living with advanced cancer face potential declines in physical activity following their diagnosis. Our study provides evidence that those engaging in less activity since their advanced cancer diagnosis experience lower levels of physical function and higher levels of pain and fatigue compared to those engaging in the same or more activity since diagnosis. In addition, we found an association between a reduction in physical activity and a lower health-related quality of life. This study provides insight regarding incorporating and promoting light-intensity activities among this growing population of adults living with advanced cancer. Future interventions should consider ways to encourage adults living with advanced cancer to prevent physical activity declines following their diagnosis.

Abbreviations PA: Physical activity; HRQoL: Health-related quality of life; UWCCC: University of Wisconsin Carbone Cancer Center; FACT-G: Functional Assessment of Cancer Therapy – General; PROMIS: Patient-Reported Outcomes Measurement Information System; ACS: American Cancer Society; ACSM: American College of Sports Medicine; NCI: National Cancer Institute; SEER: Surveillance, Epidemiology, and End Results; CHI2: Clinical and Health Informatics Institute; GSLTPQ: Godin-Shepard Leisure-Time Physical Activity Questionnaire; MSEQ: Muscle-Strength Exercise Questionnaire; FCI: Functional Comorbidity Index; REDCap: Research Electronic Data Capture; LSI: Leisure Score Index; MET: Metabolic equivalents of task; ANOVA: Analysis of variance

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00520-025-09196-0.

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Author contributions Conceptualization: MA; Methodology: MA, RG; Formal analysis and investigation: MA, SWA; Writing—original draft preparation: MA; Writing—review and editing: MA, SWA, KK, ATD, RG, CS; Funding acquisition: LCB; Resources: LCB; Supervision: LCB and SWA.

Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate This study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments. This study was approved as minimal risk by the University of Wisconsin-Madison's Minimal Risk Institutional Review Board (Protocol #2022–0966) and by the University of Wisconsin's Carbone Cancer Center's (UWCCC) Protocol Review and Monitoring Committee (Protocol UW22103).

Consent for publication An IRB approved study information sheet was mailed along with the survey. Informed consent.

from the respondent was obtained through the voluntary return of the survey.

Competing interests The authors declare no competing interests.

References

1. American Cancer Society (2020) Understanding advanced and metastatic cancer. https://www.cancer.org/treatment/understanding-your-diagnosis/advanced-cancer/what-is.html. Accessed 13 Apr 2022
2. National Cancer Institute (2011) NCI Dictionary of cancer terms: advanced Cancer. https://www.cancer.gov/publications/dictionaries/cancer-terms/def/advanced-cancer. Accessed 13 Feb 2023
3. Mollica MA, Smith AW, Tonorezos E, Castro K, Filipski KK, Guida J et al (2022) Survivorship for individuals living with advanced and metastatic cancers: National Cancer Institute meeting report. J Natl Cancer Inst 114(4):489–495
4. Howlader N, Forjaz G, Mooradian MJ, Meza R, Kong CY, Cronin KA et al (2020) The effect of advances in lung-cancer treatment on population mortality. N Engl J Med 383(7):640–649
5. Mariotto AB, Etzioni R, Hurlbert M, Penberthy L, Mayer M (2017) Estimation of the number of women living with metastatic breast cancer in the United States. Cancer Epidemiol Biomark Prev Publ Am Assoc Cancer Res Cosponsored Am Soc Prev Oncol 26(6):809–815
6. Wang T, Molassiotis A, Chung BPM, Tan JY (2018) Unmet care needs of advanced cancer patients and their informal caregivers: a systematic review. BMC Palliat Care 17(1):96
7. Rock CL, Thomson CA, Sullivan KR, Howe CL, Kushi LH, Caan BJ et al (2022) American Cancer Society nutrition and physical activity guideline for cancer survivors. CA Cancer J Clin 72(3):230–262
8. Campbell KL, Winters-Stone K, Wiskemann J, May AM, Schwartz AL, Courneya KS et al (2019) Exercise guidelines for cancer survivors: consensus statement from international multidisciplinary roundtable. Med Sci Sports Exerc 51(11):2375–2390
9. Irwin ML, Crumley D, McTiernan A, Bernstein L, Baumgartner R, Gilliland FD et al (2003) Physical activity levels before and after a diagnosis of breast carcinoma. Cancer 97(7):1746–1757
10. Toohey K, Chapman M, Rushby AM, Urban K, Ingham G, Singh B (2023) The effects of physical exercise in the palliative care phase for people with advanced cancer: a systematic review with meta-analysis. J Cancer Surviv Res Pract 17(2):399–415
11. Meyerhardt JA, Giovannucci EL, Holmes MD, Chan AT, Chan JA, Colditz GA et al (2006) Physical activity and survival after colorectal cancer diagnosis. J Clin Oncol Off J Am Soc Clin Oncol 24(22):3527–3534
12. Sheill G, Guinan E, Neill LO, Hevey D, Hussey J (2018) The views of patients with metastatic prostate cancer towards physical activity: a qualitative exploration. Support Care Cancer Off J Multinatl Assoc Support Care Cancer 26(6):1747–1754
13. Chen YJ, Li XX, Ma HK, Zhang X, Wang BW, Guo TT et al (2020) Exercise training for improving patient-reported outcomes in patients with advanced-stage cancer: a systematic review and meta-analysis. J Pain Symptom Manage 59(3):734-749.e10
14. Knowlton SE, O'Donnell EK, Horick N, Perez GK, Park E, Rabin J et al (2020) Moving forward on all fronts: impact, patterns, and barriers to exercise in cancer survivors and patients living with advanced disease. Support Care Cancer Off J Multinatl Assoc Support Care Cancer 28(10):4979–4988
15. Tsianakas V, Harris J, Ream E, Hemelrijck MV, Purushotham A, Mucci L et al (2017) CanWalk: a feasibility study with embedded randomised controlled trial pilot of a walking intervention for people with recurrent or metastatic cancer. BMJ Open 7(2):e013719
16. Nekhlyudov L, Campbell GB, Schmitz KH, Brooks GA, Kumar AJ, Ganz PA et al (2022) Cancer-related impairments and functional limitations among long-term cancer survivors: Gaps and opportunities for clinical practice. Cancer 128(2):222–229
17. Patel VR, Hussaini SMQ, Blaes AH, Morgans AK, Haynes AB, Adamson AS et al (2023) Trends in the prevalence of functional limitations among US cancer survivors, 1999–2018. JAMA Oncol 9(7):1001–1003
18. National Cancer Institute. SEER*Explorer Application. https://seer.cancer.gov/statistics-network/explorer/application.html?site=1&data_type=1&graph_type=2&compareBy=sex&chk_sex_3=3&chk_sex_2=2&rate_type=2&race=1&age_range=1&hdn_stage=101&advopt_precision=1&advopt_show_ci=on&hdn_view=0&advopt_show_apc=on&advopt_display=2. Accessed 1 Aug 2024
19. Dillman DA, Smyth JD, Christian LM (2014) Internet, phone, mail, and mixed mode surveys: The tailored design method, 4th ed. Hoboken, NJ, US: John Wiley & Sons Inc; xvii, 509 p. (Internet, phone, mail, and mixed mode surveys: The tailored design method, 4th ed)
20. Godin G (2011) The Godin-Shephard leisure-time physical activity questionnaire. Health Fit J Can 4(1):18–22
21. Welch W, Ulrich G, Salerno E, Siddique J, Mcauley E, Phillips S (2018) Measurement of physical activity and sedentary behavior in breast cancer survivors. J Community Support Oncol 19(16):e21–e29
22. Shakespear-Druery J, De Cocker K, Biddle SJH, Bennie J (2022) Muscle-strengthening exercise questionnaire (MSEQ) : an assessment of concurrent validity and test–retest reliability. BMJ Open Sport Exerc Med 8(1). https://hdl.handle.net/1854/LU-8771343. Accessed 1 Aug 2024
23. Yost K, Thompson C, Eton D, Allmer C, Ehlers S, Habermann T et al (2013) The Functional Assessment of Cancer Therapy – General (FACT-G) is valid for monitoring quality of life in non-Hodgkin lymphoma patients. Leuk Lymphoma 54(2):290–297
24. Cella DF, Tulsky DS, Gray G, Sarafian B, Linn E, Bonomi A et al (1993) The Functional Assessment of Cancer Therapy scale: development and validation of the general measure. J Clin Oncol Off J Am Soc Clin Oncol 11(3):570–579
25. Rose M, Bjorner JB, Gandek B, Bruce B, Fries JF, Ware JE (2014) The PROMIS Physical Function item bank was calibrated to a standardized metric and shown to improve measurement efficiency. J Clin Epidemiol 67(5):516–526
26. Rose M, Bjorner JB, Becker J, Fries JF, Ware JE (2008) Evaluation of a preliminary physical function item bank supported the expected advantages of the Patient-Reported Outcomes Measurement Information System (PROMIS). J Clin Epidemiol 61(1):17–33
27. Lai JS, Cella D, Choi S, Junghaenel DU, Christodoulou C, Gershon R et al (2011) How item banks and their application can

influence measurement practice in rehabilitation medicine: a PROMIS fatigue item bank example. Arch Phys Med Rehabil 92(10, Supplement):S20-7
28. Cella D, Choi SW, Condon DM, Schalet B, Hays RD, Rothrock NE et al (2019) PROMIS® adult health profiles: efficient short-form measures of seven health domains. Value Health J Int Soc Pharmacoeconomics Outcomes Res 22(5):537–544
29. Jensen RE, Potosky AL, Reeve BB, Hahn E, Cella D, Fries J et al (2015) Validation of the PROMIS physical function measures in a diverse US population-based cohort of cancer patients. Qual Life Res Int J Qual Life Asp Treat Care Rehabil 24(10):2333–2344
30. Amtmann D, Cook KF, Jensen MP, Chen WH, Choi S, Revicki D et al (2010) Development of a PROMIS item bank to measure pain interference. Pain 150(1):173–182
31. Yost KJ, Eton DT, Garcia SF, Cella D (2011) Minimally important differences were estimated for six Patient-Reported Outcomes Measurement Information System-Cancer scales in advanced-stage cancer patients. J Clin Epidemiol 64(5):507–516
32. Rothrock NE, Cook KF, O'Connor M, Cella D, Smith AW, Yount SE (2019) Establishing clinically-relevant terms and severity thresholds for Patient-Reported Outcomes Measurement Information System® (PROMIS®) measures of physical function, cognitive function, and sleep disturbance in people with cancer using standard setting. Qual Life Res Int J Qual Life Asp Treat Care Rehabil 28(12):3355–3362
33. Cella D, Choi S, Garcia S, Cook KF, Rosenbloom S, Lai JS et al (2014) Setting standards for severity of common symptoms in oncology using the PROMIS item banks and expert judgment. Qual Life Res Int J Qual Life Asp Treat Care Rehabil 23(10):2651–2661
34. Groll DL, To T, Bombardier C, Wright JG (2005) The development of a comorbidity index with physical function as the outcome. J Clin Epidemiol 58(6):595–602
35. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L et al (2019) The REDCap consortium: Building an international community of software platform partners. J Biomed Inform 95:103208
36. Brucker PS, Yost K, Cashy J, Webster K, Cella D (2005) General population and cancer patient norms for the Functional Assessment of Cancer Therapy-General (FACT-G). Eval Health Prof 28(2):192–211
37. Jensen RE, Potosky AL, Moinpour CM, Lobo T, Cella D, Hahn EA et al (2017) United States population-based estimates of patient-reported outcomes measurement information system symptom and functional status reference values for individuals with cancer. J Clin Oncol 35(17):1913–1920
38. Bail JR, Bail SV, Cagle J, Tiesi K, Caffey J, Bakitas M et al (2022) Health behaviors and well-being among those "living" with metastatic cancer in Alabama. Support Care Cancer 30(2):1689–1701

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