Advances in Research on Sedentary Behavior Among Cancer Survivors (Postprint)

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Abstract

Prognosis and quality of life are generally suboptimal in cancer survivors, while sedentary behavior is highly prevalent in this population and is closely associated with multiple adverse outcomes, warranting urgent attention. This review summarizes the relevant theories, assessment methods, influencing factors, associations with prognosis, and interventions related to sedentary behavior in cancer survivors, indicating that sedentary behavior management in cancer survivors represents one of the critical issues requiring urgent resolution. Future research should actively promote localized studies to improve patient prognosis.

Full Text

Preamble

Advances in Sedentary Behavior Research Among Cancer Survivors

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Abstract: The prognosis and quality of life of cancer survivors are generally poor, while sedentary behavior is highly prevalent among this population and closely associated with various adverse outcomes, warranting urgent attention. This review synthesizes relevant theories, assessment methods, influencing factors, prognostic correlations, and interventions related to sedentary behavior in cancer survivors. We conclude that managing sedentary behavior in cancer survivors represents a critical issue requiring immediate attention, and future research should actively develop localized studies to improve patient outcomes.

Key Words: cancer survivors; sedentary behavior; review

Cancer' s high incidence and mortality rates have made it a major public health threat to Chinese residents' lives [1]. With advancements in screening, diagnosis, and treatment technologies, the 5-year survival rate for cancer patients in China has gradually increased to 57.6% [2], creating a substantial population of cancer survivors. Cancer survivors are defined as individuals diagnosed with tumors who have completed primary cancer treatment (though they may continue maintenance therapy), show no evidence of active disease, and remain in long-term remission without being cured [3]. Despite being clinically disease-free, this population experiences multiple sequelae from cancer and its treatment, including physiological dysfunctions such as pain, fatigue, insomnia, anorexia, edema, and decreased libido [4], as well as psychological dysfunctions like anxiety and depression [4], accompanied by reduced participation in household, educational, or occupational activities [5]. These physical, psychological, and social dysfunctions often lead cancer survivors to maintain a sedentary lifestyle, making them highly susceptible to sedentary behavior.

Sedentary behavior refers to waking activities characterized by sitting or lying postures with energy expenditure $ $1.5 metabolic equivalents (METs) [6], primarily including recreational, transportation, household, and occupational sedentary behaviors. Research indicates that cancer survivors average 10.8 hours of daily sedentary time [7], with sedentary behavior accounting for 10.3% of the total disease burden in cancer [8]. Studies have confirmed that sedentary behavior is an independent predictor of mortality in cancer survivors [9] and is closely associated with decreased quality of life [10]. Furthermore, the 2022 American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Survivors emphasize the significant impact of sedentary behavior on cancer survivors' rehabilitation [11]. These findings underscore that managing sedentary behavior in cancer survivors is a pressing concern. Current international research on sedentary behavior in cancer survivors has primarily focused

on influencing factor surveys and intervention efficacy studies among breast and colorectal cancer survivors, while domestic research in this area remains underdeveloped. Therefore, this review aims to elaborate on relevant theories and assessment methods of sedentary behavior and synthesize research on influencing factors, prognostic correlations, and interventions among cancer survivors, providing a reference for developing localized management strategies.

1 Theoretical Frameworks of Sedentary Behavior

Theories represent the distillation and synthesis of variables and their relationships in practice. Understanding relevant theories of sedentary behavior helps elucidate its underlying mechanisms. The Ecological Model of Sedentary Behavior and the System of Sedentary Behavior Framework are particularly prominent. We now elaborate on these two theories to provide a theoretical depth analysis of sedentary behavior.

1.1 Ecological Model of Sedentary Behavior

Proposed by Australian scholar Owen in 2011, the Ecological Model of Sedentary Behavior posits that sedentary behavior results from the interaction between individuals and their environment [12]. This model emphasizes that sedentary behavior occurs in four contexts: recreational, transportation, household, and occupational, with specific influencing factors varying across contexts but converging into two dimensions: individual internal factors and perceived environmental factors. Individual internal factors include demographic, physiological, and psychological characteristics, as well as family environment factors. Perceived environmental factors include perceived natural environment, perceived sociocultural environment, perceived policy environment, and perceived information environment. Currently, this model has been primarily applied to analyze sedentary behavior in children and adolescents [13, 14], while its application to cancer survivors remains to be explored.

1.2 System of Sedentary Behavior Framework

Developed by British scholar Chastin in 2016, the System of Sedentary Behavior Framework examines the systems influencing sedentary behavior at individual, group, and population levels, delineating six subsystems: physical health and well-being, social and cultural context, built and natural environment, psychological and behavioral factors, policy and economic factors, and institutional and home environment [15]. The framework emphasizes that sedentary behavior emerges from the interaction among these six subsystems, with institutional and home environment identified as the most important and modifiable subsystem for research. Studies have reported that intervention programs for stroke survivors based on this framework demonstrate strong scientific rigor and systematic design [15], though its application in cancer survivors has not yet been documented.

In summary, theoretical frameworks such as the Ecological Model and System Framework facilitate top-down development of sedentary behavior knowledge systems and provide scientific foundations for management. However, their guiding value for sedentary behavior in cancer survivors requires further development.

2 Assessment Methods for Sedentary Behavior

Assessment is essential for studying relevant variables in practice. Understanding assessment methods enables accurate and effective quantification of sedentary behavior. Currently, subjective and objective measurements constitute the primary approaches. Subjective measurement relies on questionnaires, while objective measurement utilizes wearable devices. We now introduce these two methods to present the practical characteristics of sedentary behavior assessment.

2.1 International Physical Activity Questionnaire

The International Physical Activity Questionnaire (IPAQ), developed by the International Physical Activity Measurement Working Group in 2001, is a standardized self-report instrument [16]. It comprises a long version (31 items covering four domains of physical activity—recreational, transportation, household, and occupational—plus sedentary behavior) and a short version (7 items addressing walking, moderate-intensity activity, vigorous-intensity activity, and sedentary behavior). Both versions assess physical activity over the past week among adults aged 18-65. The long version provides detailed information for more accurate capture of sedentary behavior patterns but is complex and has practical limitations, while the short version is more concise and suitable for large-scale surveys or busy clinical settings. The English version of IPAQ has been applied across 12 countries with demonstrated high reliability and validity [16]; the Chinese version was translated by Qu Ningning et al. [17] and also showed good psychometric properties among university students.

2.2 Sedentary Behavior Questionnaire

The Sedentary Behavior Questionnaire (SBQ), designed by American scholar Rosenberg et al. in 2010, offers a concise yet comprehensive assessment method [18]. The questionnaire evaluates time spent in nine sedentary activities: watching television, using computers, listening to music, talking on the phone, doing homework, reading, playing musical instruments, crafting, and transportation. It assesses physical activity over the past week in overweight populations, with total sedentary time calculated as: (weekday sedentary hours $\times$ 5) + (weekend sedentary hours $\times$ 2). SBQ-derived sedentary time shows significant correlations with both IPAQ and accelerometer measurements. However, no Chinese version currently exists, and Rosenberg et al. recommend adapting the SBQ when applying it to different populations.

2.3 Wearable Devices

Wearable devices are portable instruments worn directly on the body or integrated into clothing and accessories, enabling functionality through software support and data interaction. Accelerometers are the most common wearable devices for assessing sedentary behavior. These small electronic devices, typically worn on the hip, store physical activity data in computers and provide objective, accurate, and continuous measurements that effectively detect different types of trunk movements to identify sedentary behavior [19]. However, limitations include measuring only vertical plane movements and being influenced by wear position and usage patterns [20]. Global Positioning Systems (GPS) can objectively and accurately measure physical activity during free-living conditions but cannot be used independently [21]. Consequently, accelerometers and GPS are often combined to accurately capture sedentary behavior.

In summary, questionnaires are widely used for sedentary behavior assessment due to their simplicity and low cost, but their reliance on self-reporting limits accuracy. Future research on sedentary behavior in cancer survivors should select appropriate assessment methods based on research needs and population characteristics to provide robust support for management efforts.

3 Influencing Factors of Sedentary Behavior in Cancer Survivors

Sedentary behavior among cancer survivors has begun to attract scholarly attention. However, the lack of cohort studies and randomized controlled trials prevents verification of specific targets and complete pathways underlying sedentary behavior, leaving its mechanisms unclear. Current research primarily examines influencing factors. Therefore, this review focuses on synthesizing these factors. The Ecological Model of Sedentary Behavior offers the most explanatory power for investigating influencing factors. Based on this model, we reveal the development patterns of sedentary behavior in cancer survivors from both individual internal and perceived environmental dimensions.

3.1 Individual Internal Dimension

Based on the Ecological Model, individual internal dimensions include demographic, physiological, and psychological factors, as well as family environment factors [12]. Boyle et al. [22] found that breast cancer survivors with higher education levels, no comorbidities, and higher pre-diagnosis physical activity levels were less likely to engage in prolonged sedentary behavior, while patients aged $ 70 had sedentary time at least twice their physical activity time. This indicates advanced age is a risk factor, possi
Borowski et al. [23] reported similar sedentary time across different cancer types and no significant differences
term($5 years since diagnosis) and short-term survivors (<5 years), suggesting cancer type and survival duration have minimal impact, though limited sample sizes require further validation of these findings' external validity. Additional research indicates that higher income among breast cancer survivors correlates

with shorter sedentary time, while higher body mass index (BMI) correlates with longer daily sedentary time [24]. Baseline poor health status and high body fat also predict increasing sedentary time among colorectal cancer survivors [25]. Poor health status can limit mobility and activity, consequently increasing sedentary behavior. Beyond physical limitations, psychological constraints from disease also exist. Scholars suggest that sadness, anxiety, stress, and worry can increase sedentary behavior in breast cancer survivors [26], while colorectal cancer survivors with better baseline emotional status maintain lower sedentary time long-term [25]. These findings enable identification of cancer survivors at high risk for sedentary behavior based on individual internal factors.

3.2 Perceived Environmental Dimension

Based on the Ecological Model, perceived environmental dimensions include perceived natural environment, perceived sociocultural environment, perceived policy environment, and perceived information environment factors [12]. Lawrence et al. [27] found that built environments (indoor, neighborhood, community) significantly impact sedentary behavior in colorectal cancer survivors, particularly the home indoor environment. Lack of recreational facilities in communities and tense neighborhood environments contrast sharply with relaxed, familiar home settings, making home-based sedentary behavior more likely. Some scholars have also conducted qualitative research to understand factors influencing sedentary behavior from survivors' perspectives. A qualitative synthesis [28] revealed that built environment, social support, and sociocultural atmosphere are important influencing factors, complementing and corroborating quantitative findings. Greater support from friends and relatives increases survivors' motivation to improve sedentary behavior. Additionally, prevailing sociocultural beliefs that cancer survivors should "rest and recuperate" during rehabilitation facilitate sedentary behavior development. These findings demonstrate that both individual internal and perceived environmental factors warrant attention, requiring a holistic perspective on sedentary behavior development in cancer survivors.

In summary, international scholars have conducted research on influencing factors of sedentary behavior in cancer survivors, though the impacts of family environment, perceived policy environment, and perceived information environment remain underexplored. Domestic research on influencing factors is also lacking. Furthermore, current studies are predominantly cross-sectional, with unclear specific relationships and effect sizes between factors and sedentary behavior, indicating that temporal patterns of factors and pathways among them require deeper investigation.

4 Correlation Between Sedentary Behavior and Prognosis in Cancer Survivors

Numerous studies confirm close associations between sedentary behavior and clinical outcomes in cancer survivors, encompassing both objective outcomes (body composition and mortality) and patient-reported outcomes (PROs). We now focus on these two aspects to elaborate on the prognostic correlations.

4.1 Body Composition and Mortality

Body composition and mortality are common objective indicators of sedentary behavior' s prognostic impact. Body composition measures primarily include BMI, waist circumference, and fat-free mass. In a prospective national health survey [29], after adjusting for age, ethnicity, and total energy intake, sedentary time remained positively correlated with BMI among breast cancer survivors, suggesting an independent effect of sedentary behavior on BMI. Boyle et al. [30] used isotemporal substitution modeling, replacing 30 minutes of sedentary time with non-sedentary time, resulting in a 0.94 cm reduction in waist circumference among breast cancer survivors. Additionally, a longitudinal study [31] found that each 10% increase in sedentary time among acute lymphoblastic leukemia survivors corresponded to a 1% decrease in fat-free mass. Beyond process indicators like body composition, research has also examined clinical outcome indicators such as mortality. A meta-analysis [9] investigating relationships between sedentary behavior and health outcomes in cancer survivors revealed that longer sedentary time increased all-cause mortality risk (HR=1.22, 95%CI=1.06-1.41) and colorectal cancer-specific mortality risk (HR=1.53, 95%CI=1.14-2.06). However, insufficient original studies prevented subgroup analysis, hindering clarification of heterogeneity across cancer types. These findings indicate that assessing and intervening on sedentary behavior can improve body composition and enhance survival opportunities.

4.2 Patient-Reported Outcomes

As a health-related behavior in a special population, sedentary behavior in cancer survivors involves both objective and subjective components. Its prognostic impact extends beyond objective outcomes like mortality and body composition to encompass PROs. Common PROs in current research include quality of life, fatigue, anxiety, and depression. D' Silva et al. [32] analyzed correlations between sedentary behavior and quality of life among 540 lung cancer survivors, finding that longer sedentary time correlated with lower quality of life (β=-0.07). Phillips et al. [33] conducted a 6-month follow-up of 358 breast cancer survivors using accelerometers to measure sedentary behavior, revealing that sedentary time was proportional to fatigue duration. Additionally, research [34] found that anxiety and depression symptoms in breast cancer survivors worsened with increased sedentary time. These findings suggest that effective management of sedentary behavior in cancer survivors would positively impact both objective indicators and subjective experiences, thereby promoting holistic recovery.

In summary, sedentary behavior has become a significant risk factor affecting cancer survivors' prognosis, contradicting the traditional belief of "resting after serious illness." This suggests that sedentary behavior interventions could serve as a breakthrough for improving outcomes. However, given heterogeneity across cancer types, the impact and magnitude of sedentary behavior on different cancer patients' prognosis will vary, necessitating further research across cancer types to fully elucidate its role in clinical decision-making.

5 Interventions for Sedentary Behavior in Cancer Survivors

Under the combined influence of individual internal and perceived environmental factors, cancer survivors are prone to sedentary behavior, which severely impacts mortality, body composition, and PROs, necessitating urgent intervention. Current intervention research includes physical activity interventions alone and combined interventions targeting both sedentary behavior and physical activity. We now elaborate on the current state of interventions.

5.1 Physical Activity Interventions

WHO guidelines suggest that physical activity of varying intensities can offset sedentary behavior hazards to varying degrees, making physical activity interventions one of the most effective measures for improving sedentary behavior [35]. Ormel et al. [36] conducted a 12-week physical activity intervention for cancer survivors, requiring participants to exercise at least 30 minutes daily, five days per week, with smartphone-based self-monitoring. Results showed sedentary time decreased by 19% and 27% at 6 and 12 weeks post-intervention, respectively, demonstrating that mobile health applications provide feasible intervention tools for this population. Beyond self-monitoring, external influences play crucial roles. Weiner et al. [37] randomized 87 breast cancer survivors into two groups for a 12-week physical activity intervention. The intervention group received a face-to-face motivational interview to establish physical activity goals and plans, wore activity trackers (with weekly data checks by interventionists), participated in two 20-minute phone consultations at weeks 2 and 6 to discuss progress and problem-solve, and received standardized biweekly email reminders to wear trackers. The control group received standardized emails every three days about women' s health topics. Results showed sedentary time decreased by 24.9 min/day in the intervention group versus 4.8 min/day in the control group, a statistically significant difference. However, some studies show physical activity interventions alone do not significantly improve sedentary behavior. Pinto et al. [38] used peer volunteer phone follow-up for a 12-week physical activity intervention among 76 breast cancer survivors, encouraging progression from 10 minutes/day on at least 2 days/week to 30 minutes/day on at least 5 days/week, with weekly phone and email contacts and monthly calls during the 3-month post-intervention period. Results showed no significant reduction in sedentary time at 12 or 24 weeks, with researchers attributing the lack of efficacy to the intervention' s focus on encouraging physical activity without

explicitly targeting sedentary behavior reduction. These findings suggest that while physical activity interventions are important for improving sedentary behavior, with mobile health providing substantial implementation support, future research should develop interventions specifically targeting sedentary behavior to open new avenues for improvement.

5.2 Combined Sedentary Behavior and Physical Activity Interventions

Combined interventions address both increasing physical activity to offset sedentary behavior hazards and directly reducing sedentary time, creating synergistic effects that enhance intervention efficacy. Lynch et al. [39] randomized 83 breast cancer survivors to receive a 12-week combined intervention reducing sedentary behavior and increasing physical activity. The intervention group wore activity monitors for 12 weeks, received weekly reports on physical activity and sedentary behavior, participated in meetings to establish behavior change goals, and received five phone consultations focusing on behavior change strategies and technical problem-solving, while the control group received no intervention. Results showed total sedentary time decreased by 37 min/day, superior to physical activity interventions alone. Building on this study, Lynch et al. [40] followed the same participants for an additional 12 weeks, finding that sedentary time increased slightly by 7 min/day but remained substantially lower than pre-intervention levels, indicating sustained intervention effects. Another study [41] conducted a 6-month combined intervention among 410 colorectal cancer survivors, providing intervention participants with a participant handbook, pedometer, incentive cards, quarterly newsletters, and 11 telephone-based health coaching sessions delivered by nurses, psychologists, or health promotion practitioners, while the control group received only an educational handbook. Results showed sedentary time decreased by 0.65 hours and 1.21 hours at intervention completion and 6 months post-intervention, respectively, further corroborating that combined interventions reduce and sustainably improve sedentary behavior. However, intervention content and implementation details vary across studies, leaving the optimal combined intervention protocol to be determined.

In summary, both physical activity interventions alone and combined interventions can improve sedentary behavior in cancer survivors to some extent (Table 1). However, current intervention research focuses primarily on physical activity and sedentary behavior themselves, neglecting behavioral mechanisms, and often lacks theoretical grounding with inconsistent intervention doses. Future research should consider theory-based intervention design and examine dose-response relationships to maximize intervention efficacy.

6 Summary and Outlook

Sedentary behavior in cancer survivors is influenced by individual and environmental factors, leading to high prevalence and close associations with numerous adverse outcomes, making its management an urgent priority. Future efforts

must prioritize sedentary behavior management in cancer survivors, designing scientific and precise localized intervention strategies based on comprehensive analysis of contributing factors to improve patient outcomes.

Literature Search Strategy: This study employed a combination of subject headings and free-text terms to search PubMed, Web of Science, CINAHL, Cochrane Library, CNKI, Wanfang Data Knowledge Service Platform, and Chinese Biomedical Literature Service System for literature published from database inception to April 2022, supplemented by reference tracking of included studies. English search terms included: neoplasm, carcinoma, cancer, tumor, survivor*, sedentar*, physical inactivity, lack of physical activity. Chinese search terms included: cancer survivors, tumor survivors, survivors, sedentary, sitting, static behavior. Inclusion criteria: review articles and clinical original studies on sedentary behavior in cancer survivors published in Chinese or English. Exclusion criteria: non-full-text articles and duplicate publications.

Conflict of Interest Statement: This article has no conflicts of interest.

Table 1 Intervention Studies on Sedentary Behavior in Cancer Survivors

Study	Country	Participants	Intervention Duration	Intervention Content	Control Group Content	Main Outcomes	Study Design
Ormel et al. [36]	New Zealand	Cancer survivors (n=32, intervention=16, control=16)	12 weeks	Exercise $ $30 min/day, 5 days/week. Smartphone app for physical activity self-monitoring.	Standard care	Sedentary time decreased by 19% and 27% at 6 and 12 weeks.	Randomized controlled trial

Study	Country	Participants	Intervention Duration	Intervention Content	Control Group Content	Main Outcomes	Study Design
Weiner et al. [37]	USA	Breast cancer survivors (female) (n=87, intervention=44, control=43)	12 weeks	Activity tracker provided. Face-to-face motivational interview at start. Two 20-min phone consultations at weeks 2 and 6. Weekly tracker data checks by interventionists. Additional phone support for participants with $ $20% activity reduction. Biweekly standardized emails reminding tracker use.	Standardized emails every 3 days on women' s health topics	Intervention group decreased sedentary time by 24.9 min/day vs. 4.8 min/day in control group.	Randomized controlled trial

Study	Country	Participants	Intervention Duration	Intervention Content	Control Group Content	Main Outcomes	Study Design
Pinto et al. [38]	USA	Breast cancer survivors (female) (n=76, intervention=39, control=37)	12 weeks	Home logs, pedometer, and heart rate monitor provided. Gradual progression from 10 min/day on $ $2 days/week to 30 min/day on $ $5 days/week. Weekly phone contacts and emails with progress feedback. Monthly phone calls for 3 months post-intervention.	Weekly calls from coaches assessing general health, answering breast cancer questions, and providing printed health education materials	No significant reduction in sedentary time at 12 or 24 weeks.	Randomized controlled trial

Study	Country	Participants	Intervention Duration	Intervention Content	Control Group Content	Main Outcomes	Study Design
Lynch et al. [39, 40]	Australia	Breast cancer survivors (female) (n=83, intervention group unspecified)	12 weeks	Behavioral feedback and goal-setting meetings with workbook. Weekly activity/sedentary behavior reports and meetings using motivational interviewing. Wearable activity monitor for 12 weeks. Five phone consultations focusing on behavior change strategies.	Blank control	At 12 weeks: moderate-to-vigorous physical activity increased by 69 min/week; total sedentary time decreased by 37 min/day. At 24 weeks: physical activity increased by 14 min/week; sedentary time increased by 7 min/day but remained far below baseline.	Randomized controlled trial

Study	Country	Participants	Intervention Duration	Intervention Content	Control Group Content	Main Outcomes	Study Design
Lynch et al. [41]	Australia	Colorectal cancer survivors (n=410, intervention=205, control=205)	6 months	11 telephone health coaching sessions by nurses/psychologists/health promoters. Participant handbook. Incentive cards. Pedometer. Quarterly newsletters.	Educational handbook only	Sedentary time decreased by 0.65 hours and 1.21 hours at intervention end and 6 months post-intervention.	Randomized controlled trial

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Note: Figure translations are in progress. See original paper for figures.