ORIGINAL RESEARCH

Changes in physical activity and associations with quality of life among a global sample of cancer survivors during the COVID-19 pandemic

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Abstract

Purpose Meeting physical activity (PA) guidelines (i.e., ≥ 150 min/week of aerobic PA and/or 2 days/week of resistance training) is beneficial for maintaining cancer survivors' well-being. The impact of the COVID-19 pandemic on PA participation in cancer survivors and its association on quality of life (QoL) remains unknown. The purpose of this study was to compare PA levels prior to and during the COVID-19 pandemic, and examine the association between changes in PA and QoL in cancer survivors.

Methods A global sample of cancer survivors participated in a cross-sectional, online survey. Participants self-reported their PA participation before and during the pandemic using the Godin Leisure Time Exercise Questionnaire and QoL with the Functional Assessment of Cancer Therapy (FACT) scales. Paired t-tests compared PA before and during the pandemic. Analysis of covariance examined differences in QoL between PA categories: non-exercisers, inactive adopters, complete and partial relapsers, single and combined guideline maintainers.

Results PA participation of cancer survivors ($N = 488$) significantly decreased during the pandemic (p's $< .001$). Cancer survivors were classified as non-exercisers (37.7%), inactive adopters (6.6%), complete (13.1%) and partial (6.1%) relapsers, and single (23.8%) or combined (12.7%) guideline maintainers. Partial relapsers had significantly lower QoL and fatigue than inactive adopters, and combined guideline maintainers (p's $< .05$) that were clinically meaningful.

Conclusion PA decreased during the pandemic which has negative implications for QoL and fatigue in cancer survivors.

Implications for Cancer Survivors PA is critical for maintaining QoL during the pandemic; therefore, behavioral strategies are needed to help cancer survivors adopt and maintain PA.

Keywords COVID-19 · Physical activity · Quality of life · Cancer

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Introduction

In March 2020, the World Health Organization declared the novel coronavirus (SARS-CoV-2) a global pandemic (COVID-19) [1]. In February 2021, nearly 1 year since the start of the pandemic, 223 countries have been affected with 108,822,960 confirmed cases and 2,403,641 deaths from COVID-19 [2]. The landscape of cancer care has undergone substantial changes including delays in screening, detection, and non-urgent appointments, changes to treatment delivery, and a widespread utilization of telemedicine [3–6]. This shift in care and disruptions to typical support options (e.g., social workers, financial advising, support from others) [7, 8] is likely to have negative implications on the already compromised physical and mental well-being of cancer survivors during the pandemic [9–14]. Cancer survivors, here

referring to any individual who has previously received a cancer diagnosis [15], have reported worry surrounding health and safety, heightened symptoms of depression, anxiety, fatigue, and loneliness or isolation, and poorer global and domain-specific (i.e., social, emotional, role, and cognitive functioning) quality of life (QoL) since the COVID-19 pandemic [9–12, 16].

Since the start of the pandemic, there has been a call to action for the promotion of physical activity (PA) for individuals diagnosed with cancer [17, 18]. Substantial research conducted prior to the pandemic indicates that PA is beneficial for maintaining the health and well-being, reducing anxiety and depression, and improving physical functioning, cancer-related fatigue, and QoL of cancer survivors [19–21]. PA can also reduce the risk of common comorbidities (e.g., hypertension, diabetes) that further increase susceptibility for severe COVID-19 outcomes and has a potentially immuno-protective effect [22]. Together, this indicates that the uptake and maintenance of PA during the pandemic is critical [17, 18, 22]. It is recommended that cancer survivors engage in a minimum of 150 min/week of moderate-to-vigorous aerobic PA (MVPA) and at least 2 days of resistance training for optimal health benefits, or 30 min of MVPA and/or resistance training, three times per week for cancer-specific benefits [23]. Uptake of these guidelines is low with 46–63% of cancer survivors meeting neither aerobic nor resistance training guidelines and few meeting aerobic only (16–22%), resistance only (7–10%), or combined guidelines (10–20%) [24–26]. Physical distancing measures to help minimize spread of COVID-19 may impose additional and novel barriers to engaging in PA for cancer survivors (e.g., closure of fitness facilities), leading to further reductions in PA participation [17, 18, 27]. Worldwide, general adult populations have reported a substantial reduction in PA [28–32], with between 18 and 34% relapsing to inactivity [30, 32, 33]. Furthermore, these reductions in PA have been associated with poorer mental health outcomes such as increased stress, anxiety, and depressive symptoms [32, 34].

There is considerable evidence prior to the pandemic indicating that regular aerobic and resistance training performed both independently and concurrently can lead to more favorable QoL in cancer survivors [20, 35, 36]. It is uncertain whether these associations between PA and QoL hold true amidst the novel threats to cancer survivors' well-being presented by the COVID-19 pandemic. Thus, understanding the impact of the pandemic on the PA behaviors and QoL of cancer survivors is an essential first step needed to inform effective strategies for improving PA and subsequent health outcomes [38]. To our knowledge, only one study to date has examined PA participation of cancer survivors during the pandemic [27]. In a cross-sectional survey of cancer survivors who previously participated in an exercise program designed for cancer survivors ($n=61$), 67.2% of participants self-reported a decrease in PA [27]. Though this study suggests COVID-19 has negative implications for cancer survivors, the relationship between PA changes and QoL during the pandemic remains unexplored. Work in larger, population-based samples is needed to substantiate these findings and determine the relationship between changes in PA and QoL during the COVID-19 pandemic. Therefore, the primary purpose of this study was to examine changes in PA participation of cancer survivors since the start of the COVID-19 pandemic. Secondary objectives included examining the association between QoL of cancer survivors during the COVID-19 pandemic and change in PA participation across various categories: non-exercisers, inactive adopters, complete relapsers, partial relapsers, and single and combined guideline maintainers. Based on research in healthy populations during the COVID-19 pandemic [31, 32], it is hypothesized that cancer survivors adopting or maintaining PA will have higher QoL compared to relapsers and those remaining inactive.

Methods

Design

A cross-sectional, self-administered online survey was conducted between July and November 2020. Informed consent was provided prior to partaking in the study. Ethics approval was obtained from the University of Toronto's Research Ethics Board.

Study participants

Eligibility for the study included the following: (a) ≥ 18 years of age, (b) diagnosed with any cancer, and (c) able to complete the survey in English. There were no geographical constraints on who could participate in the study. Eligibility was self-reported after providing informed consent.

Cancer survivors received direct access to the survey on REDCap through a publicly available link on online recruitment materials or through Prolific. The survey took an estimated 45 min to complete. Cancer survivors were recruited using an existing database of survivors previously consenting to being contacted for future research, community cancer organizations, social media, and word of mouth. In addition, the survey was posted on Prolific (www.prolific.co), an international online survey distribution service. Participants recruited through community organizations had the option to enter into a draw to win 1 of 6 $25 CAD Amazon gift cards, and participants using Prolific were compensated with $6.50 CAD via PayPal for their participation.

Measures

Demographic and clinical characteristics

Commonly reported demographic (e.g., gender, age, ethnicity) and clinical (e.g., treatment type, current cancer status) characteristics were self-reported [39–41].

COVID-19 prevention measures

Researcher-generated questions assessed personal and government-mandated COVID-19 infection control measures. Cancer survivors self-reported the country that they were residing in at the time of study participation. For government-mandated prevention measures, the following question was asked "What measures are currently enacted in your country/region in order to reduce the spread of COVID-19?" Response options included "complete lockdown," "mandatory shelter-in-place," "suggested shelter-in-place," "social distancing," "other," or "none." To assess personal measures, participants were asked "What measures have you personally taken to ensure personal health and safety during the COVID-19 pandemic, regardless of regional mandates?" Response options assessed isolation for various reasons including suspected or diagnosed COVID-19 case, experiencing symptoms, recent travel, or perceived vulnerability, social/physical distancing, and relocation from home.

Physical activity

PA participation was assessed using a modified version of the Godin Leisure Time Exercise Questionnaire (GLETQ) [42] which has been used extensively in cancer populations [e.g., 40, 41, 43, 44]. Participants were asked to recall their average weekly leisure time PA *prior to* and *since the start* of the COVID-19 outbreak in their country/region. Using an open response format, participants reported the frequency (i.e., sessions per week) and the average duration (i.e., minutes/session) of time spent performing light, moderate, and vigorous aerobic activity and resistance training for a typical week during these timeframes. The GLETQ has reliability coefficients of 0.83 and 0.85 [42].

Consistent with the current aerobic guidelines (i.e., ≥ 150 min of moderate PA or 75 min of vigorous PA) [23, 45], MVPA was calculated by summing the total weekly moderate PA and two times the weekly vigorous PA. Performing resistance training at least two times per week was considered meeting resistance training guidelines. Participants were classified into meeting neither guidelines, aerobic only, resistance training only, and combined guidelines for both before and during the pandemic. Change in MVPA participation was further categorized into six PA change classifications: non-exercisers (i.e., not meeting guidelines),

inactive adopters (i.e., meeting any guideline during COVID-19, but not prior to), complete relapsers (i.e., meeting any guideline prior to, but not during COVID-19), partial relapsers (i.e., meeting combined guidelines prior to, but only a single guideline during the pandemic), single guideline maintainers (i.e., meeting a single guideline prior to and during COVID-19), and combined guideline maintainers (i.e., meeting any guideline prior to, and combined guidelines after).

Quality of life

QoL was measured using the Functional Assessment of Cancer Therapy (FACT) scales [46, 47]. The FACT-General is a 27-item questionnaire comprised of four subscales, physical well-being (PWB), social well-being (SWB), emotional well-being (EWB), and functional well-being (FWB) [46, 47]. The FACT-Fatigue includes the FACT-General with an additional 13-item fatigue subscale. PWB, FWB, and fatigue subscales are summed to form the Trial Outcome Index-Fatigue (TOI-Fatigue) scale. Higher FACT scale scores indicate better QoL. Psychometric properties including coefficients of reliability and validity were high and the scale is responsive to clinical change. Internal consistency (Cronbach's α) for the FACT-General and FACT-Fatigue scale was 0.92 and 0.95, respectively. Test–retest correlation coefficients was 0.92 for FACT-General and 0.87 for the FACT-Fatigue scale [46, 47].

Statistical analysis

Statistical analyses were conducted in R environment for statistical computing (Version 4.1.0). To minimize bias from participants who may be carelessly responding to survey questions, several post hoc methods within the Careless R package [48] were used to determine responses at a high risk of careless responding. These methods included the longstring index (i.e., longest string of the same response), Mahalanobis distance (i.e., multivariate outlier detection), and psychometric synonyms (i.e., within-person correlations between highly positively correlated scale items [critical value = 0.55]) [49, 50]. Any responses with a Mahalanobis distance z-score of > 3.0, a negative psychometric synonyms index, and a longstring index of > 15 and failed reverse-worded items on the FACT-General and FACT-Fatigue scales were considered high risk of careless responding and removed from the analysis. Descriptive statistics were used to describe the sample and COVID-19 prevention measures. Paired-sample t-tests were used to compare PA participation (i.e., minutes/week) before and during the COVID-19 pandemic. Pearson's chi-square tests were conducted to compare prevalence of meeting modality-specific PA guidelines from pre-pandemic to during the pandemic.

Separate analyses of covariance (ANCOVAs) for the FACT-General, FACT-Fatigue, and TOI-Fatigue were conducted to examine the difference in QoL across PA change categories. All models were adjusted for the following covariates (determined a priori): age, gender, body mass index (BMI), cancer type, cancer spread, current cancer status, number of months since diagnosis, and months since last treatment. Tukey's HSD post hoc comparisons were conducted on all models reporting statistically significant differences in QoL scores across the PA change categories. Results were interpreted in both their statistical and clinical significance. Statistical significance was set at $p < 0.05$. Minimally important differences (MIDs) were used to determine if differences in QoL between PA groups were clinically meaningful. MIDs for the FACT-General, FACT-Fatigue, and TOI-Fatigue are 3, 7, and 5 points, respectively [51].

Results

Sample characteristics

Participant flow through the study is presented in Fig. 1. Of the 592 participants' responses, 12 were excluded because they indicated they were not diagnosed with cancer, did not provide any cancer-related information, or did not complete the study in English as per the study's inclusion criteria. Of the remaining 580 survey responses, 516 provided complete PA and QoL responses (i.e., completed ≥ 50% items for each FACT subscale and provided GLETQ responses for both prior to and during the pandemic). After removal of careless responders ($n = 28$), 488 survey responses remained and were included in the final analysis.

Demographic, medical, and behavioral characteristics of the participants are displayed in Table 1. Cancer survivors were predominantly White (90.0%) and female (69.7%) with a mean age of 48.8 ± 15.6 years. Cancer survivors were primarily diagnosed with localized breast (29.5%), hematologic (11.9%) or gynecologic (11.5%) cancer, and were a mean of 58.1 ± 77.3 months from their last treatment. Participants resided predominantly in the UK (38.1%), the USA (21.9%), and Canada (21.5%). Most cancer survivors indicated government-mandated physical distancing (94.3%) and/or a suggested stay-at-home/shelter-in-place (46.5%).

Change in physical activity participation

Table 2 presents the comparisons of PA before and during the COVID-19 pandemic. Prior to the pandemic, cancer survivors were spending on average 207.0 ± 237.9 min/week performing MVPA and only 155.5 ± 195.1 min/week during the COVID-19 pandemic. The percentage of cancer survivors reporting not meeting any PA guidelines significantly increased during the pandemic from 44.3 to 50.8% ($\chi^2(1) = 180.66$, $p < 0.001$). Cancer survivors were engaging in significantly less MVPA during the pandemic when compared to PA prior to the start ($M_{\text{diff}} = -51.53$ min/week;

Fig. 1 Flow diagram of participant flow through the study
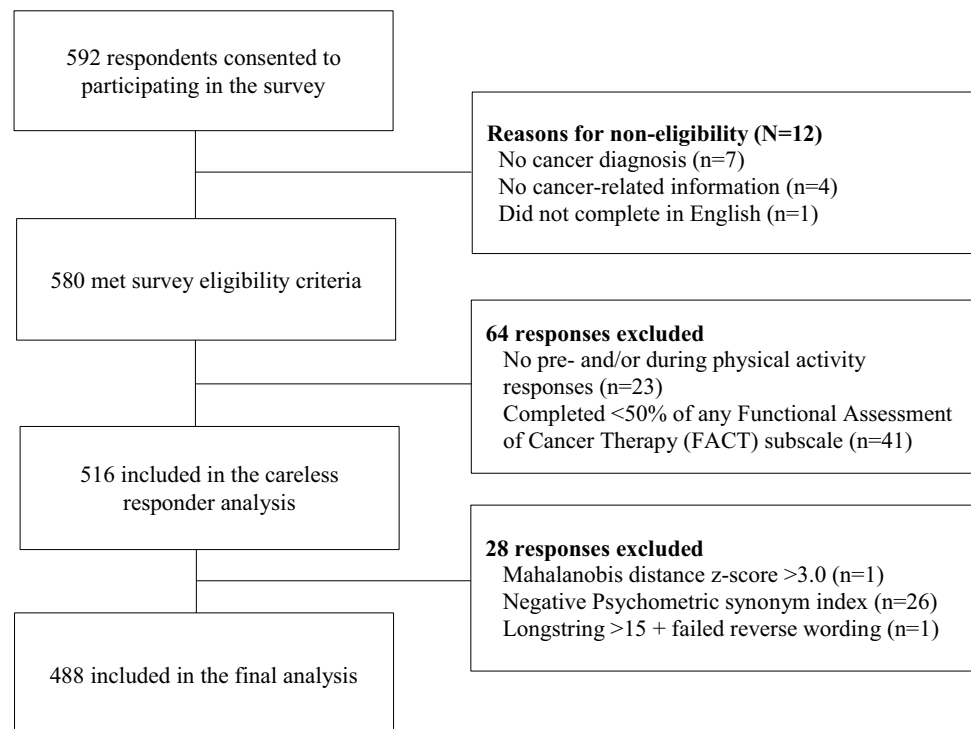
Table 1 Demographic, medical, and behavioral characteristics of cancer survivors of mixed malignancies during the COVID-19 pandemic (July 2020–November 2020; $N = 488$)

Variable	$M \pm SD$ or n (%)
Demographic	
Age (years)	48.8 ± 15.6
Gender	
Male	144 (29.5)
Female	340 (69.7)
Self-identify	2 (0.4)
Undisclosed	2 (0.4)
Education	
Some/completed high school	86 (17.6)
Some/completed university/college	286 (58.6)
Some/completed graduate school	115 (23.6)
Undisclosed	1 (0.2)
Marital status	
Married/common law	303 (62.1)
Not married	185 (37.9)
Employment	
Full Time	181 (37.1)
Retired	103 (21.1)
Part-time	98 (20.1)
Temporarily unemployed	56 (11.5)
Disability	33 (6.8)
Homemaker	17 (3.5)
Ethnicity	
White	439 (90.0)
Southeast Asian	10 (2.0)
Latin American	9 (1.8)
Black	8 (1.6)
South Asian	7 (1.4)
Mixed ethnic background	6 (1.2)
West Asian and North African	2 (0.4)
Chinese	1 (0.2)
Other	4 (0.8)
Undisclosed	2 (0.4)
Body mass index (BMI; kg/m^2)	27.1 ± 6.4
Medical	
Number of comorbidities	
None	158 (32.4)
1	129 (26.4)
2–4	171 (35.0)
>4	30 (6.1)
Type	
Breast	144 (29.5)
Hematologic	58 (11.9)
Gynecologic	56 (11.5)
Skin	44 (9.0)
Multiple	26 (5.3)
Prostate	23 (4.7)
Thyroid	22 (4.5)

Table 1 (continued)

Variable	$M \pm SD$ or n (%)
Testicular	22 (4.5)
Colorectal	20 (4.1)
Kidney	15 (3.1)
Lung	14 (2.9)
Bladder	10 (2.0)
Head and neck	9 (1.8)
Brain	5 (1.0)
Bone	4 (0.8)
Other	14 (2.9)
Undisclosed	2 (0.4)
Months since diagnosis	86.4 ± 82.3
Disease stage	
Localized	373 (76.4)
Metastatic	72 (14.8)
Unsure	37 (7.6)
Undisclosed	6 (1.2)
Treatment[a]	
Received surgery treatment	381 (78.1)
Received drug treatment	231 (47.3)
Received radiation treatment	181 (37.1)
Received immunotherapy	27 (5.5)
Received hormonal therapy	91 (18.6)
Active surveillance	6 (1.2)
Treatment status	
Completed treatment	362 (74.2)
Still receiving maintenance therapy	82 (16.8)
Still receiving primary treatment	40 (8.2)
Undisclosed	4 (0.8)
Months since last treatment	58.1 ± 77.3
Current cancer status	
Cancer gone from the body	348 (71.3)
Cancer still in the body	63 (12.9)
Unsure	77 (15.8)
COVID-19 variables	
Geographic location	
UK	186 (38.1)
USA	107 (21.9)
Canada	105 (21.5)
Poland	21 (4.3)
Italy	14 (2.9)
Australia	7 (1.4)
Portugal	7 (1.4)
South Africa	7 (1.4)
Ireland	5 (1.0)
Other	29 (5.9)
Government-mandated prevention measures[a]	
Complete lockdown	28 (5.7)
Mandatory shelter-in-place/stay-at-home	35 (7.2)
Suggested shelter-in-place/stay-at-home	227 (46.5)
Physical distancing	460 (94.3)

Table 1 (continued)

Variable	$M \pm$ SD or n (%)
Other	78 (16.0)
None	3 (0.6)
Personal prevention measures[a]	
Mandatory isolation	
International travel	34 (7.0)
Potential exposure	45 (9.2)
Experiencing symptoms	23 (4.7)
Awaiting test results	18 (3.7)
Confirmed case of COVID-19	7 (1.4)
Self-isolate (due to perceived vulnerability)	138 (28.3)
Physical distancing	440 (90.2)
Relocated	4 (0.8)
Other	23 (4.7)
None	14 (2.9)

[a]Could indicate more than one response

95% CI = 35.28–67.78; $t(487) = 6.23$, $p < 0.001$, $d = 0.23$). Cancer survivors were primarily classified as non-exercisers (37.7%), single guideline maintainers (23.8%), complete relapsers (13.1%), and combined guideline maintainers (12.7%). Few cancer survivors were classified as inactive adopters (6.6%) or partial relapsers (6.1%).

Associations between physical activity and quality of life

Differences in QoL across PA change classifications are presented in Table 3. In the adjusted models, there was a significant difference in FACT-Fatigue ($F(5,454) = 2.53$;

$p = 0.03$) and TOI-Fatigue ($F(5,454) = 3.78$; $p < 0.01$) scores across the PA change classifications. Post hoc comparisons (Table 4) revealed that compared to inactive adopters, partial relapsers had significantly lower QoL and higher fatigue on the FACT-Fatigue (-21.55; 95% CI $= -40.56$ to -2.54; $p = 0.02$) and TOI-Fatigue (-17.19; 95% CI $= -31.66$ to -2.71; $p < 0.01$). Combined guideline maintainers had significantly lower fatigue and higher QoL on the TOI-Fatigue (13.84 points; 95% CI = 1.15–26.52; $p = 0.02$) than partial relapsers. All between-group differences in QoL and fatigue were clinically meaningful. There were no significant differences in scores on the FACT-General ($F(5,454) = 1.91$; $p = 0.09$) across PA change classifications.

Discussion

The primary purpose of this study was to examine the impact that the COVID-19 pandemic has had on the PA participation of cancer survivors. PA participation significantly decreased (i.e., -51.5 min/week of MVPA and -6.5 min/week of resistance training) since the start of the COVID-19 outbreak. While most cancer survivors maintained their pre-pandemic MVPA levels, 19.3% of cancer survivors relapsed in participation and only 6.6% of inactive cancer survivors adopted new PA behaviors, mirroring results seen in general adult populations indicating a decline in PA during the pandemic [28–30]. In a cross-sectional survey, Rhodes and colleagues [30] compared PA behavior of Canadian adults ($N = 1055$) prior to and during the COVID-19 pandemic with results showing a substantial decrease (-46.7 min/week) in MVPA participation. Furthermore, in studies using smartphone and wearable technologies, substantial decreases in

Table.2 Comparison of physical activity participation of cancer survivors prior to and during the COVID-19 pandemic (July 2020–November 2020; $N = 488$)

Weekly physical activity participation	Mean minutes per week ($M \pm$ SD)		M_{Diff} (95% CI)	p-value	Cohen's d
	Prior to the COVID-19 pandemic	During the COVID-19 pandemic			
MVPA	207.0 ± 237.9	155.5 ± 195.1	-51.53 (-35.28 to -67.78)	<.001	0.23
Vigorous intensity	49.0 ± 81.8	29.4 ± 58.3	-19.55 (-13.84 to -25.27)	<.001	0.26
Moderate intensity	104.6 ± 129.3	91.7 ± 124.0	-12.91 (-2.94 to -22.87)	.01	0.10
Light intensity	138.8 ± 160.8	126.5 ± 151.4	-12.23 (-0.32 to -24.14)	.04	0.08
Resistance Training	26.7 ± 53.6	20.2 ± 42.2	-6.45 (-2.86 to -10.05)	<.001	0.13
Meeting physical activity guidelines, n (%)					
Aerobic only guidelines	138 (28.3)	123 (25.2)	---	<.001	---
Strength only guidelines	42 (8.6)	49 (10.0)	---	<.001	---
Combined guidelines	92 (18.9)	68 (13.9)	---	<.001	---
Neither	216 (44.3)	248 (50.8)	---	<.001	---

Note: M_{Diff}, mean difference; *95% CI*, 95% confidence interval

Table.3 Quality of life of cancer survivors during the COVID-19 pandemic (July–November 2020) using the Functional Assessment of Cancer Therapy (FACT) scales (N=488)

	Non-exercisers[a,b] (n=184)	Inactive adopter[a,b] (n=32)	Complete relapser[a,b] (n=64)	Partial relapser[a,b] (n=30)	Single guideline maintainer[a,b] (n=116)	Combined guideline maintainer[a,b] (n=62)	p-value
FACT-General (0–108)	72.8±17.7	77.4±14.8	71.2±16.3	64.4±14.7	74.3±17.9	73.6±20.0	
FACT-General (0–108)	72.8±1.2	78.5±3.0	71.7±2.1	65.8±3.1	73.7±1.6	73.0±2.1	.09
FACT-Fatigue (0–160)	107.2±29.3	116.5±21.8	106.9±25.1	95.0±26.2	112.2±27.5	112.4±30.3	
FACT-Fatigue (0–160)	107.1±1.9	118.9±4.7	107.8±3.3	97.3±4.8	111.1±2.5	111.6±3.3	.03
TOI-Fatigue (0–108)	72.6±22.7	80.8±14.8	73.6±19.3	64.1±22.6	78.0±20.4	80.0±21.7	
TOI-Fatigue (0–108)	72.4±1.5	82.9±3.6	74.3±2.5	65.7±3.7	77.2±1.9	79.6±2.5	<.01

Note: Models adjusted for age, gender, BMI, cancer type, cancer spread, months since diagnosis, months since treatment, current cancer status

[a]Mean±standard deviation

[b]Estimated marginal mean±error

TOI-Fatigue=Trial Outcome Index-Fatigue

Non-exercisers=not meeting any guidelines before or during the pandemic

Inactive adopter=not meeting any guidelines before the pandemic, meeting aerobic only, strength only, or combined guidelines during the pandemic

Active adopter=meeting aerobic only or strength only guidelines before the pandemic, meeting combined guidelines during the pandemic

Complete relapse=meeting aerobic only, strength only or combined guidelines before the pandemic, not meeting any guidelines during the pandemic

Partial relapse=meeting combined guidelines before the pandemic, meeting aerobic only or strength only during the pandemic

Single guideline maintainer=meeting aerobic only or strength only before and during the pandemic

Combined guideline maintainer=meeting combined guidelines before and during the pandemic

daily step counts have also been documented in non-clinical adult populations [29].

These results are unsurprising for several reasons. First, stress, anxiety, mental health, and PA during the pandemic have all been positively associated with one another [32, 34, 52]. The mental well-being of cancer survivors may be particularly compromised during the COVID-19 pandemic because of factors such as increased vulnerability, inaccessibility of support and coping resources, and uncertainty surrounding health [9–12, 16, 53]. As such, it is possible that this enhanced distress may indirectly impact PA behaviors as cancer survivors experiencing greater mental distress may be less likely to perform PA [31, 52, 53]. Secondly, PA is largely influenced by social and environmental contexts; therefore, COVID-19 prevention measures (i.e., physical distancing and stay-at-home orders) can lead to reduced participation [54]. Changes to the physical and social environment surrounding PA was dramatically changed, as fitness facilities were unavailable or avoided by cancer survivors due to a potential increased risk of COVID-19 transmission [27, 52]. Home-based PA promotion strategies for cancer

survivors that reflect this new landscape surrounding PA environments are needed [17, 27].

Our results suggest clinically meaningful differences in QoL scores across PA change classifications. In general, cancer survivors performing PA during the pandemic (i.e., inactive adopters, single and combined guideline maintainers) had higher QoL and lower fatigue than those who are inactive (i.e., non-exercisers, complete and partial relapsers), though only differences between partial relapsers and inactive adopters, and combined guideline maintainers were significant. There are no studies conducted during the pandemic in which to compare our results to; however, these results align with pre-pandemic research indicating that meeting any PA guideline is associated with better QoL [36, 40, 55]. Additionally, much like pre-pandemic research [36, 40, 55], differences in TOI-Fatigue scores across PA change categories suggest that the associations between QoL and PA during the pandemic may be driven primarily by QoL domains related to physical well-being (e.g., fatigue, physical function) compared to social and emotional well-being. Though the association between PA and social and

Table.4 Tukey's post hoc comparisons across physical activity change categories for Functional Assessment of Cancer Therapy (FACT)-Fatigue and Trial Outcome Index (TOI)-Fatigue (*N*=488)

	FACT-Fatigue			TOI-Fatigue		
	M_{diff}	95% CI	*p*	M_{diff}	95% CI	*p*
Inactive adopter vs. non-exerciser	11.79	(−2.58 to 26.17)	.18	10.53	(−0.42 to 21.47)	.07
Complete relapser vs. non-exerciser	0.69	(−10.14 to 11.53)	1.00	1.90	(−6.35 to 10.15)	.99
Partial relapser vs. non-exerciser	−9.76	(−24.47 to 4.96)	.40	−6.66	(−17.86 to 4.55)	.53
Single guideline maintainer vs. non-exerciser	3.96	(−4.99 to 12.92)	.80	4.82	(−2.00 to 11.64)	.33
Combined guideline maintainer vs. non-exerciser	4.49	(−6.51 to 15.50)	.85	7.18	(−1.20 to 15.56)	.14
Complete relapser vs. inactive adopter	−11.10	(−27.36 to 5.16)	.37	−8.63	(−21.01 to 3.75)	.34
Partial relapser vs. inactive adopter	−21.55*	(−40.56 to −2.54)	.02	−17.19*	(−31.66 to −2.71)	<.01
Single guideline maintainer vs. inactive adopter	−7.83	(−22.84 to 7.18)	.66	−5.71	(−17.14 to 5.72)	.70
Combined guideline maintainer vs. inactive adopter	−7.30	(−23.52 to 8.92)	.79	−3.35	(−15.70 to 9.00)	.97
Partial relapser vs. complete relapser	−10.45	(−27.00 to 6.09)	.46	−8.55	(−21.15 to 4.05)	.37
Single guideline maintainer vs. complete relapser	3.27	(−8.39 to 14.93)	.97	2.92	(−5.96 to 11.80)	.93
Combined guideline maintainer vs. complete relapser	3.80	(−9.56 to 17.16)	.96	5.28	(−4.89 to 15.46)	.67
Single guideline maintainer vs. partial relapser	13.72	(−1.62 to 29.06)	.11	11.47	(−0.21 to 23.15)	.06
Combined guideline maintainer vs. partial relapser	14.25	(−2.41 to 30.91)	.14	13.84*	(1.15 to 26.52)	.02
Combined guideline maintainer vs. single guideline maintainer	0.53	(−11.27 to 12.33)	1.00	2.36	(−6.62 to 11.35)	.97

Note: Models adjusted for age, gender, BMI, cancer type, cancer spread, months since diagnosis, months since treatment, current cancer status; *M_Diff*, mean difference; *95% CI*, 95% confidence interval; * = Clinically meaningful difference

TOI-Fatigue = Trial Outcome Index-Fatigue

Non-exercisers = not meeting any guidelines before or during the pandemic

Inactive adopter = not meeting any guidelines before the pandemic, meeting aerobic only, strength only, or combined guidelines during the pandemic

Active adopter = meeting aerobic only or strength only guidelines before the pandemic, meeting combined guidelines during the pandemic

Complete relapser = meeting aerobic only, strength only or combined guidelines before the pandemic, not meeting any guidelines during the pandemic

Partial relapser = meeting combined guidelines before the pandemic, meeting aerobic only or strength only during the pandemic

Single guideline maintainer = meeting aerobic only or strength only before and during the pandemic

Combined guideline maintainer = meeting combined guidelines before and during the pandemic

emotional well-being may not be as strong, the potential protective effects of PA on these aspects of well-being should not be overlooked. The FACT subscales are widely used in understanding cancer-specific QoL, but they may not be sensitive to the social and emotional challenges presented by COVID-19. PA shows promise in improving the well-being in general adult populations given that meeting MVPA guidelines during the pandemic is associated with more positive mental health, decreased depression, loneliness, and stress in general adult populations [32]; yet, this remains to be examined in cancer populations. Further work using a broader scope to examine mental well-being is needed to gain a more comprehensive understanding of cancer survivors' QoL and mental health during the pandemic.

Inactive adopters and combined guideline maintainers had significantly better QoL than those who relapsed, suggesting that PA participation during the pandemic is associated with QoL independently from pre-pandemic PA levels. Studies conducted prior to the pandemic show

contradictory findings in terms of whether meeting both PA guidelines is superior to meeting only a single guideline [36, 56, 57]. Our results suggest that there is no difference in QoL for those meeting single or combined guidelines. Cancer survivors should therefore strive to perform PA of any modality during the pandemic. Interestingly, despite meeting combined guidelines prior to the pandemic, partial relapsers had the lowest QoL which was clinically meaningful. This suggests that a reduction in PA of any capacity during the pandemic may have detrimental effects on QoL. Caution is needed when interpreting these results as the causal pathway of these relationships cannot be determined in the current analysis. It may also be possible that cancer survivors experiencing poorer QoL during the COVID-19 pandemic may be more susceptible to a relapse in PA. Regardless of directionality, these results are consistent with the relationship between PA and QoL in research conducted prior to the pandemic [20, 35–37]. Therefore, PA programming for cancer survivors during

and beyond the pandemic should include a behavioral component for PA maintenance [52, 58].

To the best of our knowledge, this is the first study to suggest that reductions in PA during the pandemic are associated with poorer QoL for cancer survivors. Furthermore, the survey was widely disseminated to a global sample to examine PA and QoL of cancer survivors during the COVID-19 pandemic. This study is also subject to limitations. Firstly, although self-report measures provide an easy, accessible, and practical avenue for measuring PA participation in a population-based sample, self-report measures are subject to recall bias and overreporting of MVPA [59]. Given the retrospective nature of PA prior to the pandemic measured at least 4 months following the start of data collection, the estimates of pre-pandemic PA behaviors may also be subject to recall bias. Additionally, directionality of the relationship between change in PA and QoL cannot be determined due to the cross-sectional study design. Participants were primarily White women diagnosed with breast cancer and may not be representative of the broader cancer population. Though this work provides preliminary insight into the PA behaviors and QoL of cancer survivors during the COVID-19 pandemic, it may only represent a subset of this population. Cancer survivors of different racial and cultural backgrounds diagnosed with different cancer types and individuals who may not have time to complete a survey were not reached; thus, it is possible that PA and its associations with QoL may present differently in a population not captured through this survey. Purposeful recruitment efforts aimed at reaching underserved populations are needed to increase inclusivity in participation and generalizability of findings to the larger population.

Conclusion

With 18 million people living with cancer globally [60, 61] and facing disruptions to medical and supportive care, it is imperative to investigate strategies that can simultaneously target physical and mental health during the COVID-19 pandemic. The effects of PA on health and well-being of cancer survivors have been well-documented [62], and PA should be considered essential for addressing many of the physical and mental consequences imposed by COVID-19 infection control measures [17, 18].

To optimize benefits from PA, behavioral strategies and interventions are needed to assist cancer survivors in adopting PA and also preventing current exercisers from relapsing [58]. Strategies during the COVID-19 pandemic include educating survivors on how to remain active yet physically distant from others, self-regulatory strategies to prevent momentary lapses and overcome barriers, and utilizing live, virtual programming to facilitate personal connections, provide rapid feedback and personalized instruction [17, 52,

58, 63]. This requires a thorough understanding of the motivational and environmental determinants of PA in cancer populations during the pandemic. PA promotion strategies and interventions for this population should consider utilizing social ecological approaches, targeting all levels of influence including individual, interpersonal, and environmental factors. Overall, meeting any of the PA guidelines can have a positive effect on QoL and fatigue of cancer survivors during the COVID-19 pandemic.

Declarations

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