

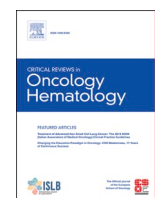


Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

# Critical Reviews in Oncology / Hematology

journal homepage: [www.elsevier.com/locate/critrevonc](http://www.elsevier.com/locate/critrevonc)

## Exercise oncology during and beyond the COVID-19 pandemic: Are virtually supervised exercise interventions a sustainable alternative?

Paola Gonzalo-Encabo<sup>a,b</sup>, Rebekah L. Wilson<sup>a,b</sup>, Dong-Woo Kang<sup>a,b</sup>, Amber J. Normann<sup>a,c</sup>, Christina M. Dieli-Conwright<sup>a,b,\*</sup>

<sup>a</sup> Division of Population Sciences, Department of Medical Oncology, Dana-Farber Cancer Institute, Boston, MA, United States

<sup>b</sup> Department of Medicine, Harvard Medical School, Boston, MA, United States

<sup>c</sup> Department of Health Sciences, Boston University, Boston, MA, United States

### ARTICLE INFO

#### Keywords:

Virtual supervision  
Home-based exercise  
Telehealth  
Cancer  
COVID-19

### ABSTRACT

During the COVID-19 pandemic, new challenges are presented in clinical research settings to increase exercise levels, particularly in vulnerable populations such as cancer survivors. While in-person supervised exercise is an effective format to improve patient-reported outcomes and physical function for cancer survivors, the COVID-19 pandemic limited this form of exercise as a feasible option within research and cancer care. As such, exercise oncology interventions were adapted to home-based instruction. In this review, we examine the current evidence of exercise interventions in cancer populations during and beyond the COVID-19 pandemic. We identified that group-based virtually supervised home-based exercise was the most used format among exercise oncology interventions during the pandemic. Preliminary results support feasibility and effectiveness of this emerging exercise setting in cancer survivors; however, it needs to be further investigated in adequately designed larger trials. Additionally, we provide recommendations and perspective for the implementation of virtually supervised home-based exercise.

### 1. Introduction

The novel coronavirus (SARS-CoV-2 or COVID-19) is an unprecedented public health challenge that affected the entire world with several high impact changes in daily life and was classified as a global pandemic by the World Health Organization on March 11th of 2020 (Sohrabi et al., 2020). Prior to COVID-19, physical inactivity was considered a major public health concern (Guthold et al., 2018) and recognized as a global pandemic (Kohl et al., 2012). This lack of physical activity was further exacerbated by the implementation of COVID-19-related “stay at home” mandates with increases in sedentary behavior seen worldwide (Stockwell et al., 2021; Gonzalo-Encabo et al., 2021). In this regard, new challenges are presented in clinical and research settings to increase physical activity and exercise levels (Tuttle, 2020; Martinez-Ferran et al., 2020). This is especially difficult in clinical populations such as cancer survivors, who are highly susceptible to infection and at risk for severe illness from COVID-19 (Liu et al., 2020), due to the nature of disease development at an older age as well as the

immunosuppressive state caused by cancer and its treatments (Yang et al., 2020).

Exercise is a critical adjuvant therapy for cancer survivors and has been shown to improve cancer and treatment-related outcomes (e.g., patient-reported outcomes and physical function) (Campbell et al., 2019). However, most cancer survivors were already insufficiently active prior to the COVID-19 pandemic (Ottenbacher et al., 2015), and “stay at home” mandates have resulted in further activity declines (Natalucci et al., 2021). In terms of exercise interventions in research, in-person supervised exercise programs are more effective in improving cancer- and treatment-related side effects than self-directed, home-based interventions (Baumann et al., 2021, 2012; Buffart et al., 2017). Given that most individuals living with cancer report a preference for exercising at home (Wong et al., 2018), integrating virtual supervision (e.g., telehealth) may be a potential tool for improving home-based exercise programs (Bland et al., 2020). During the pandemic, several clinical trials in exercise oncology transitioned their interventions from supervised to home-based or were postponed/terminated (Newton et al.,

\* Correspondence to: Division of Population Sciences, Department of Medical Oncology, Dana-Farber Cancer Institute, 375 Longwood Avenue, Boston, MA 02215, United States.

E-mail address: [ChristinaM\\_Dieli-Conwright@DFCI.Harvard.edu](mailto:ChristinaM_Dieli-Conwright@DFCI.Harvard.edu) (C.M. Dieli-Conwright).

<https://doi.org/10.1016/j.critrevonc.2022.103699>

Received 8 February 2022; Received in revised form 29 April 2022; Accepted 2 May 2022

Available online 5 May 2022

1040-8428/© 2022 Elsevier B.V. All rights reserved.

2020). Consequently, researchers and clinicians had the opportunity to examine different home-based exercise programs to overcome barriers to engage cancer survivors in exercise during COVID-19.

To our knowledge, this is the first review that aims to investigate different exercise interventions and discuss potential effectiveness in cancer survivors before, during, and beyond COVID-19. We provide recommendations for designing effective supervised home-based exercise interventions post-pandemic for cancer survivors. Furthermore, we discuss the challenges and perspectives for exercise oncology clinical trials beyond COVID-19.

We conducted a systematic search using PubMed, Google Scholar and Web of Science databases for published studies and conference abstracts until January 2022. Search terms included various combinations of: COVID-19; oncology; exercise. The key criterion was to identify clinical exercise oncology studies during COVID-19 pandemic. Furthermore, randomized and non-randomized clinical trials, single-arm studies, case series and cohort studies were included if they involved an exercise/physical activity component. Extracted data included the first author’s name, year of publication, population (e.g., sex, cancer type, stage, age, minorities), study design, intervention period, exercise prescription, adherence and results. Twelve published studies met our inclusion criteria and were included in this review. Given the heterogeneity of studies, a narrative review was chosen to discuss a wider array of studies and provide a more complete critical perspective.

## 2. Exercise-oncology research before the COVID-19 pandemic

Exercise should be tailored to the targeted patient group, cancer type, treatment, and outcome of interest; however, the delivery of exercise interventions is also of high importance (Table 1) and may be dictated by the needs of the patient. The superior effect of supervised exercise compared to unsupervised exercise may be attributed to a real-time, face-to-face environment. Supervised exercise ensures that the exercise selection, technique, and intensities are adhered to and appropriately prescribed to promote the desired physiological adaptations in the patient (Buffart et al., 2017). Supervised exercise also promotes safety, which is particularly important for survivors on treatment as their physical and mental health status can change daily due to the acute side effects (Wilson et al., 2021).

**Table 1**  
Settings for exercise and physical activity interventions in cancer survivors.

Exercise setting	Implementation
Supervised	<ul style="list-style-type: none"> <li>In-person, clinic-based (e.g., hospital run exercise facility with exercise oncology trainers).</li> <li>In-person, one-on-one or group, community-based (e.g., gym personal trainer).</li> <li>Virtual, one-on-one or group, home-based (e.g., exercise oncology trainer video conferences with patient in real time and provides exercise instruction).</li> </ul>
Self-directed with regular guidance	<ul style="list-style-type: none"> <li>Weekly phone calls/texts/email with exercise trainer to check progress on completing exercise recommendations and make new exercise goals (e.g., trainer provides individual prescription for progress but does not supervise execution of exercise).</li> </ul>
Self-directed unsupervised	<ul style="list-style-type: none"> <li>Home-based, surrounding neighborhood, or community facility/club (e.g., gym membership, sport club).</li> <li>Web-based (e.g., follow exercise videos on YouTube).</li> <li>Phone application-based (e.g., follow exercise programs provided through application).</li> <li>Booklet/handout (e.g., booklet of exercise recommendations with instructions on how to perform them).</li> <li>Wearable technology (e.g., using a smart watch to track step count and heart rate).</li> <li>Exercise equipment with built in on-demand programs (e.g., Tonal, Peloton, Mirror).</li> </ul>

With the establishment of in-person supervised exercise as a feasible and safe adjuvant therapy (Baumann et al., 2021; Ussing et al., 2021; Yang et al., 2020; Courneya et al., 2012; Meneses-Echávez et al., 2015), research examining self-directed, home-based exercise interventions were growing in popularity within the exercise oncology paradigm prior to COVID-19 (Lopez et al., 2020; Cheng et al., 2017; Batalik et al., 2021). Self-directed, home-based exercise can take many forms as highlighted in Table 1. The ever-developing technology industry, smart watches, phones, exercise equipment, tablets, and websites allow immediate access to exercise programs and analysis of personal fitness and activity levels. While these platforms are effective at improving fitness and activity levels for cancer survivors (Singh et al., 2021), compared to in-person supervised exercise, self-directed home-based exercise only induces smaller desirable changes in the outcome of interest (van Waart et al., 2015). Patients may not be able to gain the full potential benefits of exercise without the supervision of an exercise professional, since an understanding of how to prescribe exercise, adapt the prescription to daily physiological changes or injuries, and interpretation of the data gained from technology used (e.g., using smart watch heart rate to meet a certain intensity), is required to induce substantial beneficial changes in the targeted outcome of interest.

## 3. Home-based exercise during the COVID-19 pandemic

During the COVID-19 pandemic, many different approaches were taken on how to develop (Winters-Stone et al., 2021) or adapt (Di Blasio et al., 2021; Gothe and Erlenbach, 2021; Grazioli et al., 2020; Trevino et al., 2021; Winters-Stone et al., 2021; Wonders et al., 2021; Basen-Engquist and Liao, 2020; López-Rodríguez-Arias et al., 2021; Papandreou et al., 2021; Wu et al., 2021; Natalucci et al., 2021) new or existing studies and clinic-based programs including self-directed unsupervised (e.g. booklet of exercise recommendations), self-directed with regular guidance (e.g., weekly phone calls with exercise trainer), and supervised (e.g., virtual live exercise). Here we describe key exercise oncology-based studies during COVID-19 (Table 2).

### 3.1. Home-based self-directed unsupervised interventions

We identified two studies that reported the use of self-directed unsupervised interventions that were adapted to COVID-19 restrictions (López-Rodríguez-Arias et al., 2021; Yildiz Kabak et al., 2021). López-Rodríguez-Arias et al. examined the effect of a home-based prehabilitation program on body composition in 20 patients scheduled for colorectal surgery. Patients were recommended to complete daily exercise by following a 30–45 min aerobic and resistance exercise video (López-Rodríguez-Arias et al., 2021). They reported that prehabilitation attenuated loss of lean mass and stabilized weight and fat mass as well as reduced the length of hospitalization. Yildiz Kabak et al. examined hematopoietic stem cell transplant patients and their compliance to a home-based exercise program that was prescribed prior to the COVID-19 “stay at home” period (Yildiz Kabak et al., 2021). Compliance to exercise during this period was negatively associated with age, performance status, and symptom score, and positively associated with functionality and general health scores. However, exercise compliance significantly deteriorated during the “stay at home” period where only 13.3% stated they regularly performed the prescribed exercise; in contrast with 56% self-reporting compliance in a similar study conducted in the same clinic pre-COVID-19 (Yildiz Kabak et al., 2020).

As highlighted above, adherence continue to be a challenge in unsupervised home-based exercise interventions even during the COVID-19 pandemic among cancer patients. The understanding of why patients do and do not adhere to exercise, as well as the needs of different populations e.g., older and frail versus young and fit, will assist in the development of strategies to improve home-based exercise adherence. For example, the inclusion of supervised home-based exercise may be of benefit and provide a point of accountability for patients at home.

**Table 2**  
Exercise/Physical activity studies conducted during COVID-19 pandemic and beyond.

Author (year)	Population (n / sex /cancer type and stage/age/race and ethnicity)	Design	Intervention period (months)	Exercise prescription (FITT)	Adherence	Results
Home-based self-directed unsupervised interventions						
López-Rodríguez-Arias et al. (2021)	20 Men and women / Patients undergoing colorectal cancer surgery / Stage = 0-IV / Mean age = 66 ± 9 yr / Race/ ethnicity = NR	Two-arm RCT: Control group: standard care (n = 10) Intervention group: Prehabilitation and postoperative follow-up with exercise, nutrition and relaxation recommendations (n = 10)	Pre-Surgery: ~ 1-month Post-Surgery: ~ 45 days and 90 days	F: 7 days/wk I: NR T: 30–45 min/session Type: Combined aerobic and resistance training. Home-based, unsupervised using a video playlist	NR	<ul style="list-style-type: none"> <li>Lean mass decreased in a lesser degree in the intervention group compared to control (1.7% vs 7.1%; p = 0.17) 45 days after surgery.</li> <li>Fat mass decreased in the intervention compared to control (-8.2% vs 8.7%; p = NR).</li> <li>Hospital stay was reduced in the intervention compared to control (4.8 vs 7.2 days; p = 0.05), as well as postoperative complications (20% vs 50%; p = 0.16)</li> </ul>
Yildiz Kabak et al. (2021)	101 Men and women / Patients treated with hematopoietic stem cell transplantation (HSCT) / Stage = NA / Mean age = 51 ± 12 yr / Race/ ethnicity = NR	Individuals were referred to an exercise and walking program before COVID-19. Then, they were interviewed on the phone to assess compliance and outcomes	NR	F: NR I: NR T: 90–150 min/wk Type: walking program + home exercise unsupervised: strengthening, endurance, stretching	Walking program: 29. % Home-based: 13%	<ul style="list-style-type: none"> <li>Supportive care needs during COVID-19: physical and psychological.</li> <li>Exercise compliance was low during the pandemic, and was associated with age, performance level and QoL (p &lt; 0.05)</li> <li>Women were most vulnerable than males in psychological needs and QoL outcomes during the pandemic (p &lt; 0.05)</li> </ul>
Home-based semi-supervised intervention defined as having regular contact with staff, but no supervision of exercise performance						
Fornier et al. (2021)	17 Men and women / Patients with breast cancer (N = 7), colon (N = 5), prostate (N = 5) / Stage = I-III / Mean age = NR (aged ≥30–80 yr) / Race/ ethnicity = NR	Intervention (n = 9) Fitbit and exercise information materials/ standard of care (n = 8)	3 months	NR	NR	<ul style="list-style-type: none"> <li>Physical activity and step count increased and fatigue and QoL decreased in the intervention, with non-significant differences between groups.</li> </ul>
Natalucci et al. (2021)	30 Women / Patients with breast cancer / Stage = 0 - III / Mean age = 53 ± 8 yr / Race/ethnicity = NR	Originally an RCT, but due to the lack of meaningful differences between the two groups as a result of the COVID-19-related changes to the intervention, the results of the two groups were combined for this analysis.	3 months	F: 3 days/wk I: 40–70% HRR T: 20–60 min Type: aerobic exercise	Diet adherence improved by 28%, physical activity improved by 61.2%	<ul style="list-style-type: none"> <li>BMI, VO<sub>2max</sub>, physical activity, adherence to Mediterranean diet, heart rate, cardiac function indexes, metabolic and inflammatory parameters showed a significant improvement after the intervention (p &lt; 0.05)</li> </ul>
Papandreou et al. (2021)	44 Women / Breast cancer survivors / Stage = I-III / Mean age = 50 ± 8 yr / Race/ ethnicity = NR	Two-arm RCT: Control group: general lifestyle advice (n = 22) Intervention group: personalized dietary plans and physical activity guidelines (n = 22)	3 months	F: NR I: NR T:NR Type: Physical activity guidelines	80%	<ul style="list-style-type: none"> <li>Body weight and fat mass decreased in the intervention compared to control (p &lt; 0.001).</li> <li>Adherence to Mediterranean diet increased in the intervention group compared to control (p &lt; 0.001).</li> <li>The intervention group improved QoL after the intervention (p &lt; 0.05)</li> </ul>
Wu et al. (2021)	66 Men and women / Patients with colorectal cancer (n = 41), urology (n = 15), breast (n = 7), lung (n = 3) / Stage = NR / Mean age = NR (aged ≥ 18 yr / Race/ethnicity = White (n = 61), Other (n = 5)	Single group study (adapted due to COVID-19) Completed program (n = 100) Complete results and used for statistical analysis (n = 66)	Pre-hab From < 2 weeks to ≥ 8 weeks	F: Resistance 2days/wk I: 3 sets, 8–10 reps T: 150 min/wk aerobic Type: aerobic & resistance	Telehealth adherence: 72% Adherence to home program NR	<ul style="list-style-type: none"> <li>Home-based Prehabilitation was feasible.</li> <li>Self-perceived health increased, and fatigue decreased after the intervention (p &lt; 0.001).</li> </ul>
Virtually supervised home-based exercise interventions						
Di Blasio et al. (2021)	51 Women / Patients with breast cancer (post-surgery) / Stage =NR / Mean age = 51 ± 6 yr / Race/ethnicity = NR	Attended virtual classes plus personalized feedback (E <sup>+</sup> group) (n = 24) Could not attend virtual classes, received = NR	4.5 months	F: 3 days/wk I: 12–13 RPE (15 RPE scale) T: 50 min/session Type: Group-based circuit	Online classes: 94 ± 5%	<ul style="list-style-type: none"> <li>Sedentary time increased (P &lt; 0.05) in the E- group compared to baseline</li> <li>The presence of personal feedback and an activity monitor, in the absence of</li> </ul>

(continued on next page)

Table 2 (continued)

Author (year)	Population (n / sex/cancer type and stage/age/race and ethnicity)	Design	Intervention period (months)	Exercise prescription (FITT)	Adherence	Results
(Gothe and Erlenbach, 2021)	78 Men and women / Survivors of breast cancer (n = 47), skin (n = 4), prostate (n = 3) / Stage = 0-IV / Mean age = 55 ± 9 yr / Race/ethnicity = Caucasian (n = 71), Other (n = 7)	only personalized feedback (E' group) (n = 27) Three-arm RCT with a sample of participants (n = 15) that transition from in-person to virtual.	3 months (7 of the 12 wk of the intervention were virtual)	calisthenic and aerobic training, stretching. F: 3 days/wk I: moderate intensity T: 60 min/session Type: Group-based walking or yoga.	NR	supervised exercise, was not effective in improving physical activity during the COVID-19 era. <ul style="list-style-type: none"> <li>Higher preference for in-person sessions than online (60% vs 40%).</li> <li>66% reported no differences in enjoyment with online vs in-person.</li> <li>20% reported that the exercise intensity felt easier during online sessions.</li> <li>Engagements varied with approximately 50% of the sample reporting the same as in-person and 50% reporting less than in-person.</li> <li>Increased emotional function and decreased cognitive fatigue for both participants.</li> <li>No changes were found in all other outcomes.</li> </ul>
Grazioli et al. (2020)	2 Women / Patients with breast cancer / Stage = NR / Age = 43 and 56 yrs old / Race/ethnicity = NR	Case reports of 2 patients Virtual exercise intervention using smartphone app video calling (WhatsApp)	4 months	F: 2 days/week I: progressive 50–70% of HRmax for aerobic; (volume: progressive 10–12 reps x 3–5 exercises x 1–2 sets) T: 60 min Type: one-on-one aerobic and resistance training	100% adherence, 100% retention	<ul style="list-style-type: none"> <li>Retention (65.6%). Fitness was the most attended class (42.2%), followed by meditation (19.8%), yoga (15.3%), music (8.6%), dance (7.1%), and tai chi (6.9%).</li> <li>Anxiety/stress decreased by 84%.</li> <li>Higher retention rates with online training compared to in-person (95% vs 80%).</li> <li>No differences were found in adverse events.</li> <li>Chair stand time decreased in those breast cancer survivors who trained in-person. No differences were found for their spouses.</li> <li>Higher retention rates with online training compared to in-person (91% vs 81%).</li> <li>Adverse events (4 vs 5) and chair stand time (–20% vs –23.7%) were similar in online and in-person, respectively.</li> <li>Between-group and within differences were not measured</li> <li>Cardiovascular endurance (15%: p &lt; 0.05), muscular endurance (18%: p &lt; 0.05) and flexibility (32%: p &lt; 0.05) increased in all patients combined (n = 491)</li> <li>Physical function (timed up and go) (27%: p &lt; 0.05) decreased in all patients combined (n = 491)</li> </ul>
Trevino et al. (2021)	5948 visits / sex = NR / adult cancer patients / Stage = NR / Mean age = NR / Race/ethnicity = NR	Virtual mind-body group-based therapy sessions	2 months	NR	NR	<ul style="list-style-type: none"> <li>Retention (65.6%). Fitness was the most attended class (42.2%), followed by meditation (19.8%), yoga (15.3%), music (8.6%), dance (7.1%), and tai chi (6.9%).</li> <li>Anxiety/stress decreased by 84%.</li> <li>Higher retention rates with online training compared to in-person (95% vs 80%).</li> <li>No differences were found in adverse events.</li> <li>Chair stand time decreased in those breast cancer survivors who trained in-person. No differences were found for their spouses.</li> <li>Higher retention rates with online training compared to in-person (91% vs 81%).</li> <li>Adverse events (4 vs 5) and chair stand time (–20% vs –23.7%) were similar in online and in-person, respectively.</li> <li>Between-group and within differences were not measured</li> <li>Cardiovascular endurance (15%: p &lt; 0.05), muscular endurance (18%: p &lt; 0.05) and flexibility (32%: p &lt; 0.05) increased in all patients combined (n = 491)</li> <li>Physical function (timed up and go) (27%: p &lt; 0.05) decreased in all patients combined (n = 491)</li> </ul>
Winters-Stone et al. (2021)	31 dyads (men and women) / Breast cancer survivors and spouses / Stage = NR / Mean age survivors = 62 ± 9 yr; Mean age spouses = 66 ± 8 yr / Race/ethnicity = NR	Two-arm (adapted due to COVID-19): Virtually supervised group (n = 12 dyads) In-person supervised group (n = 19 dyads)	6 months	F: 2 days/wk I: 8–10 RM (volume: progressed to 2–3 sets, 8–10 reps) T: NR Type: group-based resistance training	Virtual: 86% ± 12% vs In-person: 81% ± 13%	<ul style="list-style-type: none"> <li>Retention (65.6%). Fitness was the most attended class (42.2%), followed by meditation (19.8%), yoga (15.3%), music (8.6%), dance (7.1%), and tai chi (6.9%).</li> <li>Anxiety/stress decreased by 84%.</li> <li>Higher retention rates with online training compared to in-person (95% vs 80%).</li> <li>No differences were found in adverse events.</li> <li>Chair stand time decreased in those breast cancer survivors who trained in-person. No differences were found for their spouses.</li> <li>Higher retention rates with online training compared to in-person (91% vs 81%).</li> <li>Adverse events (4 vs 5) and chair stand time (–20% vs –23.7%) were similar in online and in-person, respectively.</li> <li>Between-group and within differences were not measured</li> <li>Cardiovascular endurance (15%: p &lt; 0.05), muscular endurance (18%: p &lt; 0.05) and flexibility (32%: p &lt; 0.05) increased in all patients combined (n = 491)</li> <li>Physical function (timed up and go) (27%: p &lt; 0.05) decreased in all patients combined (n = 491)</li> </ul>
Wonders et al. (2021)	32 Men / Survivors of prostate cancer / Mean age (in person) = 72 ± 6 yr; Mean age (virtual) = 72 ± 7 yr / Race/ethnicity = NR	Two-arm (adapted due to COVID-19): Virtually supervised group (n = 11) In-person supervised group (n = 21)	6 months	F: 3 days/wk I: 15% BW (volume: progressed to 2–3 sets, 8–10 reps) T: 60 min Type: group-based resistance training	Virtual: 91% ± 9% vs In-person: 81% ± 12%	<ul style="list-style-type: none"> <li>Retention (65.6%). Fitness was the most attended class (42.2%), followed by meditation (19.8%), yoga (15.3%), music (8.6%), dance (7.1%), and tai chi (6.9%).</li> <li>Anxiety/stress decreased by 84%.</li> <li>Higher retention rates with online training compared to in-person (95% vs 80%).</li> <li>No differences were found in adverse events.</li> <li>Chair stand time decreased in those breast cancer survivors who trained in-person. No differences were found for their spouses.</li> <li>Higher retention rates with online training compared to in-person (91% vs 81%).</li> <li>Adverse events (4 vs 5) and chair stand time (–20% vs –23.7%) were similar in online and in-person, respectively.</li> <li>Between-group and within differences were not measured</li> <li>Cardiovascular endurance (15%: p &lt; 0.05), muscular endurance (18%: p &lt; 0.05) and flexibility (32%: p &lt; 0.05) increased in all patients combined (n = 491)</li> <li>Physical function (timed up and go) (27%: p &lt; 0.05) decreased in all patients combined (n = 491)</li> </ul>
Wonders et al. (2021)	491 Men and women / Mostly breast cancer (58%) / Stage = NR / Mean age: 60 yr / Mostly White (76%)	Single group study (adapted due to COVID-19) In person to virtual to in-person (n = 208) In-person to virtual to virtual (n = 215) Virtual to in-person (n = 15) Virtual to virtual (n = 53)	12 weeks In person: Average 2.3 visits before quarantine	F: 1 day/wk I: 30–45% predicted VO2max (volume: 3 sets, 10 reps & rest:15–20 s) T: 30 min (goal 150 min/wk) Type: aerobic & resistance & flexibility	Virtual: 84% In-person: 89–90% Withdrawn: 3.5% (N = 18)	<ul style="list-style-type: none"> <li>Retention (65.6%). Fitness was the most attended class (42.2%), followed by meditation (19.8%), yoga (15.3%), music (8.6%), dance (7.1%), and tai chi (6.9%).</li> <li>Anxiety/stress decreased by 84%.</li> <li>Higher retention rates with online training compared to in-person (95% vs 80%).</li> <li>No differences were found in adverse events.</li> <li>Chair stand time decreased in those breast cancer survivors who trained in-person. No differences were found for their spouses.</li> <li>Higher retention rates with online training compared to in-person (91% vs 81%).</li> <li>Adverse events (4 vs 5) and chair stand time (–20% vs –23.7%) were similar in online and in-person, respectively.</li> <li>Between-group and within differences were not measured</li> <li>Cardiovascular endurance (15%: p &lt; 0.05), muscular endurance (18%: p &lt; 0.05) and flexibility (32%: p &lt; 0.05) increased in all patients combined (n = 491)</li> <li>Physical function (timed up and go) (27%: p &lt; 0.05) decreased in all patients combined (n = 491)</li> </ul>

Note: NA indicate that the information is not applicable. NR indicate that the information is not reported.

Abbreviations: BMI, body mass index; BW, body weight; Days/wk, days per week; F, frequency; HRmax, heart rate maximum; HRR, heart rate reserve; I, intensity; Min, minutes; Min/session, minutes per session; Min/wk, minutes per week; Pre-hab, pre-habilitation; QoL, quality of life; RCT, randomized and controlled trial; Reps, repetitions; RPE, rate of perceived exertion; T, time; VO2max, maximal oxygen uptake; Yr, years.

Nevertheless, these preliminary results in colorectal patients support the effectiveness of self-directed unsupervised home-based exercise interventions.

### 3.2. Home-based self-directed with regular guidance

We identified four studies examining self-directed exercise/physical activity and lifestyle interventions with regular guidance. Overall, these studies used websites with online videos (Wu et al., 2021), smartwatches (e.g., fitbit) (Forner et al., 2021) and printed exercise materials to support cancer survivors with lifestyle and exercise resources during COVID-19, as well as phone calls or messages to maintain weekly contact with patients (Papandreou et al., 2021; Wu et al., 2021; Natalucci et al., 2021; Forner et al., 2021). For example, Papandreou et al. conducted a 3-month RCT in 44 breast cancer survivors to assess the impact of an adapted clinical resource (e.g. implementation of a patient food database as part of the Clinical Decision Support System [CDSS] to assist in clinical decision making for care of cancer survivors), which was complemented by phone calls every 15 days to assist with the implementation of Mediterranean diet and physical activity consultation (Papandreou et al., 2021). They reported that those exposed to the CDSS had a significantly increased adherence to the Mediterranean diet, increased physical activity levels, achieved weight and fat mass loss, and maintained glucose and lipid levels when compared to the control group who only received phone calls to discuss general lifestyle advice every 15 days.

Wu et al. also completed a prospective observational study to assess the feasibility of their COVID-19 adapted prehabilitation program for cancer survivors from in-person to home-based which included educational material, online videos, and weekly contact from staff who reinforced healthy lifestyle behaviors (Wu et al., 2021). The adapted prehabilitation program was well received with 76% of patients consenting to participate; reasons for non-acceptance included self-perceived lack of benefit, starting treatment soon, or wanted face-to-face program. Focus groups highlighted benefits of the adapted program to include flexibility, accessibility, social support from staff, and eliminating the need to exercise in front of others, therefore, removing the perceived judgment of other exercisers. Contrastingly, identified challenges included lack of digital ability and literacy, potential cost of digital resources, absence of group sessions, and reliance on self-motivation. Nevertheless, the adapted prehabilitation program led to significant improvement in self-perceived health and fatigue.

Natalucci et al. originally proposed a combined home-based and in-person exercise and nutrition protocol, which was completed for 4-weeks before COVID-19 “stay at home” mandates. All sessions became home-based with weekly phone calls from exercise and nutrition specialists to reinforce advice and recommendations (Natalucci et al., 2021). Due to the change in intervention, the control and intervention groups were combined for analysis as the control group also received weekly healthy lifestyle reminders and a preliminary analysis indicated no difference between groups. They reported that weekly healthy lifestyle reminders during the COVID-19 “stay at home” period led to improved BMI, cardiorespiratory fitness, metabolic and inflammatory parameters, cardiac function indexes, heart rate variability, and Mediterranean diet adherence. Other researchers found similar positive impacts of adapted exercise interventions as a result of COVID-19 “stay at home” mandates (Forner et al., 2021).

In this regard, home-based self-directed exercise with regular guidance from support staff (e.g., research or clinical people) during the COVID-19 pandemic was feasible in cancer patients and led to improved lifestyle behaviors (e.g., increases in physical activity), as well as health outcomes such as body composition and VO<sub>2</sub>max.

### 3.3. Virtually supervised home-based exercise interventions

Another major adaptation that occurred because of COVID-19 was the implementation of virtually supervised exercise as an alternative to supervised in-person sessions. We identified seven manuscripts that reported the use of virtually supervised or video-conferencing format as an alternative modality of exercise intervention delivery during COVID-19 (Di Blasio et al., 2021; Gothe and Erlenbach, 2021; Grazioli et al., 2020; Trevino et al., 2021; Winters-Stone et al., 2021; Wonders et al., 2021; Basen-Engquist and Liao, 2020).

Overall, various computer or smartphone applications were used (e.g., Zoom, FaceTime, Skype, or WhatsApp) and exercise sessions were mostly conducted in a group-based setting rather than a one-on-one. There are substantial heterogeneities across studies in terms of study designs (e.g., single-arm), sample sizes (e.g., ranging n = 2–491), and cancer types (e.g., breast, prostate). Furthermore, most of the studies were not designed for assessing virtual exercise and analyzed a subsample of participants who received virtual exercise as an alternative during COVID-19 (Di Blasio et al., 2021; Gothe and Erlenbach, 2021; Winters-Stone et al., 2021; Wonders et al., 2021; Basen-Engquist and Liao, 2020). However, the findings suggest that virtually supervised exercise is generally feasible and well-accepted in cancer survivors, with adherence ranging from 84.0% to 94.4% (Di Blasio et al., 2021; Gothe and Erlenbach, 2021; Grazioli et al., 2020; Trevino et al., 2021; Winters-Stone et al., 2021; Wonders et al., 2021; Basen-Engquist and Liao, 2020). Winters-Stone et al. analyzed data from two individual trials in 62 breast cancer survivors and spouses and 32 prostate cancer survivors to report the feasibility of virtually supervised exercise. Compared to in-person supervision before COVID-19, virtually supervised format showed higher rates of attendance in both interventions (80–81% vs 86–91%, respectively) and retention (80–81% vs 91–95%, respectively) (Winters-Stone et al., 2021). Wonders et al. conducted a community-based 12-week exercise program in 491 survivors of various cancer types and reported high adherence rates (84%) in the virtually supervised setting although they were lower compared to the in-person setting (90%). Although cancer survivors well-adhere to virtually supervised sessions, in-person sessions may still be preferred (Gothé and Erlenbach, 2021).

Studies also reported the preliminary efficacy of virtually supervised exercise interventions on various outcomes in cancer survivors (Baumann et al., 2012; Basen-Engquist and Liao, 2020; Christensen et al., 2018; Hallal et al., 2012; Ndjaverá et al., 2020; Ormel et al., 2018; Williams et al., 2018). For example, in a single-arm community-based exercise study, virtually supervised exercise significantly improved cardiovascular endurance by 15.2%, muscular endurance by 18.2%, flexibility by 31.9%, and agility and physical function by 27.5% (Wonders et al., 2021). Furthermore, Di Blasio et al. established that breast cancer survivors who participated in group-based virtual supervised exercise had a superior increase in physical activity and reduction of sedentary behavior when compared to those who only received personalized advice via phone call (Di Blasio et al., 2021). Moreover, virtually supervised exercise has been reported to improve patient-reported outcomes such as quality of life, feeling of support, feeling of loneliness, and anxiety/stress (Grazioli et al., 2020; Trevino et al., 2021; Wonders et al., 2021).

It should be noted that these trials were not initially designed to examine the feasibility and efficacy of virtually supervised exercise, where the findings were likely confounded due to the mixed use of in-person and virtual formats given the timeframe of the intervention periods and sudden changes in COVID-19 related restrictions. Nevertheless, the use of virtually supervised exercise is deemed feasible in cancer survivors and potentially efficacious in improving physical fitness and patient-reported outcomes, which requires further research designed to

utilize this format and to examine its feasibility, acceptability, and effectiveness in various cancer settings.

#### 4. Recommendations to conduct virtually supervised exercise interventions to optimize health outcomes in cancer survivors beyond COVID-19

Given emerging COVID-19 variants and the continuous increase in cases worldwide (World Health Organization, 2021), it is likely that virtual exercise oncology will continue to grow. As summarized in Table 3, virtually supervised exercise has several advantages including the use of a hygienic space, elimination of mask-wearing, and removal of travel burden to exercise facility. Moreover, the virtually supervised format allows researchers to maintain the rigor and fidelity of supervised exercise in a remote setting. However, several challenges must be overcome such as technology illiteracy, securing a large, safe, and uninterrupted space if a patient lives with others, cost of equipment including Wi-Fi, and patient safety, particularly if a patient has never exercised before, has comorbidities, or treatment-related side effects. With these advantages and challenges in mind, and the preliminary results of virtually supervised exercise previously discussed, we present recommendations for researchers and exercise professionals for delivering virtually supervised home-based exercise interventions for cancer survivors.

##### 4.1. Ensuring safety as a top priority

Researchers should consider various strategies to ensure patients' safety throughout each virtual exercise session. One-on-one exercise sessions are a crucial aspect to ensure safety in a virtual setting, especially when working with a clinical population with no previous exercise experience. To ensure safety during group-based exercise sessions with cancer patients, it is important to have introductory sessions to ensure proper technique and reduce injury risk. Furthermore, given that cancer survivors often experience daily changes as a result of treatment side-effects, we recommend the use of a cancer-related symptom questionnaire (e.g., Therapy-Related Symptom Checklist) before each one-on-one exercise session to identify symptoms that should be closely monitored during exercise or even preclude the exercise session (Williams et al., 2013). During a group-based exercise session, breakout rooms before the start of the exercise session could be used for this purpose to discuss health-related issues with each individual in a private space. Moreover, exercise trainers and researchers need to confirm the address where patients are training remotely, as well as having an emergency contact and knowing if the patient is home alone, in case any accident occur during the exercise session. Additionally, heart rate (HR) monitors and automated blood pressure measures can be used to conduct health screening before exercise and monitor HR during exercise, particularly patients with cardiometabolic comorbidities (Fletcher et al., 2001). It is also ideal to conduct an initial in-person exercise familiarization session to provide patients with detailed exercise instructions (e.g., proper exercise postures and use of exercise equipment), especially with older cancer survivors or those with comorbidities (e.g., severe osteoporosis, neuropathy, etc.). Lastly, it is important to include in the consent form potential liability issues (e.g., if the exercise equipment damages the floor at patient's house) and data protection issues (e.g., apps use, sharing their personal address with the exercise equipment company for delivery, etc.).

##### 4.2. Rigorous exercise prescription and implementation

A virtually supervised intervention may provide a greater opportunity to adequately meet the intended exercise prescription compared with unsupervised interventions (Okechukwu et al., 2021), but there are several points to consider. Virtually supervised home-based exercise interventions in cancer survivors should be developed using the

**Table 3**

Potential advantages and challenges of virtually supervised exercise intervention format in exercise oncology research.

For researchers / interventionists	For patients
<i>Advantages</i>	
<ul style="list-style-type: none"> <li>o Maintaining the rigor of supervised exercise</li> <li>o Potentially improving the adherence and efficacy of the intervention in a home-based setting</li> <li>o Greater freedom with location for virtual intervention</li> </ul>	<ul style="list-style-type: none"> <li>o No contact with other people in a public space and low risk of infection (especially for those who are undergoing active treatment or immunocompromised)</li> <li>o No mask wearing during exercise that helps performing exercise with cardiopulmonary exertion</li> <li>o Reducing travel burden (time and cost) and absence from home (e.g., Patients with young children or another dependent person)</li> </ul>
<i>Challenges</i>	
<ul style="list-style-type: none"> <li>o Difficulties in supervising and monitoring intervention and safety.</li> <li>o Costs for home exercise equipment, virtual sessions for those not having proper device or internet</li> </ul>	<ul style="list-style-type: none"> <li>o Limited social interactions/support with other patients</li> <li>o Safety concerns for those who are not familiar with home-based equipment</li> <li>o Technical issues with device and internet</li> <li>o Lack of enough space at home and other distractions</li> </ul>

Frequency, Intensity, Time, Type (FITT) principles and exercise volume to ensure a proper exercise prescription, and to provide better context for interpreting study results and improve research to practice translation (Bland et al., 2021). Regarding exercise modality, aerobic exercise may be simpler to implement as modes such as walking are natural for majority of people, therefore, little guidance is required to teach the exercise mode. However, if aerobic exercise equipment is utilized (e.g., stationary bike, rower etc.) this can add several challenges and barriers including high cost, assembly of equipment if delivered in parts, and exercise technique on devices that may be unfamiliar to the participant. With regard to resistance exercise, the equipment cost may be lower (e.g., resistance bands, body weight exercise, etc.), than aerobic equipment (e.g., treadmill); however, the verbal instruction of resistance exercise technique may be more challenging in a virtual environment compared to an in-person environment where physical corrections are possible. Moreover, it should be noted that trainers and researchers require an appropriate visual of the patient throughout the session to reduce injury risk and monitor proper technique in the use of weight machine alternatives (Conceicao et al., 2021).

Although increases in muscle mass and strength have been previously reported using home-based interventions in certain populations such as older adults (Chaabene et al., 2021), typically home-based resistance exercise is mostly limited to free weights, resistance bands, or body weight. While these resistance-based modes are effective and can elicit muscle mass and strength improvements (Bardstu et al., 2020), participants may not be able to achieve the same intensity needed to induce proportional improvements when compared to clinic-based programs utilizing machine-based weights. Furthermore, adaptations in muscle mass and strength can be difficult to induce in cancer patients, regardless of resistance training mode, given the effects of cancer, its treatment, and presence of comorbidities (Christensen et al., 2018). Therefore, it is important to consider if the training objective (e.g., strength or hypertrophy) is feasible in a home-based setting where equipment and space limitations may be present. Furthermore, prescribing the desired exercise intensity, is a key training variable that should be manipulated accordingly during virtual supervision. For example, treatment side effects may affect HR resulting in tachycardia or bradycardia, so we recommend using %HRmax or %HR reserve in combination with additional methods such as watt-based training prescription, rating of perceived exertion (RPE), or the Talk Test, to gauge intensity to ensure the appropriate dosage (Maginador et al., 2020; Norman et al., 2008). Effective resistance training prescriptions include using the percentage of repetition maximum (%RM) after in-person

testing combined with other methods such as the perceived exertion scale for resistance exercise (Omni-res scale) (Colado et al., 2018) or the number of repetitions in reserve (RIR) (Zourdos et al., 2016). Researchers should include frequent strength and cardiovascular testing timepoints for cancer survivors in order to meet training principles (e.g. progression or overload) (Bland et al., 2021).

#### 4.3. Provide accessibility and maintain adherence

Recognizing the diverse environments and available amenities that compromise the efficacy of home-based exercise provides important insight for designing exercise prescriptions. One of the most reported challenges by cancer survivors in home-based exercise interventions is establishing suitable space for training (i.e. create a spacious area to exercise, appropriate and safe anchor of exercise bands, etc.) (Lopez et al., 2020). Additional barriers include unsafe neighborhoods or possible interruptions during exercise sessions from cohabitants (Sallis et al., 2016). Therefore, it is important to identify home-based barriers to exercise training during baseline assessments and provide alternate options that are safe with adequate space (i.e. outdoor park settings) (Lopez et al., 2020). Cancer survivors may also experience accessibility barriers (e.g. poor technology literacy, unstable Wi-Fi, programs or websites not formatted for use on mobile phone/tablet) (Morrison et al., 2020). Researchers should consider providing patients with detailed written instructions on device function, connecting to video conferencing, and securing stable internet access (e.g., providing internet-enabled tablet). Encouraging patients to test their internet connection prior to training sessions could alleviate the disruptive and frustrating nature of internet reliability.

Adherence is a challenge in exercise oncology trials and can be improved through many facets, with primary consideration for providing flexible scheduling options to accommodate patient availability for training at home and to address possible technology delays that require rescheduling exercise sessions. Additionally, trainer education should be standardized to conduct virtual exercise sessions comparable to in-person sessions, and include the type/frequency of verbal feedback, provide adequate motivation while exercise is being performed, and assess patient's status/progress throughout the session (e.g., Borg scale or HR). Furthermore, integrating group-based sessions with other cancer survivors can enhance social interaction and potentially benefit intervention adherence and motivation.

#### 4.4. Remote exercise testing

Delivering remote exercise testing to prescribe exercise and to assess health outcomes in cancer survivors is also a great challenge, with limited evidence regarding the validity to adapt in-person to remote assessments. Winters-Stone et al. reported high reliability of transitioning the physical function tests short physical performance battery (Intra-reliability (IAR) = 0.97; inter-reliability (IER) = 0.79), the timed-up and go test (IAR = 0.96; IER = 0.99), and 4 m usual walk (IAR = 0.90; IER = 0.40) to a virtually supervised environment in cancer survivors (Winters-Stone et al., 2020). In this regard, ensuring safety and validity during a remote assessment of cardiorespiratory fitness may be more difficult, particularly for older adults or those with comorbidities. For example, preliminary data suggest adequate validity for the 6-minute walk test (6MWT) when performed outdoors independently monitored with phone applications, but not in a home-based setting, and may be a simple virtual indirect alternative to the in-clinic cardiopulmonary exercise test (CPET) (Holland et al., 2020). Overall, there is insufficient evidence to ensure the validity of virtually supervised remote exercise testing in cancer survivors, therefore we recommend striving for in-person exercise testing in order to accurately prescribe exercise and ensure valid measurements of health outcomes.

Formalizing these types of recommendations for continuity of exercise-based research during a pandemic are essential to deliver

effective virtual-based interventions that promote safety, proper prescription and testing, accessibility, and adherence for cancer survivors.

### 5. Perspective: a path forward on exercise oncology beyond COVID-19 pandemic

The COVID-19 pandemic has led to the significant emergence and integration of virtually supervised home-based exercise interventions within clinical research among cancer survivors. This approach allows us to take advantage of both at-home and in-person exercise. Emerging studies included in this review have shown feasibility and safety of virtually supervised home-based exercise interventions among cancer survivors, and improvements in several health outcomes (e.g., fatigue or quality of life). However, given the relatively recent nature of COVID-19, there is insufficient evidence supporting the effectiveness of this approach on other important cancer-related health outcomes such as body composition, physical function, or clinical outcomes (e.g., survivorship).

Moving beyond the pandemic, it is probable that in the upcoming years several exercise oncology trials will be delivered remotely. We believe that these trials should implement a virtually supervised design to maximize health benefits. Before transitioning to a remote environment, it is important to consider the cost-benefit ratio of a virtually supervised home-based exercise intervention compared to in-person as the former may present additional financial challenges for the research team that could be underestimated. Furthermore, there is a need to reflect on the future progression of exercise oncology research and which outcomes or exercise interventions need to be tested in person first. These preliminary studies will provide evidence for which interventions should and should not be delivered virtually to derive the most effective and safe exercise prescriptions for home-based use. For example, can important health outcomes for cancer patients (e.g., muscle mass, bone health) be improved long-term with a virtually supervised home-based approach? Is home-based exercise equipment able to provide a sufficient anabolic stimulus? Can high-intensity interval training be delivered safely at home? In this regard, there are several questions that are unsolved in a remote exercise setting, thus future trials in exercise oncology using this approach are needed.

Virtually supervised exercise can reduce barriers to participation in an in-person exercise intervention in cancer patients living in rural communities, countries with long distances, or countries with weak fitness facilities infrastructure reduce barriers to access to exercise facilities in rural communities or countries with long distance or weak fitness facilities infrastructure (Charlton et al., 2015). Moreover, this pandemic has led to a dramatic impact in racial/ethnic minority cancer survivors, with an increase in health inequalities and socio-economic disparities (Wang et al., 2021; Dorn et al., 2020). Therefore, barriers to enrolling in exercise oncology trials during and after the pandemic may be even greater for more vulnerable populations (Hansson et al., 2021) including older adults or those from racial/ethnic minority backgrounds. Furthermore, current data reveals that racial and ethnic minority cancer survivors experienced a higher burden to access telehealth tools (Abdel-Rahman, 2021). Regarding remote exercise interventions, it is unknown yet if technology may eliminate or exacerbate barriers to exercise in this population. Our research laboratory is currently evaluating this with multiple ongoing studies including the ROSA trial (*Reducing Metabolic Dysregulation in Obese Latina Breast Cancer Survivors*, 2022), which targets Latina and/or Hispanic breast cancer survivors and the THRIVE trial (*Testing Homebased Exercise Strategies to Improve Exercise Participation and Cardiovascular Health in Underserved Minority*, 2022) which targets Black and Hispanic cancer survivors receiving chemotherapy. The ROSA trial transitioned to a Zoom-based supervised exercise intervention due to the pandemic. We have implemented several strategies to ensure that remote exercise does not increase barriers to exercise in this population (i.e., providing a Wi-Fi-enabled tablet, training equipment). Results from this ongoing



trial will allow determining the effectiveness of this new exercise approach in important health outcomes (i.e., metabolic dysregulation, body composition), and if it reduces barriers to participation in exercise trials in this specific population. The THRIVE trial was designed to include a virtual exercise intervention from inception to outreach to patients not residing within the Greater Boston area or that lack adequate transportation for clinical in-person exercise. Collectively these trials will aid in planning for future exercise oncology intervention for minority survivors.

## 6. Conclusion

Following a review of the existing unsupervised, semi-supervised and virtually supervised exercise interventions in cancer survivors, we identify that virtually supervised group-based exercise interventions were the most common format among oncology lifestyle interventions during the pandemic. We conclude that virtually supervised home-based exercise interventions may be feasible, safe, and may improve several health outcomes in cancer survivors (e.g., fatigue, anxiety/stress, etc.). Given these studies were not designed to test feasibility and efficacy of this exercise approach, future studies should be specifically designed and powered to further investigate these outcomes and other health and clinical outcomes such as body composition, physical function, or survivorship. Recommendations for future interventions using this exercise approach include ensuring safety, proper prescription and testing, accessibility, and adherence. While infection rates continue to grow due to new COVID-19 variants, it is critical to continue to encourage the uptake of exercise among cancer survivors, given the known benefits of exercise, as the risks associated with inactivity may result in additive or synergistic risks when coupled with the risk of infection from COVID-19. Therefore, during these challenging times, there is a need to maintain and develop high-quality research in exercise oncology to support cancer survivors to start and continue exercising beyond the COVID-19 pandemic.

## Acknowledgements

The authors would like to acknowledge the contribution of Danny Nguyen in the graphical abstract.

## Funding

N/A.

## Conflict of Interest Disclosure

The authors of this paper declare no conflicts of interest.

## Author Contribution Statement

PGE and CDC conceptualized the narrative review. RLW, DWK, AJN contributed to the conception and design of the work. PGE, RLW, DWK, AJN conducted the search and screened potentially eligible studies. All authors interpreted results, drafted the manuscript and provided manuscript feedback as well as approved the final version.

## References

Abdel-Rahman, O., 2021. Patient-related barriers to some virtual healthcare services among cancer patients in the USA: a population-based study. *J. Comp. Eff. Res.* 10 (2), 119–126.

Bardstu, H.B., Andersen, V., Fimland, M.S., et al., 2020. Effectiveness of a resistance training program on physical function, muscle strength, and body composition in community-dwelling older adults receiving home care: a cluster-randomized

controlled trial. *Eur. Rev. Aging Phys. Act.* 17, 11. <https://doi.org/10.1186/s11556-020-00243-9>.

Basen-Engquist, K., Liao, Y., 2020. Active Living After Cancer: converting a group physical activity intervention for cancer survivors to a virtual format in response to the coronavirus pandemic. *Am. Soc. Clin. Oncol.*

Batalik, L., Winnige, P., Dosbaba, F., Vlazna, D., Janikova, A., 2021. Home-based aerobic and resistance exercise interventions in cancer patients and survivors: a systematic review. *Cancers* 13 (8). <https://doi.org/10.3390/cancers13081915>.

Baumann, F.T., Zopf, E.M., Bloch, W., 2012. Clinical exercise interventions in prostate cancer patients—a systematic review of randomized controlled trials. *Support Care Cancer* 20 (2), 221–233. <https://doi.org/10.1007/s00520-011-1271-0>.

Baumann, F.T., Reimer, N., Gockeln, T., et al., 2021. Supervised pelvic floor muscle exercise is more effective than unsupervised pelvic floor muscle exercise at improving urinary incontinence in prostate cancer patients following radical prostatectomy - a systematic review and meta-analysis. *Disabil. Rehabil.* 1–12. <https://doi.org/10.1080/09638288.2021.1937717>. Sep 22.

Bland, K.A., Bigaran, A., Campbell, K.L., Treviskis, M., Zopf, E.M., 2020. Exercising in isolation? The role of telehealth in exercise oncology during the COVID-19 pandemic and beyond. *Phys. Ther.* 100 (10), 1713–1716. <https://doi.org/10.1093/ptj/pzaa141>.

Bland, K.A., Neil-Sztramko, S.E., Zdravec, K., et al., 2021. Attention to principles of exercise training: an updated systematic review of randomized controlled trials in cancers other than breast and prostate. *BMC Cancer* 21 (1), 1179. <https://doi.org/10.1186/s12885-021-08701-y>.

Buffart, L.M., Kalter, J., Sweegers, M.G., et al., 2017. Effects and moderators of exercise on quality of life and physical function in patients with cancer: an individual patient data meta-analysis of 34 RCTs. *Cancer Treat. Rev.* 52, 91–104. <https://doi.org/10.1016/j.ctrv.2016.11.010>.

Campbell, K.L., Winters-Stone, K.M., Wiskemann, J., et al., 2019. Exercise guidelines for cancer survivors: consensus statement from international multidisciplinary roundtable. *Med. Sci. Sports Exerc.* 51 (11), 2375–2390. <https://doi.org/10.1249/MSS.0000000000002116>.

Chaabene, H., Prieske, O., Herz, M., et al., 2021. Home-based exercise programmes improve physical fitness of healthy older adults: a PRISMA-compliant systematic review and meta-analysis with relevance for COVID-19. *Ageing Res. Rev.* 67, 101265. <https://doi.org/10.1016/j.arr.2021.101265>.

Charlton, M., Schlichting, J., Chioreso, C., Ward, M., Vikas, P., 2015. Challenges of rural cancer care in the United States. *Oncology* 29 (9), 633–640.

Cheng, K.K.F., Lim, Y.T.E., Koh, Z.M., Tam, W.W.S., 2017. Home-based multidimensional survivorship programmes for breast cancer survivors. *Cochrane Database Syst. Rev.* 8 (8), Cd011152. <https://doi.org/10.1002/14651858.CD011152.pub2>.

Christensen, J.F., Simonsen, C., Hojman, P., 2018. Exercise training in cancer control and treatment. *Compr. Physiol.* 9 (1), 165–205. <https://doi.org/10.1002/cphy.c180016>.

Colado, J.C., Pedrosa, F.M., Juegas, A., et al., 2018. Concurrent validation of the OMNI-Resistance Exercise Scale of perceived exertion with elastic bands in the elderly. *Exp. Gerontol.* 103, 11–16. <https://doi.org/10.1016/j.exger.2017.12.009>.

Conceicao, M.S., Derchain, S., Vechin, F.C., et al., 2021. Maintenance of muscle mass and cardiorespiratory fitness to cancer patients during COVID-19 era and after SARS-CoV-2 vaccine. *Front. Physiol.* 12, 655955. <https://doi.org/10.3389/fphys.2021.655955>.

Courney, K.S., Stevinson, C., McNeely, M.L., et al., 2012. Effects of supervised exercise on motivational outcomes and longer-term behavior. *Med. Sci. Sports Exerc.* 44 (3), 542–549. <https://doi.org/10.1249/MSS.0b013e3182301e06>.

Di Blasio, A., Morano, T., Lancia, F., 2021. Effects of activity tracker-based counselling and live-web exercise on breast cancer survivors during Italy COVID-19 lockdown. *J. Funct. Morphol. Kinesiol.* 6 (2), 50.

Dorn, A.V., Cooney, R.E., Sabin, M.L., 2020. COVID-19 exacerbating inequalities in the US. *Lancet* 395 (10232), 1243–1244. [https://doi.org/10.1016/S0140-6736\(20\)30893-X](https://doi.org/10.1016/S0140-6736(20)30893-X).

Fletcher, G.F., Balady, G.J., Amsterdam, E.A., et al., 2001. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. *Circulation* 104 (14), 1694–1740. <https://doi.org/10.1161/hc3901.095960>.

Fornier, J.K., Doughty, A., Dalstrom, M., Messer, B.L., Lizer, S.K., 2021. Quality of life: a nurse-led physical activity coaching program to improve the quality of life of patients with cancer during the COVID-19 pandemic. *Clin. J. Oncol. Nurs.* 25 (5), 571–577. <https://doi.org/10.1188/21.Cjon.571-577>.

Gonzalo-Encabo, P., Cereijo, L., Remon, A.L.C., Jimenez-Beatty, J.E., Diaz-Benito, V.J., Santacruz Lozano, J.A., 2021. Associations between individual and environmental determinants and physical activity levels of an active population during the Spanish lockdown. *Prev. Med.* 153, 106719. <https://doi.org/10.1016/j.ypmed.2021.106719>.

Gothe, N.P., Erlenbach, E., 2021. Feasibility of a yoga, aerobic and stretching-toning exercise program for adult cancer survivors: the STAYFit trial. *J. Cancer Surviv.* 1–10.

Grazioli, E., Cerulli, C., Dimauro, I., Moretti, E., Murri, A., Parisi, A., 2020. New strategy of home-based exercise during pandemic COVID-19 in breast cancer patients: a case study. *Sustainability.* 12 (17), 6940.

Guthold, R., Stevens, G.A., Riley, L.M., Bull, F.C., 2018. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants. *Lancet Glob. Health* 6 (10), e1077–e1086. [https://doi.org/10.1016/S2214-109X\(18\)30357-7](https://doi.org/10.1016/S2214-109X(18)30357-7).

- Hallal, P.C., Andersen, L.B., Bull, F.C., et al., 2012. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 380 (9838), 247–257. [https://doi.org/10.1016/S0140-6736\(12\)60646-1](https://doi.org/10.1016/S0140-6736(12)60646-1).
- Hansson, R., Sallis, J.F., Coleman, N., Kauschal, N., Nocera, V.G., Keith, N., 2021. COVID-19: implications for physical activity, health disparities, and health equity. *Am. J. Lifestyle Med.* <https://doi.org/10.1177/15598276211029222>.
- Holland, A.E., Malaguti, C., Hoffman, M., et al., 2020. Home-based or remote exercise testing in chronic respiratory disease, during the COVID-19 pandemic and beyond: a rapid review. *Chron. Respir. Dis.* 17, 1479973120952418 <https://doi.org/10.1177/1479973120952418>.
- Kohl, H.W., Craig, C.L., Lambert, E.V., et al., 2012. The pandemic of physical inactivity: global action for public health. *Lancet* 380 (9838), 294–305. [https://doi.org/10.1016/S0140-6736\(12\)60898-8](https://doi.org/10.1016/S0140-6736(12)60898-8).
- Liu, C., Zhao, Y., Okwan-Duodu, D., Basho, R., Cui, X., 2020. COVID-19 in cancer patients: risk, clinical features, and management. *Cancer Biol. Med.* 17 (3), 519–527. <https://doi.org/10.20892/j.issn.2095-3941.2020.0289>.
- Lopez, C., McGarragle, K., Pritlove, C., 2020. Variability and limitations in home-based exercise program descriptions in oncology: a scoping review. *Support Care Cancer* 28 (9), 4005–4017. <https://doi.org/10.1007/s00520-020-05453-6>.
- López-Rodríguez-Arias, F., Sánchez-Guillén, L., Aranz-Ostáriz, V., et al., 2021. Effect of home-based prehabilitation in an enhanced recovery after surgery program for patients undergoing colorectal cancer surgery during the COVID-19 pandemic. *Support Care Cancer* 29 (12), 7785–7791. <https://doi.org/10.1007/s00520-021-06343-1>.
- Maginador, G., Lixandrao, M.E., Bortolozzo, H.I., et al., 2020. Aerobic exercise-induced changes in cardiorespiratory fitness in breast cancer patients receiving chemotherapy: a systematic review and meta-analysis. *Cancers* 12 (8). <https://doi.org/10.3390/cancers12082240>.
- Martinez-Ferran, M., de la Guia-Galipienso, F., Sanchis-Gomar, F., Pareja-Galeano, H., 2020. Metabolic impacts of confinement during the COVID-19 pandemic due to modified diet and physical activity habits. *Nutrients* 12 (6). <https://doi.org/10.3390/nu12061549>.
- Meneses-Echávez, J.F., González-Jiménez, E., Ramírez-Vélez, R., 2015. Effects of supervised multimodal exercise interventions on cancer-related fatigue: systematic review and meta-analysis of randomized controlled trials. *Biomed Res. Int.* 2015, 328636 <https://doi.org/10.1155/2015/328636>.
- Morrison, K.S., Paterson, C., Toohy, K., 2020. The feasibility of exercise interventions delivered via telehealth for people affected by cancer: a rapid review of the literature. *Semin. Oncol. Nurs.* 36 (6), 151092 <https://doi.org/10.1016/j.soncn.2020.151092>.
- Natalucci, V., Villarini, M., Emili, R., et al., 2021. Special attention to physical activity in breast cancer patients during the first wave of COVID-19 pandemic in Italy: the DianaWeb Cohort. *J. Pers. Med.* 11 (5) <https://doi.org/10.3390/jpm11050381>.
- Natalucci, V., Marini, C.F., Flori, M., 2021. Effects of a home-based lifestyle intervention program on cardiometabolic health in breast cancer survivors during the COVID-19 lockdown. *J. Clin. Med.* 10 (12) <https://doi.org/10.3390/jcm10122678>.
- Ndjavera, W., Orange, S.T., O'Doherty, A.F., et al., 2020. Exercise-induced attenuation of treatment side-effects in patients with newly diagnosed prostate cancer beginning androgen-deprivation therapy: a randomised controlled trial. *BJU Int.* 125 (1), 28–37. <https://doi.org/10.1111/bju.14922>.
- Newton, R.U., Hart, N.H., Clay, T., 2020. Keeping patients with cancer exercising in the age of COVID-19. *JCO Oncol. Pract.* 16 (10), 656–664. <https://doi.org/10.1200/OP.20.00210>.
- Norman, J.F., Hopkins, E., Crapo, E., 2008. Validity of the counting talk test in comparison with standard methods of estimating exercise intensity in young healthy adults. *J. Cardiopulm. Rehabil. Prev.* 28 (3), 199–202. <https://doi.org/10.1097/01.HCR.0000320072.89093.0d>.
- Okechukwu, C.E., Okechukwu, C.E., Deb, A.A., Agag, A., Naushad, N., Abbas, S., 2021. Precautionary measures before tailoring and commencing a tele-supervised home-based exercise oncology program for older patients with cancer and post-treatment cancer survivors in the COVID-19 era. *J. Geriatr. Oncol.* <https://doi.org/10.1016/j.jgo.2021.08.001>.
- Ormel, H.L., van der Schoot, G.G.F., Sluiter, W.J., Jalving, M., Gietema, J.A., Walenkamp, A.M.E., 2018. Predictors of adherence to exercise interventions during and after cancer treatment: a systematic review. *Psychooncology* 27 (3), 713–724. <https://doi.org/10.1002/pon.4612>.
- Ottenbacher, A., Yu, M., Moser, R.P., Phillips, S.M., Alfano, C., Perna, F.M., 2015. Population estimates of meeting strength training and aerobic guidelines, by gender and cancer survivorship status: findings from the Health Information National Trends Survey (HINTS). *J. Phys. Act Health* 12 (5), 675–679. <https://doi.org/10.1123/jpah.2014-0003>.
- Papandreou, P., Gioxari, A., Nimee, F., Skouliakou, M., 2021. Application of clinical decision support system to assist breast cancer patients with lifestyle modifications during the COVID-19 pandemic: a randomised controlled trial. *Nutrients* 13 (6). <https://doi.org/10.3390/nu13062115>.
- Reducing Metabolic Dysregulation in Obese Latina Breast Cancer Survivors Using Physical Activity. *ClinicalTrials.gov* identifier: NCT04717050. Updated September 9, 2021. Accessed January 6, 2022. (<https://www.clinicaltrials.gov/ct2/show/NCT04717050>).
- Sallis, J.F., Cerin, E., Conway, T.L., et al., 2016. Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. *Lancet* 387 (10034), 2207–2217. [https://doi.org/10.1016/S0140-6736\(15\)01284-2](https://doi.org/10.1016/S0140-6736(15)01284-2).
- Singh, B., Zopf, E.M., Howden, E.J., 2021. Effect and feasibility of wearable physical activity trackers and pedometers for increasing physical activity and improving health outcomes in cancer survivors: a systematic review and meta-analysis. *J. Sport Health Sci.* <https://doi.org/10.1016/j.jshs.2021.07.008>.
- Sohrabi, C., Alsafi, Z., O'Neill, N., et al., 2020. World Health Organization declares global emergency: a review of the 2019 novel coronavirus (COVID-19). *Int. J. Surg.* 76, 71–76. <https://doi.org/10.1016/j.ijsu.2020.02.034>.
- Stockwell, S., Trott, M., Tully, M., et al., 2021. Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: a systematic review. *BMJ Open Sport Exerc. Med.* 7 (1), e000960 <https://doi.org/10.1136/bmjsem-2020-000960>.
- Testing Homebased ExeRcise Strategies to Improve Exercise Participation and CardioVascular Health in Underserved Minority Patients with Cancer Undergoing Chemotherapy, the THRIVE Study. Accessed January 15, 2022. (<https://reporter.nih.gov/search/bZRZEXqPhkicrPy8WWHyw/project-details/10328010#details>).
- Trevino, K.M., Raghunathan, N., Latte-Naor, S., et al., 2021. Rapid deployment of virtual mind-body interventions during the COVID-19 outbreak: feasibility, acceptability, and implications for future care. *Support. Care Cancer J. Multinat. Assoc. Support. Care Cancer* 29 (2), 543–546. <https://doi.org/10.1007/s00520-020-05740-2>.
- Tuttle, K.R., 2020. Impact of the COVID-19 pandemic on clinical research. *Nat. Rev. Nephrol.* 16 (10), 562–564. <https://doi.org/10.1038/s41581-020-00336-9>.
- Ussing, A., Mikkelsen, M.K., Villumsen, B.R., et al., 2021. Supervised exercise therapy compared with no exercise therapy to reverse debilitating effects of androgen deprivation therapy in patients with prostate cancer: a systematic review and meta-analysis. *Prostate Cancer Prostatic Dis.* <https://doi.org/10.1038/s41391-021-00450-0>.
- van Waart, H., Stuiver, M.M., van Harten, W.H., et al., 2015. Effect of low-intensity physical activity and moderate- to high-intensity physical exercise during adjuvant chemotherapy on physical fitness, fatigue, and chemotherapy completion rates: results of the PACES Randomized Clinical Trial. *J. Clin. Oncol.* 33 (17), 1918–1927. <https://doi.org/10.1200/JCO.2014.59.1081>.
- Wang, Q., Berger, N.A., Xu, R., 2021. Analyses of risk, racial disparity, and outcomes among US patients with cancer and COVID-19 infection. *JAMA Oncol.* 7 (2), 220–227.
- Williams, A.D., Bird, M.L., Hardcastle, S.G., Kirschbaum, M., Ogden, K.J., Walters, J.A., 2018. Exercise for reducing falls in people living with and beyond cancer. *Cochrane Database Syst. Rev.* (10).
- Williams, P.D., Graham, K.M., Storlie, D.L., et al., 2013. Therapy-related symptom checklist use during treatments at a cancer center. *Cancer Nurs.* 36 (3), 245–254. <https://doi.org/10.1097/NCC.0b013e3182595406>.
- Wilson, R.L., Taaffe, D.R., Newton, R.U., Hart, N.H., Lyons-Wall, P., Galvão, D.A., 2021. Maintaining weight loss in obese men with prostate cancer following a supervised exercise and nutrition program—a pilot study. *Cancers* 13 (14). <https://doi.org/10.3390/cancers13143411>.
- Winters-Stone, K.M., Boisvert, C., Li, F., et al., 2021. Delivering exercise medicine to cancer survivors: has COVID-19 shifted the landscape for how and who can be reached with supervised group exercise? *Support Care Cancer* 1–4.
- Winter-Stone, K., Lipp, C., Guidarelli, C., Herrera-Fuentes, P., 2020. Converting physical function testing to the remote setting: adapting our research protocol during COVID-19. In: Presented at: GSA 2020 Annual Scientific Meeting.
- Wonders, K.Y., Gnaou, K., Schmitz, K.H., 2021. Measuring the feasibility and effectiveness of an individualized exercise program delivered virtually to cancer survivors. *Curr. Sports Med. Rep.* 20 (5), 271–276. <https://doi.org/10.1249/JSR.0000000000000846>.
- Wong, J.N., McAuley, E., Trinh, L., 2018. Physical activity programming and counseling preferences among cancer survivors: a systematic review. *Int. J. Behav. Nutr. Phys. Act* 15 (1), 48. <https://doi.org/10.1186/s12966-018-0680-6>.
- World Health Organization. Update on Omicron (<https://www.who.int/news/item/28-11-2021-update-on-omicron>).
- Wu, F., Rotimi, O., Laza-Cagigas, R., Rampal, T., 2021. The feasibility and effects of a telehealth-delivered home-based prehabilitation program for cancer patients during the pandemic. *Curr. Oncol.* 28 (3), 2248–2259. <https://doi.org/10.3390/curoncol28030207>.
- Yang, F., Shi, S., Zhu, J., Shi, J., Dai, K., Chen, X., 2020. Clinical characteristics and outcomes of cancer patients with COVID-19. *J. Med. Virol.* 92 (10), 2067–2073. <https://doi.org/10.1002/jmv.25972>.
- Yang, J., Choi, M., Choi, J., et al., 2020. Supervised physical rehabilitation in the treatment of patients with advanced cancer: a systematic review and meta-analysis. *J. Korean Med. Sci.* 35 (29), e242 <https://doi.org/10.3346/jkms.2020.35.e242>.
- Yildiz Kabak, V., Goker, H., Duger, T., 2020. Effects of partly supervised and home-based exercise program in patients undergoing hematopoietic stem cell transplantation: a case-control study. *Support Care Cancer* 28 (12), 5851–5860. <https://doi.org/10.1007/s00520-020-05432-x>.
- Yildiz Kabak, V., Atasavun Uysal, S., Duger, T., 2021. Screening supportive care needs, compliance with exercise program, quality of life, and anxiety level during the COVID-19 pandemic in individuals treated with hematopoietic stem cell transplantation. *Support Care Cancer* 29 (7), 4065–4073. <https://doi.org/10.1007/s00520-020-05965-1>.
- Zourdos, M.C., Klemp, A., Dolan, C., et al., 2016. Novel resistance training-specific rating of perceived exertion scale measuring repetitions in reserve. *J. Strength Cond. Res.* 30 (1), 267–275. <https://doi.org/10.1519/JSC.0000000000001049>.

**Paola Gonzalo-Encabo** is a postdoctoral fellow at Dana-Farber Cancer Institute and Harvard Medical School. She has a research interest in the benefits of exercise during the cancer continuum with a specific focus in understanding the mechanisms by which exercise can impact cancer outcomes.

**Rebekah L. Wilson** is a postdoctoral fellow at Dana-Farber Cancer Institute and Harvard Medical School. She has a research interest in the application of exercise into clinical care for cancer patients.

**Dong-Woo Kang** is a postdoctoral fellow at Dana-Farber Cancer Institute and Harvard Medical School. His research focuses on identifying the roles of exercise on clinical outcomes and the underlying mechanisms in cancer populations.

**Amber J. Normann** is a Ph.D. candidate at Boston University and graduate research assistant at Dana-Farber Cancer Institute. Her research interests center on the utility of exercise interventions in cancer populations.

**Christina M. Dieli-Conwright** is an Associate Professor of Medicine at the Harvard Medical School and in the Division of Population Sciences of the Department of Medical Oncology at the Dana-Farber Cancer Institute. Her research is focused on examining mechanisms by which post-diagnosis exercise can impact cancer prognosis with a specific focus on biomarkers related to tumor growth, inflammation, metabolic dysregulation, and body composition.