Rationale for Promoting Physical Activity Among Cancer Survivors: Literature Review and Epidemiologic Examination

Paul D. Loprinzi, PhD, and Hyo Lee, PhD

Purpose/Objectives: To review the extant literature on the link between physical activity and health outcomes among cancer survivors; identify evidence-based strategies to promote physical activity among this population; and conduct an epidemiologic study based on gaps from the literature review, examining the association between physical activity and various biologic markers.

Data Sources: The authors used PubMed and Google Scholar up to July 2013, as well as data from the 2003–2006 National Health and Nutrition Examination Survey for the empirical study.

Data Synthesis: Studies were examined through a systematic review process. In the epidemiologic study, 227 adult cancer survivors wore an accelerometer for four days or longer, with biologic markers (e.g., cholesterol) assessed from a blood sample.

Conclusions: The review study demonstrated that cancer survivors are relatively inactive, but physical activity may help to reduce the risk of cancer recurrence and cancer-related mortality, increase cancer treatment rates, reduce pain and other side effects associated with cancer treatment, and improve physical and mental health. The epidemiologic study showed that physical activity was associated with several understudied biomarkers (e.g., neutrophils, white blood cells) that are linked with cancer recurrence, cancer-related mortality, and other chronic diseases.

Implications for Nursing: Nurses are encouraged to promote physical activity in cancer survivors.

Key Words: physical activity; exercise; accelerometry; cancer; biomarkers; epidemiology

ONF, 41(2), 117–125. doi:10.1188/14.ONF.117-125

Regular participation in physical activity is gaining wide acceptance as a health-promoting behavior that can help prevent and treat many chronic diseases (Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010), including cancer (Loprinzi, Cardinal, Smit, & Winters-Stone, 2012). For example, research indicates that regular participation in physical activity is inversely associated with breast cancer risk (Loprinzi, Cardinal, Smit, et al., 2012), with physical activity also having a protective effect against cancer recurrence and cancer-related mortality (Loprinzi, Cardinal, Winters-Stone, Smit, & Loprinzi, 2012). Although limited and showing mixed findings (Ballard-Barbash et al., 2012; Löf, Bergström, & Weiderpass, 2012), epidemiologic research among cancer survivors demonstrated that physical activity can improve other health parameters (e.g., systemic inflammation) (Loprinzi et al., 2013) that may influence cancer recurrence (Allin, Bojesen, & Nordestgaard, 2009) and quality of life (McClellan, 2013).

The current article includes two components. The first part provides an overview of the extant physical activity-related literature among cancer survivors to provide up-to-date evidence of the specific effects of physical activity and how best to promote physical activity among this population. The second part includes an epidemiologic examination from the National Health and Nutrition Examination Survey (NHANES), which will be used to address gaps identified in the literature review.

Literature Review

The authors performed searches in PubMed and Google Scholar up to July 2013 using the following key words interchangeably: *physical activity*, *cancer*, *exercise*, *cancer survivors*, and *health*.

After reviewing the literature related to physical activity among cancer survivors, the authors identified several areas of research that could aid in the promotion of physical activity among this population. Where appropriate, findings were summarized from review studies, as opposed to single empirical studies.

Physical Activity Before and During Cancer Treatment

Loprinzi & Cardinal (2012a) reviewed the extant literature related to the effects of physical activity on side effects associated with cancer treatment. Their review

of exercise interventions showed that physical activity during cancer treatment may help to mitigate many of the side effects associated with cancer treatment, including fatigue, depression, decreased muscular strength, decreased aerobic capacity, weight gain, and impaired quality of life. In addition, some studies suggested that physical activity participation may increase the rate of completion of cancer treatment (Courneya et al., 2007). Emerging research indicated that high levels of physical activity preoperatively may reduce the risk of postoperative complications (Tatematsu, Park, Tanaka, Sakai, & Tsuboyama, 2013). Brown, Loprinzi, Brosky, and Topp (2014) have shown that prehabilitation exercise (i.e., exercise before treatment or surgery) may influence psychological constructs, such as outcome expectations, which may help facilitate the rehabilitation process.

Biologic Markers

Löf et al. (2012) and Ballard-Barbash et al. (2012) published review studies examining the effects of physical activity on biomarkers in cancer survivors. Löf et al. (2012) evaluated nine randomized, controlled trials and results, although mixed, showed that physical activity was associated with insulin, insulin-like growth factor (IGF)-I, IGF-II, insulin-like growth factor binding protein (IGFBP)-3, and C-reactive protein (CRP) in breast cancer survivors, with no associations occurring for interleukins. Ballard-Barbash et al. (2012) reviewed four epidemiologic studies and found that self-reported physical activity was inversely associated with leptin, IGF-I, and CRP, with no associations found for C-peptide, IGFBP-3, the ratio of IGF-I to IGFBP-3, or serum amyoid A. Although findings are mixed, these results suggest that physical activity is favorably linked with biomarkers associated with cancer recurrence among cancer survivors.

In an empirical study, Järvelä et al. (2013) showed that among long-term survivors of childhood acute lymphoblastic leukemia, physical activity may alleviate excess burden of cardiovascular disease morbidity by improving endothelial function. Showing similar beneficial effects, Elme et al. (2013) demonstrated in an empirical study that among breast cancer survivors, self-reported physical activity was inversely associated with waist circumference, triglyceride, insulin, and metabolic syndrome, but positively associated with high-density lipoprotein (HDL) cholesterol. However, in a randomized, controlled trial among postmenopausal breast cancer survivors, Jones et al. (2013) did not find an effect between the intervention and control groups for tumor necrosis factor (TNF)-alpha, interleukin-6 (IL-6), or CRP; however, participants who reached 80% of the intervention goal had lower IL-6 levels, which suggests that higher physical activity levels may help to reduce biomarkers associated with cancer development.

To the authors' knowledge, only one nationally representative study of U.S. cancer survivors used an objective measure of physical activity and examined its association with biomarkers (Lynch et al., 2010). However, in that study, the only biomarker investigated was adiposity (i.e., waist circumference and body mass index [BMI]), with the results showing an inverse association between adiposity and physical activity among breast cancer survivors.

Health Outcomes

Fong et al. (2012) published a meta-analysis of randomized, controlled trials and reported that, among cancer survivors, physical activity is associated with improvements in bench press, leg press, fatigue, depression, BMI, peak oxygen consumption, peak power output, distance walked in six minutes, handgrip strength, and quality of life. Similar results were found in a systematic review and meta-analysis by Craft, Vaniterson, Helenowski, Rademaker, and Courneya (2012) that reported that physical activity has a modest positive effect on depression symptoms and is associated with reduced pain, fatigue, and improved quality of life. Inoue-Choi, Lazovich, Prizment, and Robien (2013) and McClellan (2013) also demonstrated a positive effect of physical activity on physical functioning and quality of life.

Cancer Recurrence and Mortality

Loprinzi, Cardinal, Winters-Stone, et al. (2012) reviewed the literature and reported six studies examining the influence of physical activity on breast cancer-related mortality, with two of those studies also examining breast cancer recurrence. Findings showed that four of the six studies demonstrated a protective effect of physical activity on breast cancer-related mortality, and the two breast cancer recurrence studies reported nonsignificant risk reductions. Fontein et al. (2013) identified 12 studies that examined the association between physical activity and breast cancer-related mortality and showed that eight of those studies found a protective effect of physical activity in reducing death from breast cancer. Although likely complex, the mechanism through which physical activity could have a protective effect on cancer recurrence and cancer-related mortality may be found in its influence on body weight (Davies, Batehup, & Thomas, 2011), with excess body weight being a strong risk factor for cancer recurrence and death (Ligibel, 2012). Other potential mechanisms include physical activity-induced changes in hormones, markers of insulin resistance, and inflammation (Loprinzi, Cardinal, Smit, et al., 2012), with emerging research also suggesting that physical activity may help to reduce breast and prostate cancer risk and recurrence through suppression of vasoactive intestinal peptide (VIP) by increasing anti-VIP antibodies (Veljkovic et al., 2011).

Physical Activity Levels

In general, cancer survivors engage in less physical activity than people who were never diagnosed with cancer (Smith, Nolan, Robison, Hudson, & Ness, 2011), with one estimate showing that about 32% of cancer survivors report no leisure-time physical activity (Underwood et al., 2012). Loprinzi, Lee, and Cardinal (2013) described the accelerometer-determined activity patterns of U.S. cancer survivors and reported that only 13% were sufficiently active (i.e., engage in at least 150 minutes per week of moderate-intensity or at least 75 minutes per week of vigorous-intensity physical activity). In addition, obese cancer survivors, when compared to nonobese survivors, engaged in less moderate-to-vigorous physical activity. Mason et al. (2013) demonstrated that physical activity levels tend to decline with age among breast cancer survivors.

Physical Activity Preferences

In a population-based sample of kidney cancer survivors, Trinh, Plotnikoff, Rhodes, North, and Courneya (2012) described physical activity preferences. Encouragingly, more than 80% felt they were able to participate in physical activity, and more than 70% indicated that they were interested in doing so. To help inform the development of physical activity interventions, those cancer survivors indicated that they wanted to receive physical activity-related information from fitness experts at the cancer center (56%), receive printed information (50%), exercise at home (52%), and walk in the summer (64%) and winter (48%).

Strategies to Promote Physical Activity

Several studies have demonstrated use of the social cognitive theory (SCT) for promoting physical activity behavior among cancer survivors (Brunet & Sabiston, 2011; Phillips & McAuley, 2013; Short, James, & Plotnikoff, 2013). SCT postulates a reciprocal association between cognition, behavior, and environmental influences, with behavior affected by the interactions. Key constructs from SCT (e.g., self-efficacy, outcome expectations, social support) play an important role in influencing the activity behavior of cancer survivors. In addition to SCT, key constructs from the theory of planned behavior, including individual, normative, and control beliefs, have been associated with physical activity among breast cancer survivors (Bélanger, Plotnikoff, Clark, & Courneya, 2012; Vallance, Lavallee, Culos-Reed, & Trudeau, 2012). The parameters of the theory of planned behavior influence an individual's behavioral intention, ultimately affecting behavioral engagement. The transtheoretical model is a stage-matched framework that examines an individual's readiness to change behavior, which has been used effectively to promote physical activity among cancer survivors (Husebo, Dyrstad, Soreide, & Bru, 2013).

Evidence exists among older colorectal cancer survivors that participating in physical activity in a social setting may be particularly important for improving or maintaining mental health (Thraen-Borowski, Trentham-Dietz, Edwards, Koltyn, & Colbert, 2013), with the act of attending community-based wellness workshops also likely to have beneficial effects on physical activity and health-related quality of life (Spector, Battaglini, Alsobrooks, Owen, & Groff, 2012). Proper physical activity promotion among older adult cancer survivors appears to be safe and feasible (Klepin, Mohile, & Mihalko, 2013; Rajotte et al., 2012), with findings, although limited, also showing that physical activity may be safe and effective among patients with advanced-stage cancer (Albrecht & Taylor, 2012). However, healthcare providers should refer to other sources (Burr, Shephard, & Jones, 2012) for clinical risk assessment before recommending physical activity to cancer survivors.

In addition to tailoring a physical activity program to enhance psychosocial constructs, healthcare providers should understand physical activity-related barriers that cancer survivors may encounter. Cancer treatment may influence a patient's perceptions, beliefs, and attitudes toward his or her body, which in turn may influence his or her desire or motivation to engage in physical activity. Research has shown that, among breast cancer survivors, regular engagement in physical activity may help to restore positive body-related perceptions (Brunet, Sabiston, & Burke, 2013) and help regain control and reduce distress associated with cancer (Maley, Warren, & Devine, 2013). Other common physical activity-related barriers and concerns include fear of movement and perceived risk of injury, which may negatively influence mental health outcomes (e.g., depression) among cancer survivors (Velthuis et al., 2012). Another reported barrier is pain associated with movement (Prinsloo, Gabel, Lyle, & Cohen, 2013; Sabiston, Brunet, & Burke, 2012). A study by Sabiston et al. (2012) demonstrated that physical activity may mediate the relationship between pain and depression among cancer survivors, suggesting that physical activity may serve as a therapeutic strategy to manage and treat pain and depression. An emerging area of research has focused on the neuromodulation of cancer pain (Prinsloo et al., 2013), with initial research showing that brain-based learning may influence neuroplasticity (i.e., changes in neural pathways and synapses) and alter perceptions of pain. Although additional research is needed in this emerging area of research, physical activity participation may alter perceptions of pain through its established neuroplasticity effects (Hötting & Röder, 2013).

Those findings demonstrate that healthcare providers can effectively promote physical activity to cancer survivors by employing evidence-based strategies with the use of established theoretical models. For example, teaching cancer survivors how to enlist social support, use behavioral and cognitive skills, and enhance their perceptions of self-efficacy may serve as effective strategies to promote physical activity. Healthcare providers may want to employ those strategies in person; however, evidence indicates that web-based physical activity interventions may be feasible and acceptable among younger cancer survivors (Rabin, Dunsiger, Ness, & Marcus, 2011). Future research investigating feasible methods for physical activity promotion is needed because patients with cancer are the least likely to be advised by their physicians to exercise, when compared to healthy patients, overweight patients, or patients with other chronic diseases (e.g., diabetes) (Barnes & Schoenborn, 2012). Although speculative, healthcare providers may selectively promote physical activity based on their perception of whether they think the patient would be successful in losing weight and adhering to a physical activity program. However, a sensible strategy would be for healthcare providers to promote physical activity to all patients when feasible, as research indicates that some healthcare providers have limited accuracy in predicting which patients will improve weight and physical activity levels (Chisholm, Hart, Mann, Harkness, & Peters, 2012; Pollak et al., 2012).

Healthcare providers should use caution when promoting physical activity to certain subgroups of cancer survivors. Specific precautions for cancer survivors include delaying exercise for those with severe anemia, avoiding public gyms and public pools for those with compromised immune function, avoiding chlorine exposure to irradiated skin for those undergoing radiation, and avoiding pools for those with indwelling catheters or feeding tubes (Rock et al., 2012). In addition, those with significant peripheral neuropathies or ataxia may wish to use a stationary reclining bicycle instead of walking on a treadmill.

Epidemiologic Examination

The literature identified that only one nationally representative study of U.S. cancer survivors used an objective measure of physical activity and examined its association with biologic markers (Lynch et al., 2010). However, in that study, the only marker investigated was adiposity (i.e., waist circumference and BMI), with the results showing an inverse association between adiposity and physical activity among breast cancer survivors.

The epidemiologic examination reported in the current article will further the work in this area by using an objective measure of physical activity in a national sample of different types of cancer survivors and examining understudied biologic markers (e.g., white blood cells [WBCs], neutrophils, homocysteine).

Methods for the Epidemiologic Examination

Data from the 2003–2006 NHANES were used. NHANES is an ongoing study conducted by the Centers for Disease Control and Prevention (CDC) that uses a representative sample of noninstitutionalized U.S. civilians selected by a complex, multistage probability design. Participants were interviewed in their homes and subsequently examined in mobile examination centers. All NHANES study procedures were approved by the National Center for Health Statistics ethics review board, with informed consent obtained from all participants prior to data collection (CDC, 2012).

In the 2003–2006 NHANES cycles, 401 participants reported being diagnosed with a cancer that has been associated with physical activity behavior (i.e., breast, prostate, colon, rectal, lung, endometrium/uterus, ovarian, and pancreatic). Of those, 307 provided data on the covariates (i.e., age, gender, race/ethnicity, BMI, cotinine, poverty-to-income ratio [PIR], and comorbidity index). After excluding those with insufficient accelerometry data (i.e., less than four days of 10 or more hours per day of monitoring), 227 participants remained, with those participants comprising the analytic sample. Participants ranged from age 21–85 years. With regard to the final analytic sample (N = 227) and the 80 participants excluded because of insufficient accelerometry data, no differences existed ($p > 0.1$) with respect to age, gender, race/ethnicity, BMI, cotinine, PIR, and comorbidity index.

Measures

Physical activity: Participants were asked to wear an ActiGraph 7164 accelerometer on their waist for seven days during all activities, with the exception of water-based activities and while sleeping. The accelerometer measured the frequency, intensity, and duration of physical activity by generating an activity count proportional to the measured acceleration. More details about the mechanics of the ActiGraph 7164 accelerometer can be found in another study (Chen & Bassett, 2005).

Estimates for sedentary behavior were classified as less than or equal to 99 counts per minute; light-intensity physical activity was classified between 100 and 2,019 counts per minute; moderate- to vigorous-intensity physical activity (MVPA) was classified as less than or equal to 2,020 counts per minute. Moderate- and vigorous-intensity physical activity were combined because participants spent little time at vigorous-intensity physical activity ($\bar{X} = 0.39$ minutes per day, standard error [SE] = 0.13). All estimates were summarized in one-minute bouts. For the

analyses described, and to represent habitual physical activity patterns, only those participants with at least four days of 10 or more hours per day of monitoring data were included in the analyses (Troiano et al., 2008). To determine the amount of time the monitor was worn, nonwear was defined as a minimum of 60 consecutive minutes of zero activity counts, with the allowance of 1–2 minutes of activity counts between 0 and 99 (Troiano et al., 2008).

Biologic and health markers: The following biologic and health markers were chosen as they have previously (Humphreys, McLeod, & Ruseski, 2014; Loprinzi & Cardinal, 2012b, 2013; Loprinzi & Pariser, 2013; Loprinzi et al., 2013; Warburton et al., 2010) been associated with physical activity: BMI, waist circumference, systolic and diastolic blood pressure (average of up to four measurements), CRP, HDL cholesterol, fasting low-density lipoprotein (LDL) cholesterol, total cholesterol, fasting triglycerides, fasting glucose, fasting insulin, homocysteine (marker of endothelial function), and blood glycohemoglobin (HbA_{1C}). These measurements were taken in the mobile examination center prior to the measurement of physical activity. Details on the assessment of the variables can be found elsewhere (www.cdc.gov/nchs/nhanes.htm).

Covariates: Information about age, gender, and race/ethnicity were obtained from a questionnaire. As a measure of socioeconomic status, PIR was assessed, with a PIR of less than 1 considered below the poverty threshold. Serum cotinine was measured as a marker of active smoking status or environmental exposure to tobacco (i.e., passive smoking). Serum cotinine was measured by an isotope dilution high-performance liquid chromatography/atmospheric pressure chemical ionization tandem mass spectrometry. BMI was calculated from measured weight and height (weight in kilograms divided by the square of height in meters). A comorbidity index variable was created to classify the number of comorbidities each participant experienced (Charlson, Pompei, Ales, & MacKenzie, 1987; Quan et al., 2011). Participants were classified as having zero, one, two, or three or more comorbidities based on self-report of the

Table 1. Multivariable Linear Regression Analysis Examining the Association Between Accelerometer-Determined Variables and Biologic/Health Parameters (N = 227)

	Intensity Level (Unstandardized Beta Coefficient [95% CI])		
Variable	**Sedentary**	**Light**	**Moderate to Vigorous**
Body mass index (kg/m²)	0.002 [–0.004, 0.009]	–0.007 [–0.01, 0.001]	–0.11 [–0.17, –0.04]**
C-reactive protein (mg/dl)	0.0001 [–0.0005, 0.0007]	–0.0002 [–0.001, 0.0007]	–0.0003 [–0.005, 0.004]
Diastolic blood pressure (mmHg)	–0.009 [0.03, 0.01]	0.004 [–0.02, 0.03]	0.04 [–0.09, 0.18]
Glucose (mg/dl)	0.01 [–0.03, 0.05]	–0.02 [–0.06, 0.01]	–0.14 [–0.30, 0.02]
HbA_{1C}	0.0006 [–0.0001, 0.001]	–0.0001 [–0.001, 0.0008]	–0.002 [–0.007, 0.003]
HDL cholesterol (mg/dl)	0.006 [–0.01, 0.02]	–0.004 [–0.04, 0.03]	0.21 [0.008, 0.41]*
Homocysteine (umol/L)	0.001 [–0.002, 0.005]	–0.001 [–0.008, 0.006]	–0.01 [–0.04, 0.01]
Insulin (u/ml)	–0.003 [–0.01, 0.01]	–0.02 [–0.03, –0.003]**	–0.02 [–0.09, 0.05]
Insulin resistance[a]	–0.001 [–0.007, 0.004]	–0.006 [–0.01, –0.001]*	0.002 [–0.05, 0.05]
LDL cholesterol (mg/dl)	–0.01 [–0.07, 0.04]	–0.05 [–0.13, 0.01]	–0.25 [–0.86, 0.34]
Neutrophils (1,000 cells/mcl)	–0.001 [–0.004, 0.001]	–0.002 [–0.005, –0.0004]*	–0.02 [–0.04, –0.001]*
Systolic blood pressure (mmHg)	–0.02 [–0.05, 0.007]	0.003 [–0.03, 0.03]	–0.11 [–0.32, 0.1]
Total cholesterol (mmol/L)	–0.001 [–0.002, 0.0003]	–0.001 [–0.003, 0.0009]	0.004 [–0.007, 0.01]
Triglycerides (mg/dl)	–0.08 [–0.27, 0.10]	–0.15 [–0.33, 0.01]	–0.11 [–0.92, 0.68]
Waist circumference (cm)	0.01 [–0.002 to 0.03]	–0.02 [–0.04, 0.0004]*	–0.3 [–0.45, –0.14]***
White blood cells (1,000 cells/mcl)	–0.001 [–0.005, 0.001]	–0.004 [–0.006, –0.001]**	–0.03 [–0.05, –0.005]**

* $p \leq 0.05$; ** $p < 0.01$; *** $p < 0.001$

[a] Measured using the Homeostasis Model Assessment (Matthews et al., 1985)

CI—confidence interval; HDL—high-density lipoprotein; LDL—low-density lipoprotein

following physician-diagnosed chronic diseases or events: arthritis, coronary heart disease, heart attack, congestive heart failure, stroke, emphysema, chronic bronchitis, and hypertension.

Data Analysis

All statistical analyses were done using STATA, version 12.0. The analyses accounted for the complex survey design used in NHANES by using survey sample weights, clustering, and primary sampling units. New sample weights were created for the combined NHANES cycles following analytic guidelines for the continuous NHANES. Mobile examination center sample weights were used for all analyses with nonfasting variables; fasting sample weights were used for analyses with fasting variables (i.e., LDL cholesterol, triglycerides, glucose, and insulin).

To examine the association between sedentary behavior and physical activity and the biologic and health variables (which were the dependent variables), multivariate linear regression models were computed. A model was computed for each biologic and health variable. The three accelerometer-determined variables (i.e., sedentary, light, and MVPA) all were included in each model, as well as the covariates of age, gender, race/ethnicity, BMI, cotinine, PIR, and comorbidity index. BMI was not adjusted in the waist circumference model because of collinearity (r = 0.85). In addition, the models with systolic or diastolic blood pressure as the outcome variable controlled for drug therapy (i.e., self-report of taking any hypertensive-lowering medication). The models with HDL cholesterol, LDL cholesterol, triglycerides, or total cholesterol as the outcome variable controlled for drug therapy (i.e., self-report of taking any cholesterol medication). The models with glucose, insulin, or HBA_{1C} as an outcome variable, controlled for drug therapy (i.e., self-report of taking insulin or pills for diabetes).

Results of the Epidemiologic Examination

Among the 227 cancer survivors in the empirical study, the mean age was 68.1 years (SE = 1.1). Of the participants, 69% (SE = 3.7) were female, and 85% (SE = 2.3) were Caucasian. The mean PIR was 2.9 (SE = 0.1), which is well above the poverty threshold (i.e., 1), and the mean BMI was 27.7 (SE = 0.5). The proportion of those with zero, one, two, and three or more comorbidities, respectively, was 20%, 32%, 28%, and 20%. The mean minutes per day of sedentary, light-intensity physical activity, and MVPA, respectively, was 525.3 (SE = 7.8), 295.4 (SE = 6.6), and 11.5 (SE = 1.2). Participants, on average, were cancer survivors for 12.3 years (95% confidence interval [6.0, 18.7]).

Table 1 shows the results of the multivariable linear regression analyses examining the association between the accelerometer-determined variables and the biologic health parameters. Sedentary behavior was not independently associated with any of the biologic parameters. After adjustments, including controlling for sedentary behavior and MVPA, light-intensity physical activity was inversely associated with WBC, neutrophils, insulin, and insulin resistance. After controlling for sedentary behavior, light-intensity physical activity, and other covariates, MVPA was inversely associated with BMI, waist circumference, WBC, and neutrophils, but it was positively associated with HDL cholesterol. Although not a primary objective of this analysis, cotinine was positively associated with neutrophils and inversely associated with HDL cholesterol.

Knowledge Translation

Cancer survivors do not engage in sufficient physical activity.

Cancer survivors are encouraged to engage in regular physical activity, as it may help to reduce cancer recurrence, cancer-related mortality, and side effects associated with cancer treatment, as well as increase cancer treatment rates.

Promotion of any physical activity among cancer survivors is recommended because of its favorable association with biomarkers linked with cancer and other chronic diseases.

Implications for Nursing

The findings in the current article underscore the importance of promoting physical activity among cancer survivors. Several frameworks, including the transtheoretical model, have demonstrated efficacy in increasing physical activity behavior among cancer survivors. When promoting physical activity behavior among cancer survivors, nurses should tailor the individual program to the cancer survivors' physical activity preferences and develop strategies to overcome exercise-specific barriers. Given the finding that light-intensity physical activity was associated with several biomarkers among cancer survivors, nurses could promote light-intensity physical activity (e.g., slow walking) before progressing to higher-intensity activities (e.g., brisk walking, cycling, swimming).

Conclusion

The purpose of the current article was to review the literature and provide up-to-date evidence on the specific effects of physical activity and how best to promote physical activity among cancer survivors, as well as conduct an epidemiologic study delineating the relationship between objectively measured physical activity and various biomarkers among cancer survivors.

From the literature review, the authors found that cancer survivors are relatively inactive, but the promotion of physical activity among this population is highly encouraged because it may help to reduce the risk of cancer recurrence and cancer-related mortality, increase cancer treatment rates, reduce pain and other side effects associated with cancer treatment, improve physical and mental health, and improve biologic parameters associated with various chronic diseases. With regard to the latter, the results from the authors' epidemiologic examination extend previous work by showing that objectively measured physical activity, including light-intensity physical activity, is associated with several understudied biomarkers (i.e., WBC, neutrophils, and insulin resistance) that are linked with cancer recurrence, cancer-related mortality, and other chronic diseases (Coussens & Werb, 2002; Erlinger, Muntner, & Helzlsouer, 2004; Mantovani & Pierotti, 2008; Oh et al., 2011; Park, Lim, Shin, & Yun, 2006). The authors encourage future research related to physical activity promotion among cancer survivors to focus on individuals with cancers other than breast cancer because the majority of studies reviewed focused on breast cancer survivors.

The authors gratefully acknowledge Bradley J. Cardinal, PhD, for his suggestions on an earlier version of this manuscript.

Paul D. Loprinzi, PhD, is an assistant professor in the Department of Exercise Science in the Donna and Allan Lansing School of Nursing and Health Sciences at Bellarmine University in Louisville, KY, and Hyo Lee, PhD, is an assistant professor in the Department of Sport and Health Sciences at Sangmyung University in Seoul, Korea. No financial relationships to disclose. Loprinzi can be reached at ploprinzi@bellarmine.edu, with copy to editor at ONFEditor@ons.org. (Submitted September 2013. Accepted for publication September 12, 2013.)

References

Albrecht, T.A., & Taylor, A.G. (2012). Physical activity in patients with advanced-stage cancer: A systematic review of the literature. *Clinical Journal of Oncology Nursing*, *16*, 293–300. doi:10.1188/12.CJON.293-300

Allin, K.H., Bojesen, S.E., & Nordestgaard, B.G. (2009). Baseline C-reactive protein is associated with incident cancer and survival in patients with cancer. *Journal of Clinical Oncology*, *27*, 2217–2224. doi:10.1200/JCO.2008.19.8440

Ballard-Barbash, R., Friedenreich, C.M., Courneya, K.S., Siddiqi, S.M., McTiernan, A., & Alfano, C.M. (2012). Physical activity, biomarkers, and disease outcomes in cancer survivors: A systematic review. *Journal of the National Cancer Institute*, *104*, 815–840. doi:10.1093/jnci/djs207

Barnes, P.M., & Schoenborn, C.A. (2012). Trends in adults receiving a recommendation for exercise or other physical activity from a physician or other health professional. *National Center Health Statistics Data Brief*, *86*, 1–8.

Bélanger, L.J., Plotnikoff, R.C., Clark, A.M., & Courneya, K.S. (2012). Determinants of physical activity in young adult cancer survivors. *American Journal of Health Behavior*, *36*, 483–494. doi:10.5993/AJHB.36.4.5

Brown, K., Loprinzi, P.D., Brosky, J.A., & Topp, R. (2014). Prehabilitation influences exercise-related psychological constructs such as self-efficacy and outcome expectations to exercise. *Journal of Strength and Conditioning Research*, *28*, 201–209. doi:10.1519/JSC.0b013e318295614a

Brunet, J., & Sabiston, C.M. (2011). Self-presentation and physical activity in breast cancer survivors: The moderating effect of social cognitive constructs. *Journal of Sport and Exercise Psychology*, *33*, 759–778.

Brunet, J., Sabiston, C.M., & Burke, S. (2013). Surviving breast cancer: Women's experiences with their changed bodies. *Body Image*, *10*, 344–341. doi:10.1016/j.bodyim.2013.02.002

Burr, J.F., Shephard, R.J., & Jones, L.W. (2012). Physical activity for cancer patients: Clinical risk assessment for exercise clearance and prescription. *Canadian Family Physician*, *58*, 970–973.

Centers for Disease Control and Prevention. (2012). NCHS Research Ethics Review Board (ERB) Approval. Retrieved from http://www.cdc.gov/nchs/nhanes/irba98.htm

Charlson, M.E., Pompei, P., Ales, K.L., & MacKenzie, C.R. (1987). A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. *Journal of Chronic Diseases*, *40*, 373–383. doi:10.1016/0021-9681(87)90171-8

Chen, K.Y., & Bassett, D.R., Jr. (2005). The technology of accelerometry-based activity monitors: Current and future. *Medicine and Science in Sports and Exercise*, *37*(Suppl.), S490–S500. doi:10.1249/01.mss.0000185571.49104.82

Chisholm, A., Hart, J., Mann, K.V., Harkness, E., & Peters, S. (2012). Preparing medical students to facilitate lifestyle changes with obese patients: A systematic review of the literature. *Academic Medicine*, *87*, 912–923. doi:10.1097/ACM.0b013e3182580648

Courneya, K.S., Segal, R.J., Mackey, J.R., Gelmon, K., Reid, R.D., Friedenreich, C.M., . . . McKenzie, D.C. (2007). Effects of aerobic and resistance exercise in breast cancer patients receiving adjuvant chemotherapy: A multicenter randomized controlled trial. *Journal of Clinical Oncology*, *25*, 4396–4404. doi:10.1200/JCO.2006.08.2024

Coussens, L.M., & Werb, Z. (2002). Inflammation and cancer. *Nature*, *420*, 860–867. doi:10.1038/nature01322

Craft, L.L., Vaniterson, E.H., Helenowski, I.B., Rademaker, A.W., & Courneya, K.S. (2012). Exercise effects on depressive symptoms in cancer survivors: A systematic review and meta-analysis. *Cancer Epidemiology, Biomarkers and Prevention*, *21*, 3–19. doi:10.1158/1055-9965.EPI-11-0634

Davies, N.J., Batehup, L., & Thomas, R. (2011). The role of diet and physical activity in breast, colorectal, and prostate cancer survivorship: A review of the literature. *British Journal of Cancer*, *105*(Suppl.), S52–S73. doi:10.1038/bjc.2011.423

Elme, A., Utriainen, M., Kellokumpu-Lehtinen, P., Palva, T., Luoto, R., Nikander, R., . . . Saarto, T. (2013). Obesity and physical inactivity are related to impaired physical health of breast cancer survivors. *Anticancer Research*, *33*, 1595–1602.

Erlinger, T.P., Muntner, P., & Helzlsouer, K.J. (2004). WBC count and the risk of cancer mortality in a national sample of U.S. adults: Results from the Second National Health and Nutrition Examination Survey mortality study. *Cancer Epidemiology, Biomarkers and Prevention*, *13*, 1052–1056.

Fong, D.Y., Ho, J.W., Hui, B.P., Lee, A.M., Macfarlane, D.J., Leung, S.S., . . . Cheng, K.K. (2012). Physical activity for cancer survivors: Meta-analysis of randomised controlled trials. *BMJ*, *344*, E70. doi:10.1136/bmj.e70

Fontein, D.B., de Glas, N.A., Duijm, M., Bastiaannet, E., Portielje, J.E., Van de Velde, C.J., & Liefers, G.J. (2013). Age and the effect of physical activity on breast cancer survival: A systematic review. *Cancer Treatment Reviews*, *39*, 958–965. doi:10.1016/j.ctrv.2013.03.008

Hötting, K., & Röder, B. (2013). Beneficial effects of physical exercise on neuroplasticity and cognition. *Neuroscience and Biobehavioral Reviews*, *37*, 2243–2257. doi:10.1016/j.neubiorev.2013.04.005

Humphreys, B.R., McLeod, L., & Ruseski, J.E. (2014). Physical activity

and health outcomes: Evidence from Canada. *Health Economics, 23*, 33–54. doi:10.1002/hec.2900

Husebo, A.M., Dyrstad, S.M., Soreide, J.A., & Bru, E. (2013). Predicting exercise adherence in cancer patients and survivors: A systematic review and meta-analysis of motivational and behavioural factors. *Journal of Clinical Nursing*, *22*, 4–21. doi:10.1111/j.1365-2702.2012.04322.x

Inoue-Choi, M., Lazovich, D., Prizment, A.E., & Robien, K. (2013). Adherence to the World Cancer Research Fund/American Institute for Cancer Research recommendations for cancer prevention is associated with better health-related quality of life among elderly female cancer survivors. *Journal of Clinical Oncology*, *31*, 1758–1766. doi:10.1200/JCO.2012.45.4462

Järvelä, L.S., Niinikoski, H., Heinonen, O.J., Lähteenmäki, P.M., Arola, M., & Kemppainen, J. (2013). Endothelial function in long-term survivors of childhood acute lymphoblastic leukemia: Effects of a home-based exercise program. *Pediatric Blood and Cancer, 60*, 1546–1551. doi:10.1002/pbc.24565

Jones, S.B., Thomas, G.A., Hesselsweet, S.D., Alvarez-Reeves, M., Yu, H., & Irwin, M.L. (2013). Effect of exercise on markers of inflammation in breast cancer survivors: The Yale exercise and survivorship study. *Cancer Prevention Research*, 6, 109–118. doi:10.1158/1940-6207.CAPR-12-0278

Klepin, H.D., Mohile, S.G., & Mihalko, S. (2013). Exercise for older cancer patients: Feasible and helpful? *Interdisciplinary Topics in Gerontology*, *38*, 146–157. doi:10.1159/000343597

Ligibel, J. (2012). Lifestyle factors in cancer survivorship. *Journal of Clinical Oncology,* 30, 3697–3704. doi:10.1200/JCO.2012.42.0638

Löf, M., Bergström, K., & Weiderpass, E. (2012). Physical activity and biomarkers in breast cancer survivors: A systematic review. *Maturitas*, 73, 134–142. doi:10.1016/j.maturitas.2012.07.002

Loprinzi, P., Cardinal, B., Crespo, C., Brodowicz, G., Andersen, R., Sullivan, E., . . . Smit, E. (2013). Objectively measured physical activity and C-reactive protein: National Health and Nutrition Examination Survey 2003–2004. *Scandinavian Journal of Medicine and Science in Sports*, *23*, 164–170. doi:10.1111/j.1600-0838.2011.01356.x

Loprinzi, P.D., & Cardinal, B.J. (2012a). Effects of physical activity on common side effects of breast cancer treatment. *Breast Cancer, 19*, 4–10. doi:10.1007/s12282-011-0292-3

Loprinzi, P.D., & Cardinal, B.J. (2012b). Interrelationships among physical activity, depression, homocysteine, and metabolic syndrome with special considerations by sex. *Preventive Medicine, 54*, 388–392. doi:10.1016/j.ypmed.2012.03.016

Loprinzi, P.D., & Cardinal, B.J. (2013). Association between biologic outcomes and objectively measured physical activity accumulated in ≥ 10-minute bouts and < 10-minute bouts. *American Journal of Health Promotion, 27*, 143–151. doi:10.4278/ajhp.110916-QUAN-348

Loprinzi, P.D., Cardinal, B.J., Smit, E., & Winters-Stone, K.M. (2012). Physical activity and breast cancer risk. *Journal of Exercise Science and Fitness*, *10*, 1–7. doi:10.1016/j.jesf.2012.04.004

Loprinzi, P.D., Cardinal, B.J., Winters-Stone, K., Smit, E., & Loprinzi, C.L. (2012). Physical activity and the risk of breast cancer recurrence: A literature review. *Oncology Nursing Forum*, *39*, 269–274. doi:10.1188/12.ONF.269-274

Loprinzi, P.D., Lee, H., & Cardinal, B.J. (2013). Objectively measured physical activity among US cancer survivors: Considerations by weight status. *Journal of Cancer Survivorship, 7*, 493–499. doi:10.1007/s11764-013-0293-7

Loprinzi, P.D., & Pariser, G. (2013). Physical activity intensity and biological markers among adults with diabetes: Considerations by age and gender. *Journal of Diabetes and Its Complications*, *27*, 134–140. doi:10.1016/j.jdiacomp.2012.09.004

Lynch, B.M., Dunstan, D.W., Healy, G.N., Winkler, E., Eakin, E., & Owen, N. (2010). Objectively measured physical activity and sedentary time of breast cancer survivors, and associations with adiposity: Findings from NHANES (2003–2006). *Cancer Causes and Control*, *21*, 283–288. doi:10.1007/s10552-009-9460-6

Maley, M., Warren, B.S., & Devine, C.M. (2013). A second chance: Meanings of body weight, diet, and physical activity to women who have experienced cancer. *Journal of Nutrition Education and Behavior*, *45*, 232–239. doi:10.1016/j.jneb.2012.10.009

Mantovani, A., & Pierotti, M.A. (2008). Cancer and inflammation: A complex relationship. *Cancer Letters*, *267*, 180–181. doi:10.1016/j.canlet.2008.05.003

Mason, C., Alfano, C.M., Smith, A.W., Wang, C.Y., Neuhouser, M.L., Duggan, C., . . . McTiernan, A. (2013). Long-term physical activity trends in breast cancer survivors. *Cancer Epidemiology, Biomarkers and Prevention, 22*, 1153–1161. doi:10.1158/1055-9965.EPI-13-0141

Matthews, D.R., Hosker, J.P., Rudenski, A.S., Naylor, B.A., Treacher, D.F., & Turner, R.C. (1985). Homeostasis model assessment: Insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*, *28*, 412–419. doi:10.1007/BF00280883

McClellan, R. (2013). Exercise programs for patients with cancer improve physical functioning and quality of life. *Journal of Physiotherapy*, *59*, 57. doi:10.1016/S1836-9553(13)70150-4

Oh, S.W., Park, C.Y., Lee, E.S., Yoon, Y.S., Lee, E.S., Park, S.S., . . . Ro, J. (2011). Adipokines, insulin resistance, metabolic syndrome, and breast cancer recurrence: A cohort study. *Breast Cancer Research*, *13*, R34. doi:10.1186/bcr2856

Park, S.M., Lim, M.K., Shin, S.A., & Yun, Y.H. (2006). Impact of prediagnosis smoking, alcohol, obesity, and insulin resistance on survival in male cancer patients: National Health Insurance Corporation Study. *Journal of Clinical Oncology, 24*, 5017–5024. doi:10.1200/JCO.2006.07.0243

Phillips, S.M., & McAuley, E. (2013). Social cognitive influences on physical activity participation in long-term breast cancer survivors. *Psycho-Oncology*, *22*, 783–791. doi:10.1002/pon.3074

Pollak, K.I., Coffman, C.J., Alexander, S.C., Tulsky, J.A., Lyna, P., Dolor, R.J., . . . Ostbye, T. (2012). Can physicians accurately predict which patients will lose weight, improve nutrition and increase physical activity? *Family Practice*, *29*, 553–560. doi:10.1093/fampra/cms004

Prinsloo, S., Gabel, S., Lyle, R., & Cohen, L. (2013). Neuromodulation of cancer pain. *Integrative Cancer Therapies, 13*, 30–37. doi:10.1177/1534735413477193

Quan, H., Li, B., Couris, C.M., Fushimi, K., Graham, P., Hider, P., . . . Sundararajan, V. (2011). Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. *American Journal of Epidemiology*, *173*, 676–682. doi:10.1093/aje/kwq433

Rabin, C., Dunsiger, S., Ness, K.K., & Marcus, B.H. (2011). Internet-based physical activity intervention targeting young adult cancer survivors. *Journal of Adolescent and Young Adult Oncology*, *1*, 188–194. doi:10.1089/jayao.2011.0040

Rajotte, E.J., Yi, J.C., Baker, K.S., Gregerson, L., Leiserowitz, A., & Syrjala, K.L. (2012). Community-based exercise program effectiveness and safety for cancer survivors. *Journal of Cancer Survivorship*, *6*, 219–228. doi:10.1007/s11764-011-0213-7

Rock, C.L., Doyle, C., Demark-Wahnefried, W., Meyerhardt, J., Courneya, K.S., Schwartz, A.L., . . . Gansler, T. (2012). Nutrition and physical activity guidelines for cancer survivors. *CA: A Cancer Journal for Clinicians*, *62*, 243–274. doi:10.3322/caac.21142

Sabiston, C.M., Brunet, J., & Burke, S. (2012). Pain, movement, and mind: Does physical activity mediate the relationship between pain and mental health among survivors of breast cancer? *Clinical Journal of Pain*, *28*, 489–495. doi:10.1097/AJP.0b013e31823853ac

Short, C.E., James, E.L., & Plotnikoff, R.C. (2013). How social cognitive theory can help oncology-based health professionals promote physical activity among breast cancer survivors. *European Journal of Oncology Nursing, 17*, 482–489. doi:10.1016/j.ejon.2012.10.009

Smith, W.A., Nolan, V.G., Robison, L.L., Hudson, M.M., & Ness, K.K. (2011). Physical activity among cancer survivors and those with no history of cancer: A report from the National Health and Nutrition Examination Survey 2003–2006. *American Journal of Translational Research*, *3*, 342–350.

Spector, D., Battaglini, C., Alsobrooks, A., Owen, J., & Groff, D. (2012). Do breast cancer survivors increase their physical activity and enhance their health-related quality of life after attending

community-based wellness workshops? *Journal of Cancer Education*, *27*, 353–361. doi:10.1007/s13187-011-0306-z

Tatematsu, N., Park, M., Tanaka, E., Sakai, Y., & Tsuboyama, T. (2013). Association between physical activity and postoperative complications after esophagectomy for cancer: A prospective observational study. *Asian Pacific Journal of Cancer Prevention*, *14*, 47–51. doi:10.7314/APJCP.2013.14.1.47

Thraen-Borowski, K.M., Trentham-Dietz, A., Edwards, D.F., Koltyn, K.F., & Colbert, L.H. (2013). Dose-response relationships between physical activity, social participation, and health-related quality of life in colorectal cancer survivors. *Journal of Cancer Survivorship*, *7*, 369–378. doi:10.1007/s11764-013-0277-7

Trinh, L., Plotnikoff, R.C., Rhodes, R.E., North, S., & Courneya, K.S. (2012). Physical activity preferences in a population-based sample of kidney cancer survivors. *Supportive Care in Cancer*, *20*, 1709–1717. doi:10.1007/s00520-011-1264-z

Troiano, R.P., Berrigan, D., Dodd, K.W., Masse, L.C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and Science in Sports and Exercise*, *40*, 181–188. doi:10.1249/mss.0b013e31815a51b3

Underwood, J.M., Townsend, J.S., Stewart, S.L., Buchannan, N., Ekwueme, D.U., Hawkins, N.A., . . . Fairley, T.L. (2012). Surveillance of demographic characteristics and health behaviors among adult cancer survivors—Behavioral Risk Factor Surveillance System, United States, 2009. *Morbidity and Mortality Weekly Report: Surveillance Summaries*, *61*, 1–23.

Vallance, J.K., Lavallee, C., Culos-Reed, N.S., & Trudeau, M.G. (2012). Predictors of physical activity among rural and small town breast cancer survivors: An application of the theory of planned behaviour. *Psychology, Health and Medicine*, *17*, 685–697.

Veljkovic, M., Dopsaj, V., Dopsaj, M., Branch, D.R., Veljkovic, N., Sakarellos-Daitsiotis, M.M., . . . Colombatti, A. (2011). Physical activity and natural anti-VIP antibodies: Potential role in breast and prostate cancer therapy. *PLoS ONE*, *6*, e28304. doi:10.1371/journal.pone.0028304

Velthuis, M.J., Peeters, P.H., Gijsen, B.C., van den Berg, J.P., Koppejan-Rensenbrink, R.A., Vlaeyen, J.W., . . . May, A.M. (2012). Role of fear of movement in cancer survivors participating in a rehabilitation program: A longitudinal cohort study. *Archives of Physical Medicine and Rehabilitation*, *93*, 332–338. doi:10.1016/j.apmr.2011.08.014

Warburton, D.E., Charlesworth, S., Ivey, A., Nettlefold, L., & Bredin, S.S. (2010). A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. *International Journal of Behavioral Nutrition and Physical Activity*, *7*, 39. doi:10.1186/1479-5868-7-39