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Focusing on Sedentary Behavior in Comprehensive Cardiac Rehabilitation

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In recent years, the adverse effects of prolonged sedentary behavior in daily life, so-called 'sitting too much', on health have been pointed out. Sedentary behavior is defined as 'all waking behavior in which the energy expenditure in a sitting, semi-recumbent, or recumbent position is 1.5 metabolic equivalents or less'. Even if a person engages in the level of physical activity recommended in the guidelines, sitting for too long at other times may increase the risk of developing various diseases and death. For patients with cardiovascular disease, a comprehensive cardiac rehabilitation program that systematically includes not only medical treatment but also exercise therapy, patient education, and disease management is extremely important. Also, differences in sedentary behavior during the acute and recovery phases are known to affect physical function and activities of daily living at the time of hospital discharge. Here, we discuss cardiac rehabilitation that addresses sedentary behavior and review the previous related research.

Key Words: Cardiac rehabilitation; Cognitive function; Physical activity; Physical function; Sedentary behavior

The Japanese National Plan for Promotion of Measures Against Cerebrovascular and Cardiovascular Disease highlights the importance of addressing lifestyle factors, including sedentary behavior, in the prevention and management of cardiovascular disease (CVD).[1–3] Local initiatives, such as those in Hyogo Prefecture, further emphasize the need for targeted interventions to reduce sedentary time.[4]

To promote physical activity (PA), recent research has highlighted the health risks associated with sedentary behavior, defined as any behavior while awake that results in an energy expenditure of 1.5 metabolic equivalents or less when an individual is sitting, reclining, or lying down.[5–7] The risks of death, obesity, diabetes, and CVD are increased in those with sedentary behavior.[5–7]

Research has shown that sedentary time is associated with adverse health outcomes in older adults, including increased risk of CVD.[5] Systematic reviews have highlighted the need for interventions that address both PA and sedentary behavior in various settings, including workplaces and public open spaces.[6,7]

Cardiac rehabilitation (CR) is a comprehensive program designed to improve the cardiovascular (CV) health of individuals recovering from heart-related conditions.[8,9] It typically includes exercise training, education on heart-healthy living, and counseling to reduce stress and improve mental health. Addressing sedentary behavior in CR is crucial as it can modulate and impact overall outcomes of CR. This underscores the importance of integrating strategies to reduce sedentary behavior into CR programs to enhance their effectiveness. Disentangling the complex relationship between sedentary behavior and CR can enable targeted and evidence-based interventions.

Therefore, this narrative review aimed to examine how behavior, such as sedentary behavior, in CR affects factors such as physical function and activities of daily living (ADL), and to outline the current state of knowledge on this topic, identifying existing gaps and future directions (**Figure**).

PA and CV Health

CVD is the leading cause of mortality globally, accounting for a significant proportion of deaths each year. PA has been identified as a crucial factor in the prevention and management of CVD. The authors synthesized current research on the relationship between PA, particularly daily step counts, and CV health outcomes, by examining recent studies and meta-analyses.

Daily Step Count of PA in Relation to Exercise Capacity and Mortality

In 2023, to investigate the relationship between daily step count and mortality, Banach et al.[10] conducted a comprehensive meta-analysis of 17 cohort studies with 226,889 generally healthy participants or patients at CV risk with a median follow up of 7.1 years. They found that a 1000-step increment was associated with a 15% decreased risk of all-cause mortality (hazard ratio [HR] 0.85; 95% confidence interval [CI] 0.81–0.91; P<0.001), whereas a 500-step

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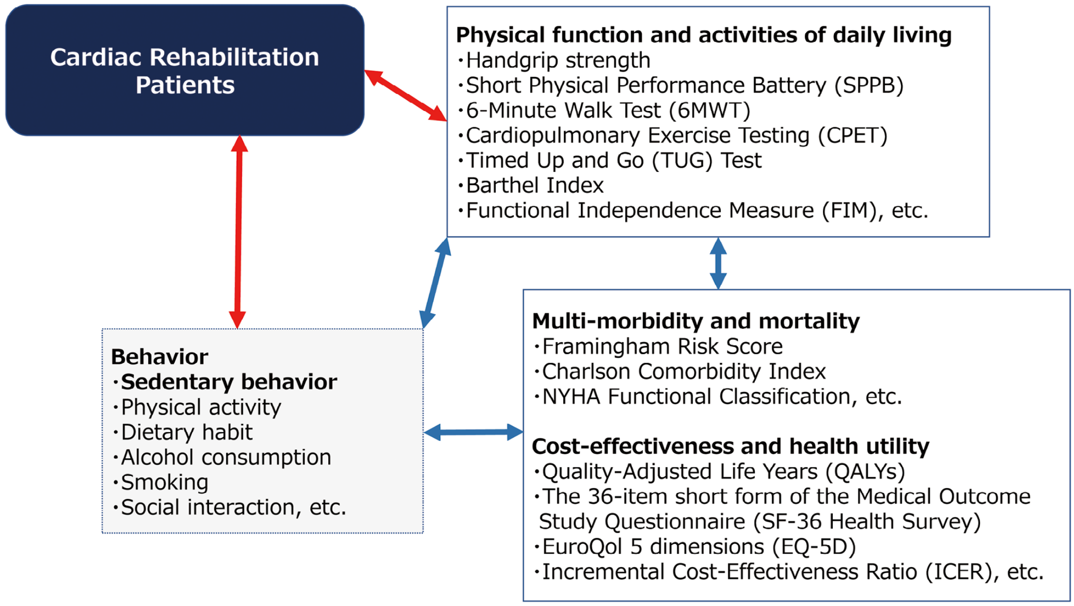

Figure. Conceptual framework of the relationships between behavior, physical function, activities of daily living, multi-morbidity, mortality, cost-effectiveness, and health utility in cardiac rehabilitation patients. NYHA, New York Heart Association.

increment was associated with a 7% decrease in CV mortality (HR 0.93; 95% CI 0.91–0.95; P<0.001). A significant inverse association between daily step count and all-cause mortality and CV mortality indicated that the more steps the better over cutoff values of 3,867 steps/day for all-cause mortality and only 2,337 steps for CV mortality. These findings highlighted the importance of regular PA in maintaining CV health.

Izawa et al.[11] also explored the usefulness of step counts in predicting mortality among Japanese patients with heart failure. In this prospective observational study comprising 170 heart failure outpatients (mean age 65.2 years; 77% male) over an average follow up of 1,377.1 (median 1,335) days, 31 CV-related deaths occurred. Multivariate analysis showed PA of ≤4,889.4 steps/day to be a strong and independent predictor of prognosis (HR 2.28; 95% CI 1.31–6.30; P=0.008). Higher step counts were linked to better survival rates, suggesting that even modest increases in daily PA could have substantial benefits for heart failure patients. In another study, Izawa et al.[12] examined the relationship between PA and exercise capacity in 157 stable middle- and older-aged patients with chronic heart failure (age 60.3±11.5 years; 79.6% male). These patients, with a measured exercise capacity of ≥5 metabolic equivalents, completed approximately 6,000 steps/day, which was measured using an electronic pedometer. Cutoff values determined using receiver operating characteristic curve analysis were 6,045 steps in middle-aged patients and 6,070 steps in older-aged patients. Regular PA correlated positively with exercise capacity, as measured in metabolic equivalents, and overall health outcomes.

PA in Relation to Sleep Quality, Mental Health, and Health-Related Quality of Life (QOL)

The relationship between sleep quality and PA in chronic heart failure patients was investigated by Izawa et al.[13] in 149 chronic heart failure outpatients (mean age 58 years); the patients were divided into 2 groups based on the level of sleep quality determined via a self-reported questionnaire: shallow sleep group, and deep sleep group. Using receiver operating characteristics curves, target cutoff values for PA resulting in high-quality sleep were determined to be 5,723.6 steps/day and 156.4 kcal/day for 1 week. Better sleep quality was associated with higher levels of PA, and PA was suggested to not only benefit CV health but also to improve other aspects of health, such as sleep quality, that can further influence CV outcomes. Another study[14] also examined the link between mental health and PA in patients with chronic heart failure and found that PA had a positive impact on mental health by reducing symptoms of depression and anxiety. Patients with chronic heart failure (n=243; mean age 57.1 years) were divided into 2 groups according to mental health assessed using the Short Form-36 score: good mental health (≥68 points) group, and poor mental health (<68 points) group. Average step count (steps) and energy expenditure on PA (EE; kcal) per day for 1 week of PA were assessed using an accelerometer and compared between groups. After adjustment for patient characteristics, steps and EE were significantly lower in the poor mental health group compared with the good mental health group (5,020.1±280.7 vs. 7,174.1±221.5 steps; P<0.001; 133.9±10.8 vs. 215.9±8.4 kcal; P<0.001). Cutoff values of 5,590.8 steps and 141.1 kcal were determined as PA target values associated with improved mental health. These findings underscore the holistic benefits of PA, which extend beyond physical health to mental well-being.

Another study evaluated the long-term effects of exercise maintenance on PA and health-related QOL after phase II CR in 109 patients (89 men, 20 women; mean age 63.5±10.1 years) with acute myocardial infarction. The mean time from myocardial infarction to evaluation of outcomes was 18.8±3.4 months. Ninety (82.6%) of 109 patients continued exercise for >6 months after CR (exercise group), and 19 (17.4%) patients quit exercise after CR (non-exercise group). The exercise group performed significantly better than the non-exercise group in terms of leisure-time objective PA level and scored significantly higher than the non-exercise group for 7 of 8 health-related QOL measures, attaining scores similar to those in the normal Japanese population. The authors concluded that sustained exercise was beneficial for improving QOL, a finding that emphasizes the importance of long-term adherence to PA programs for CVD patients.[15]

The studies that were reviewed consistently demonstrate the significant benefits of PA for CV health. Regular PA is associated with reduced mortality, improved exercise capacity, better sleep quality, enhanced mental health, and higher QOL. These findings have important implications for clinical practice, suggesting that healthcare providers should encourage patients to increase their daily PA levels as PA plays a crucial role in maintaining CV health and reducing the risk of mortality. The promotion of regular PA is a key component of CVD prevention and management strategies. Future research should continue to explore the optimal types and amounts of PA for different populations to maximize their health benefits.

Sedentary Behavior and CV Health

Sedentary behavior, characterized by low energy expenditure activities such as sitting or lying down, has become increasingly prevalent in modern societies.[16–18] This shift towards more sedentary lifestyles has significant implications for CV health. Drawing on recent studies and meta-analyses, this section synthesizes current research on the relationship between sedentary behavior and CV health outcomes.

Impact of Sedentary Behavior on CV Health

The Ministry of Health, Labour and Welfare in Japan has highlighted the growing concern over sedentary lifestyles and their impact on public health. Sedentary behavior has been linked to various adverse health outcomes, including CVD, which is the leading cause of mortality globally.[16,17] Owen et al.[17] provided a comprehensive overview of the population health science of sedentary behavior, emphasizing that prolonged sitting is associated with increased risks of CV morbidity and mortality. Their study underscored the need for public health interventions to reduce sedentary time and promote more active lifestyles.

Epidemiology of Sedentary Behavior and Disease Risk

Bauman et al.[18] conducted a descriptive epidemiologic study on sitting across 20 countries using the International Physical Activity Questionnaire (IPAQ) and revealed significant variations in sitting time across different populations, with higher sitting times associated with increased CV risk. This study included 49,493 adults aged 18–65 years from 20 countries, with a median reported sitting time of 300 (interquartile range 180–480) min/day. Countries reporting the lowest amount of sitting time included Portugal, Brazil, and Colombia (medians ≤180 min/day), whereas adults in Taiwan, Norway, Hong Kong, Saudi Arabia, and Japan reported the highest sitting times (medians ≥360 min/day). In adjusted analyses, adults aged 40–65 years were significantly less likely to be in the highest quintile for sitting than adults aged 18–39 years (adjusted odds ratio [OR]=0.796), and those with postschool education had higher sitting times than those with high school or less education (OR=1.349). PA showed an inverse relationship, with those reporting low activity on the IPAQ 3 times more likely to be in the highest quintile for sitting compared with those reporting high PA. This global perspective highlights the widespread nature of sedentary behavior and its potential impact on CV health.

Biswas et al.[19] conducted a systematic review and meta-analysis to examine the association between sedentary time and the risk of disease incidence, mortality, and hospitalization in adults. Meta-analyses were performed on outcomes for CVD and diabetes (14 studies), cancer (14 studies), and all-cause mortality (13 studies). Prospective cohort designs were used in all but 3 studies, and sedentary times were quantified based on self-reporting in all but 1 study. Significant associations in HRs were found with all-cause mortality (HR 1.240; 95% CI 1.090–1.410), CVD mortality (HR 1.179; 95% CI 1.106–1.257), CVD incidence (HR 1.143; 95% CI 1.002–1.729), cancer mortality (HR 1.173; 95% CI 1.108–1.242), cancer incidence (HR 1.130; 95% CI 1.053–1.213), and type 2 diabetes incidence (HR 1.910; 95% CI 1.642–2.222). HRs associated with sedentary time and outcomes were generally more pronounced at lower levels of PA than at higher levels. Their findings indicating that higher sedentary time was associated with an increased risk of CVD, all-cause mortality, and hospitalization provide robust evidence to support the detrimental effects of prolonged sedentary behavior on CV health. Moreover, the relationship between sedentary behavior and health outcomes was further explored by Patterson et al.[20] in a systematic review and dose-response meta-analysis of 34 studies (1,331,468 unique participants) covering 8 exposure-outcome combinations. For total sedentary behavior, the PA-adjusted relationship was non-linear for all-cause mortality (rate ratio [RR] per 1 h/day was 1.01 [1.00–1.01] ≤8 h/day; 1.04 [1.03–1.05] >8 h/day of exposure), and for CVD mortality (1.01 [0.99–1.02] ≤6 h/day; 1.04 [1.03–1.04] >6 h/day). The association was linear (1.01 [1.00–1.01]) with type 2 diabetes and non-significant with cancer mortality. Stronger PA-adjusted associations were found for TV viewing (h/day): non-linear for all-cause mortality (1.03 [1.01–1.04] ≤3.5 h/day; 1.06 [1.05–1.08] >3.5 h/day) and for CVD mortality (1.02 [0.99–1.04] ≤4 h/day; 1.08 [1.05–1.12] >4 h/day). Associations with cancer mortality (1.03 [1.02–1.04]) and type 2 diabetes were linear (1.09 [1.07–1.12]). Higher levels of sedentary behavior were associated with increased risks of all-cause, CV, and cancer mortality, and incident type 2 diabetes, further underscoring the importance of reducing sedentary time to improve overall health outcomes.

Sedentary Behavior and Risk of Diseases in Several Populations

Osumi et al.[21] recently examined the effects of sedentary behavior on complications experienced by pregnant women in a systematic review of 11 studies that were included after screening. The mean age of the eligible pregnant women ranged from 28.5 to 32.9 years. Five studies with outcomes of psychological effects on the mother were extracted, 5 with gestational diabetes mellitus (GDM), and 1 with gestational hypertension/preeclampsia. Longer sedentary time was associated with increased risks of prepartum/postpartum depression in 3 of 5 studies and GDM in 3 of

5 studies. No association was found between sedentary behavior and the risk for gestational hypertension/ preeclampsia. Higher sedentary behavior in the second trimester of pregnancy was likely to be associated with postpartum depression. While longer sitting time might increase the risk of prenatal or postnatal depression and GDM, no relationship was proven for gestational hypertension and preeclampsia in 1 study. That study found that prolonged sedentary behavior during pregnancy was associated with adverse outcomes, including increased risk of GDM and hypertensive disorders. Targeted interventions are needed to reduce sedentary time in specific populations, such as pregnant women, to improve CV health outcomes.

Ekelund et al.[22] also conducted a harmonized meta-analysis to investigate whether PA could attenuate or eliminate the detrimental association of sitting time with mortality. Of the 16 studies included, 13 provided data on sitting time and all-cause mortality. These studies included 1,005,791 individuals followed up for 2–18.1 years, during which 84,609 (8.4%) died. Compared with the referent group (i.e., those sitting <4 h/day and in the most active quartile [>35.5 MET-h per week]), mortality rates during follow up were 12–59% higher in the 2 lowest quartiles of PA (from HR 1.12: 95% CI 1.08–1.16, for the second lowest quartile of PA [<16 MET-h per week] and sitting <4 h/day; to HR 1.59: 95% CI 1.52–1.66, for the lowest quartile of PA [<2.5 MET-h per week] and sitting >8 h/day). Daily sitting time was not associated with increased all-cause mortality in those in the most active quartile of PA. Compared with the reference (<4 h of sitting per day and highest quartile of PA [>35.5 MET-h per week]), there was no increased risk of mortality during follow up in those who sat for >8 h/day but who also reported >35.5 MET-h per week of activity (HR 1.04; 95% CI 0.99–1.10). In contrast, those who sat the least (<4 h/day) and were in the lowest activity quartile (<2.5 MET-h per week) had a significantly increased risk of dying during follow up (HR 1.27; 95% CI 1.22–1.31). Six studies had data on TV-viewing time (n=465,450; 43,740 deaths). Watching TV for ≥3 h per day was associated with increased mortality regardless of PA, except in the most active quartile, where mortality was significantly increased only in people who watched TV for ≥5 h/day (HR 1.16; 95% CI 1.05–1.28). The findings of this study suggested that engaging in regular PA can mitigate the negative effects of sedentary behavior on CV health. Emerging insights and opportunities for promoting CV health were provided by Dunstan et al.,[23] who encouraged individuals to 'sit less and move more'. Their study emphasized the importance of integrating PA into daily routines to counteract the harmful effects of sedentary behavior, which aligns with public health recommendations to reduce sedentary time and increase PA levels.

Mediating Mechanisms of Sedentary Behavior and CVD

Today's modern lifestyle, with its reliance on technology and desk-bound occupations, has led to increased sedentary time, which is associated with various adverse health outcomes, particularly CVD. Carter et al.[24] identified several pathways through which sedentary behavior increases the risk of CVD. These mechanisms include metabolic dysfunction, inflammation, and endothelial dysfunction. Metabolic dysfunction involves disruptions in glucose and lipid metabolism that result in insulin resistance and dyslipidemia. Inflammation, another critical pathway, contributes to the development of atherosclerosis and other CV conditions. Endothelial dysfunction, characterized by impaired vasodilation and increased vascular stiffness, further exacerbates CV risk. Pinto et al.[25] expanded on these findings by examining the physiological aspects of sedentary behavior. They highlighted that prolonged sitting leads to reduced muscle contractions, which in turn decreases blood flow and reduces shear stress on the vascular endothelium, a key factor in endothelial dysfunction. Sedentary behavior is also associated with increased adiposity, which contributes to metabolic and inflammatory disturbances.

These reviewed studies[24,25] consistently indicate the significant negative impact of sedentary behavior on CV health. Individuals who spend a large portion of their day sitting have higher rates of hypertension, coronary artery disease (CAD), and stroke. Furthermore, the relationship between sedentary behavior and CV risk is dose-dependent, meaning that the more time spent sitting, the greater the risk.

Different populations may experience varying levels of risk associated with sedentary behavior. For example, older adults are particularly vulnerable due to age-related declines in physical function and increased prevalence of comorbidities. Similarly, individuals with pre-existing health conditions, such as diabetes or obesity, may face heightened CV risks from prolonged sitting. Understanding these population-specific risks is crucial for developing targeted interventions.[24,25]

Both Carter et al.[24] and Pinto et al.[25] emphasize the importance of incorporating PA into daily routines to counteract the adverse effects of prolonged sitting. Even short bouts of light-intensity activity, such as standing or walking, can significantly improve CV health by enhancing blood flow, reducing inflammation, and improving metabolic function. Therefore, to address the public health challenge posed by sedentary behavior, it is essential to promote active lifestyles through various strategies. Public health campaigns should focus on raising awareness about the risks of prolonged sitting and the benefits of regular PA. Workplace interventions, such as sit-stand desks and regular breaks for movement, can also play a crucial role in reducing sedentary time. Urban planning and community programs that encourage active transportation, such as walking and cycling, can help integrate PA into daily life. Sedentary behavior is a significant risk factor for CVD that is mediated through mechanisms such as metabolic dysfunction, inflammation, and endothelial dysfunction. Engaging in regular PA can mitigate the risks of sedentary behavior on CV health, highlighting the importance of promoting active lifestyles.[24,25]

Understanding Sedentary Behavior in Patient CR

CVD remains a leading cause of morbidity and mortality worldwide.[8,9] CR is a comprehensive intervention designed to improve the physical, psychological, and social functioning of patients with CVD. Here, the authors synthesize current research on the benefits, challenges, and future directions of CR, drawing on recent guidelines and studies.

Recommendations and Benefits of CR

The Japanese Circulation Society (JCS) and the Japanese Association of Cardiac Rehabilitation (JACR) have jointly developed a guideline for the rehabilitation of patients with

CVD.[8] The JCS/JACR 2021 guideline emphasizes the importance of a multidisciplinary approach to CR that includes exercise training, patient education, risk factor modification, and psychological support. This guideline highlights the need for individualized rehabilitation programs tailored to the specific needs of each patient, considering factors such as age, comorbidities, and severity of the CV condition.[8]

CR provides numerous benefits for patients with CVD.[8,9] According to Thomas,[9] CR significantly reduces mortality and morbidity, improves exercise capacity, and enhances QOL. The structured exercise programs included in CR help patients regain physical strength and endurance, which are crucial for daily activities and overall well-being. Educational components incorporated into CR programs often empower patients to manage their condition more effectively, leading to better long-term outcomes.

Challenges and Advances in CR

Despite the well-documented benefits of CR, several challenges hinder its widespread implementation and utilization. Low rates of referral and participation are 1 major challenge. Thomas[9] notes that many eligible patients do not receive referrals to CR programs, and even among those who do, participation rates are often suboptimal. Barriers to participation include lack of awareness, transportation issues, and financial constraints. Addressing these barriers requires concerted efforts from healthcare providers, policymakers, and community organizations. Recent advances in CR have focused on enhancing accessibility and effectiveness. The integration of technology, such as tele-rehabilitation and mobile health (mHealth) applications, has shown promise in increasing patient engagement and adherence to CR programs. These technological solutions provide flexible and convenient options for patients who may face barriers to attending traditional center-based programs. Additionally, personalized exercise prescriptions based on individual assessments, such as the Short Physical Performance Battery (SPPB), have been developed to optimize the benefits of CR. The SPPB is a quick and useful tool for assessing physical performance and stratifying fall risk among older adults. Welch et al.[26] showed that the SPPB could effectively identify patients at higher risk of falls, allowing for targeted interventions to prevent falls and improve overall physical function. In 417 community-dwelling adults aged ≥65 years at risk for mobility decline who were recruited from 9 primary care practices, the median age was 76 (interquartile range 70–82) years, and 67.2% were female with a mean baseline SPPB score of 8.7±2.3. Self-reported falls were assessed in person at baseline and via telephone interviews quarterly for 4 years. Multivariable negative binomial regression models were used to evaluate the relationship of the SPPB and each of its 3 components with fall rates over 1 and 4 years of follow up. Poor performance on the SPPB and on each of its 3 components independently predicted a higher fall risk in the first year. After 4 years, the low total baseline SPPB (RR 1.53; 95% CI 1.09–2.17) and gait time performances (RR 1.61; 95% CI 1.07–2.41) predicted a higher fall risk. After stratifying the sample according to the Stopping Elderly Accidents, Deaths, and Injuries model, the authors observed the highest 1-year fall risk among those with a (+) fall risk screen who also scored lowest on the SPPB. Incorporating the SPPB into CR programs can help tailor exercise prescriptions to the specific needs and capabilities of each patient, thereby enhancing the safety and efficacy of the rehabilitation process.

Sedentary Behavior and Physical Function in CR

Sedentary behavior remains a significant concern among these patients, potentially impacting their physical health. This section of the review synthesizes current research on the relationship between sedentary behavior and physical function and ADL in CR patients.

Evaluation of Sedentary Behavior and Intervention in CR

Izawa et al.[27] investigated the relationship between sedentary behavior and physical function in phase I CR. In a final analysis that included 353 patients (mean age 69.6 years; 75.6% male), of whom 47.6% (168 of 353) were patients with high sedentary behavior, total sitting sedentary behavior time was higher in the high sedentary behavior group compared with the low sedentary behavior group (733.6±155.3 vs. 246.4±127.4 min/day; P<0.001), and the mean SPPB score was lower in the high sedentary behavior group compared with the low sedentary behavior group (10.5±2.4 vs. 11.2±1.6 points; P=0.001). Multiple regression analysis identified sedentary behavior as an explanatory variable for total SPPB score (P=0.017)). Patients with higher sedentary behavior had significantly lower SPPB scores, indicating poorer physical function.

Previously, Bakker et al.[28] examined sedentary behavior in CVD patients and its impact on CR with 3 objectives. For objective 1, they recruited 131 CVD patients and 117 controls who were asked about their general characteristics and medical history. Sedentary behavior was assessed using an objective accelerometer (activPAL3 micro). For objective 2, 2,584 CVD patients were asked to complete a questionnaire about their general characteristics, lifestyle, medical history, and their sedentary behavior. For objective 3, 131 CVD patients were followed over time and measured before, directly after, and 2 months after CR. As for their results, for objective 1, CVD patients spent 10.4 h/day (25th quartile 9.5 h; 75th quartile 11.2 h) sedentary, which was higher than that in healthy controls (9.4 h/day [25th quartile 8.4 h; 75th quartile 10.29 h]). For objective 2, CVD patients who were male, single or divorced, employed, physically inactive, reported high alcohol consumption, lived in an urban environment, and had comorbidities and cardiac anxiety showed greater odds for large amounts of sedentary behavior. For objective 3, the CR program significantly reduced sedentary time (−0.4 h/day [95% CI −0.7, −0.1]), which remained low at 2 months after CR (−0.3 h/day [95% CI −0.6, −0.03]). This study highlighted the need for personalized approaches to reduce sedentary behavior and improve CR outcomes. Tailored interventions are needed to target the high amount of sedentary time in these patients.

Sedentary Behavior in Relation to Physical Outcomes and Activities of Daily Living in Older CR Patients

The impact of sedentary behavior on physical outcomes and ADL in older CVD patients participating in phase I CR was explored by Izawa et al.[29] This study examined 402 patients (mean age 76.7 years; 35.3% female). After adjustment for baseline characteristics, gait speed (0.80±0.27 vs. 0.96±0.23 m/s; P<0.001) was lower and 5 times sit to stand test time (11.31±4.19 vs. 9.39±3.11 s; P<0.001) was higher in the high sedentary behavior group compared with the low sedentary behavior group. Motor (85.82±8.82 vs. 88.09±5.04 points; $P<0.001$), cognitive (33.32±2.93 vs. 34.04±2.24 points; $P<0.001$), and total Functional Independence Measure scores (119.13±10.66 vs. 122.02±6.30 points; $P<0.001$) were significantly lower in the high compared with low sedentary behavior group after adjustment. In older CVD patients participating in phase I CR, sedentary behavior time might influence physical outcomes and ADL at hospital discharge. These results suggest that reducing sedentary behavior is crucial for improving physical function and daily living activities in older CR patients.

Sedentary Behavior and Cognitive Function

Sedentary behavior is a significant concern among older CR patients that can potentially impact their physical and cognitive health. The authors draw on recent studies to synthesize current research on the relationship between sedentary behavior and cognitive function.

Siddarth et al.[30] investigated the association between sedentary behavior and medial temporal lobe (MTL) thickness in middle-aged and older adults. They assessed 35 middle-aged and older adults (25 women, 10 men; age 45–75 years) without dementia using the IPAQ for older adults, which quantifies PA levels in MET-equivalent units and asks about the average number of hours spent sitting per day. All participants underwent high-resolution magnetic resonance imaging scans performed on a Siemens Allegra 3T scanner, which allows detailed investigation of the MTL. After controlling for age, total MTL thickness correlated inversely with hours of sitting/day ($r=-0.37$; $P=0.03$). MTL subregion analysis showed that parahippocampal ($r=-0.45$; $P=0.007$), entorhinal ($r=-0.33$; $P=0.05$), and cortical and subiculum ($r=-0.36$, $P=0.04$) thicknesses correlated inversely with hours of sitting/day. No significant correlations were observed between PA levels and MTL thickness. These findings suggest that prolonged sedentary behavior may negatively impact cognitive health, thus highlighting the importance of reducing sedentary time to preserve cognitive function.

Ishihara et al.[31] conducted a systematic review of 6 studies investigating the effects of CR on cognitive function that included 1,085 patients with acute coronary syndrome. Overall positive effects of CR on cognitive function in these patients were reported across the 6 studies. All studies included aerobic exercise, resistance exercise, and patient education in CR. However, meta-analysis could not be undertaken because each dataset used different methods to evaluate cognitive function, and the outcomes were different. Nevertheless, these findings show the potential cognitive benefits of CR and the importance of incorporating cognitive assessments and interventions into CR programs.

These reviewed studies consistently reveal the significant impact of sedentary behavior on both physical and cognitive health in CR patients. Increased sedentary behavior is associated with poorer physical function, reduced ADL, and negative cognitive outcomes. However, participation in CR programs can mitigate these effects by improving both physical and cognitive health. CR programs should incorporate interventions to reduce sedentary behavior and promote cognitive health. Future research should continue to explore the optimal strategies for reducing sedentary behavior and enhancing cognitive function in CR patients.

Intervention for Sedentary Behavior and Use of Self-Monitoring and Mobile Health in Several Diseases

Interventions aimed at reducing sedentary behavior are crucial for improving health outcomes in patients with CV conditions. The authors explore the effectiveness of self-monitoring and mHealth interventions in reducing sedentary behavior and enhancing PA among patients with CVD.

Interrupting Sedentary Behavior With PA

Dempsey et al.[32] investigated the effects of interrupting prolonged sitting with brief bouts of light walking or simple resistance activities (SRAs) on resting blood pressure (BP) and plasma noradrenaline levels in patients with type 2 diabetes. In the authors' randomized crossover trial, 24 inactive overweight/obese adults with type 2 diabetes (14 men; mean±SD age 62±6 years) consumed standardized meals during 3×8 h conditions: uninterrupted sitting (SIT); sitting+half-hourly bouts of walking (3.2 km/h for 3 min; light-intensity walking); and sitting+half-hourly bouts of SRAs for 3 min, each separated by a washout period of 6–14 days. Resting seated BP was measured hourly (mean of 3 recordings, ≥20 min after activity). Plasma noradrenaline was measured at 30-min intervals for the first hour after meals and hourly thereafter. Compared with SIT, mean resting systolic BP and diastolic BP were significantly reduced ($P<0.001$) for both light-intensity walking (mean±SEM −14±1/−8±1 mmHg) and SRA (−16±1/−10±1 mmHg), with a more pronounced effect observed for SRA ($P<0.05$ vs. light-intensity walking). Similarly, mean plasma noradrenaline was significantly reduced for both light-intensity walking (−0.3±0.1 nmol/L) and SRA (−0.6±0.1 nmol/L) compared with SIT, with SRA lower than light-intensity walking ($P<0.05$). Mean resting heart rate was lowered by light-intensity walking (−3±1 beats/min; $P<0.05$), but not by SRA (−1±1 beats/min). These brief interruptions significantly reduced resting BP and plasma noradrenaline levels, suggesting that by incorporating short activity breaks into daily routines, even minimal PA can have substantial health benefits and potentially mitigate the negative effects of sedentary behavior.

Self-Monitoring Approaches in CR

A randomized controlled trial (RCT) was conducted to evaluate the effectiveness of a self-monitoring approach on exercise maintenance during Phase II CR.[33] The trial found that patients who used self-monitoring tools such as pedometers and activity logs were more likely to maintain their exercise routines and achieve better health outcomes. Thus, self-monitoring may be a valuable strategy for encouraging long-term adherence to PA. The effectiveness of accelerometer use in promoting PA was also investigated among patients in Phase I CR.[34] This RCT found that patients who used accelerometers to track their activity levels experienced significant increases in PA compared with those who did not use them. Accelerometers can be an effective tool for motivating patients to increase their PA levels.

In a relatively recent systematic review and meta-analysis of self-monitoring, Kanejima et al.[35] assessed the impact of self-monitoring on PA in patients with CVD. Six studies were included, with the oldest study published in 2005. Participants included 693 patients, of whom 541 completed each study program. The mean age of patients was 60.8 years, and 79.6% were men. From these 6 studies, a meta-analysis was conducted with 269 patients of 4 studies including only RCTs with step counts in the intervention and control groups. Self-monitoring significantly increased PA (95% CI 1,916–3,090 steps/day; P<0.05) over an average intervention period of approximately 5 months. Moreover, 4 studies involved intervention via the internet, and 5 studies confirmed the use of self-monitoring combined with other behavioral change techniques. These studies support the use of self-monitoring as a practical approach to enhance PA in CVD patients.

Also, Kitamura et al.[36] explored the effects of self-monitoring using an accelerometer on PA in older adults with long-term care insurance coverage in Japan. Participants completing the study to the end of the 5-week follow-up period and drop-out participants with available outcome data were included in the final analysis comprising 47 participants: n=24 (age 79.8±8.8 years; 25.5% male) in the intervention group, and n=23 (age 82.5±8.5 years; 39.1% male) in the control group. Comparisons between the 2 groups at baseline showed no significant differences. In the results of a 2-way mixed analysis of variance analysis including 2 (group: control, intervention)×2 (term: baseline, 5-week follow up) factors, an interaction was observed in the number of steps, sedentary behavior, and light PA (P<0.05). Self-monitoring significantly increased PA levels, suggesting that self-monitoring could be an effective intervention for promoting PA in this population group.

In a recent RCT, Kroesen et al.[37] investigated the effects of a hybrid CR intervention to reduce sedentary time in patients with CAD participating in CR at 2 hospitals (1 : 1 pairing, stratified for sex and hospital). The control group received CR, whereas the SIT LESS participants also received a 12-week hybrid behavioral change intervention. The primary outcome was change in accelerometer-derived sedentary time from before to after CR and at 3 months after CR. Secondary outcomes included changes in sedentary time and PA characteristics, subjective outcomes, and CV risk factors. Among the participants (23% female; SIT LESS n=108; control n=104; age 63±10 years), the SIT LESS patients experienced greater reductions in sedentary time than the control subjects after CR (−1.7 [95% CI −2.0, −1.4] vs. −1.1 [95% CI −1.4, −0.8] h/day; P for interaction 0.009), but not at 3 months after CR (P for interaction 0.61). Only the secondary outcome of light-intensity PA differed between groups, with greater post-CR increases in SIT LESS patients compared with control subjects (+1.4 [95% CI +1.2, +1.6] vs. + 1.0 [95% CI +0.8, +1.3] h/day; P for interaction 0.020). A significant reduction in sedentary time and increase in light-intensity PA occurred over the short term with the SIT LESS program, but the differences were not significant at 3 months after CR. These findings highlight the difficulty in inducing sustainable behavioral changes in patients with CAD if continued support is not provided.

Mobile Health Interventions to Reduce Sedentary Behavior Time

A systematic review and meta-analysis was conducted by Yoshihara et al.[38] to evaluate the effectiveness of mHealth interventions in reducing sedentary time and physical inactivity in patients with CVDs after hospital. After screening 502 articles, they included 5 RCTs. In 1 study, sedentary time was shorter in the intervention group than the control group by 61.5 min/day at 24 weeks. Three studies that used physical inactivity as outcome measures were included in a meta-analysis, and the pooled OR was 0.38 (95% CI 0.22–0.65), favoring the intervention group. All studies showed high risk of performance bias but low risk of selection and reporting bias. The findings of these studies highlight the potential of mHealth technologies to support behavioral change and improve health outcomes in CVD patients.

Self-monitoring and mHealth interventions appear to be effective strategies for reducing sedentary behavior and increasing PA in patients with CVD. These interventions can help patients achieve better health outcomes by promoting sustained PA and reducing the negative effects of prolonged sitting. Future research should continue to explore the optimal types and combinations of self-monitoring and mHealth interventions to maximize their effectiveness and bring them to a broader patient population.

Study Limitations

This review has several limitations. First, it primarily focuses on studies conducted in Japan, which may limit its generalizability to other populations. Second, the review does not include all possible factors that can influence PA and sedentary behavior in patients with CVD. Last, this is a narrative review, not a systematic review, that focuses on the effects of sedentary behavior in CR in Japan and a few other countries and reflects the authors' current thoughts, intentions, and recommendations for the future.

Conclusion and Future Directions

Both PA and sedentary behavior play crucial roles in CV health. Although PA is beneficial, sedentary behavior can have detrimental effects. Therefore, interventions that promote PA and reduce sedentary behavior are essential in managing patients with CVD. Improving PA and reducing sedentary behavior by various interventions such as mobile applications and self-monitoring are complex tasks requiring a multifaced approach. Currently, the effects of sedentary behavior on outcomes such as multimorbidity and mortality, cost-effectiveness, and health utility are still unclear and will require further clarification in the future. Future interdisciplinary collaborations between many clinicians, nurses, therapists, and public health scholars, among others, can advance our understanding of how to effectively use various interventions to reduce sedentary behavior in patients participating in CR.

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Author Contributions

K.P.I.: conceptualization, methodology, writing – original draft; K.O.: writing – review and editing.

Data Availability / Ethics Statement

Not applicable.

References

1. Ministry of Health, Labour and Welfare, Japan. Cerebrovascular and Cardiovascular Disease Control Act [in Japanese]. 2018. https://www.mhlw.go.jp/web/t_doc?dataId=80ab6708&dataType=0&pageNo=1 (accessed July 20, 2024).
2. Ministry of Health, Labour and Welfare, Japan. The Japanese national plan for promotion of measures against cerebrovascular and cardiovascular disease [in Japanese]. 2020. https://www.mhlw.go.jp/content/000688359.pdf (accessed July 20, 2024).
3. Kuwabara M, Mori M, Komoto S. Japanese national plan for promotion of measures against cerebrovascular and cardiovascular disease. *Circulation* 2021; **143:** 1929–1931.
4. Hyogo Prefectural Government, Hyogo, Japan. [in Japanese]. 2024. https://web.pref.hyogo.lg.jp/kf16/junkanki3.html (accessed July 20, 2024).
5. Copeland JL, Ashe MC, Biddle SJ, Brown WJ, Buman MP, Chastin S, et al. Sedentary time in older adults: A critical review of measurement, associations with health, and interventions. *Br J Sports Med* 2017; **51:** 1539.
6. Lin CY, Koohsari MJ, Liao Y, Ishii K, Shibata A, Nakaya T, et al. Workplace neighbourhood built environment and workers' physically-active and sedentary behaviour: A systematic review of observational studies. *Int J Behav Nutr Phys Act* 2020; **17:** 148.
7. Motomura M, Koohsari MJ, Lin CY, Ishii K, Shibata A, Nakaya T, et al. Associations of public open space attributes with active and sedentary behaviors in dense urban areas: A systematic review of observational studies. *Health Place* 2022; **75:** 102816.
8. Makita S, Yasu T, Akashi YJ, Adachi H, Izawa H, Ishihara S, et al.; Japanese Circulation Society/the Japanese Association of Cardiac Rehabilitation Joint Working Group. JCS/JACR 2021 guideline on rehabilitation in patients with cardiovascular disease. *Circ J* 2022; **87:** 155–235.
9. Thomas RJ. Cardiac rehabilitation: Challenges, advances, and the road ahead. *N Engl J Med* 2024; **390:** 830–841.
10. Banach M, Lewek J, Surma S, Penson PE, Sahebkar A, Martin SS, et al. The association between daily step count and all-cause and cardiovascular mortality: A meta-analysis. *Eur J Prev Cardiol* 2023; **30:** 1975–1985.
11. Izawa KP, Watanabe S, Oka K, Hiraki K, Morio Y, Kasahara Y, et al. Usefulness of step counts to predict mortality in Japanese patients with heart failure. *Am J Cardiol* 2013; **111:** 1767–1771.
12. Izawa KP, Watanabe S, Oka K, Hiraki K, Morio Y, Kasahara Y, et al. Relation between physical activity and exercise capacity of ≥5 metabolic equivalents in middle- and older-aged patients with chronic heart failure. *Disabil Rehabil* 2012; **34:** 2018–2024.
13. Izawa KP, Watanabe S, Oka K, Hiraki K, Morio Y, Kasahara Y, et al. Relation between sleep quality and physical activity in chronic heart failure patients. *Recent Pat Cardiovasc Drug Discov* 2011; **6:** 161–167.
14. Izawa KP, Watanabe S, Oka K, Hiraki K, Morio Y, Kasahara Y, et al. Association between mental health and physical activity in patients with chronic heart failure. *Disabil Rehabil* 2014; **36:** 250–254.
15. Izawa KP, Yamada S, Oka K, Watanabe S, Omiya K, Iijima S, et al. Long-term exercise maintenance, physical activity, and health-related quality of life after cardiac rehabilitation. *Am J Phys Med Rehabil* 2004; **83:** 884–892.
16. Ministry of Health, Labour and Welfare, Japan. Physical activity and exercise guide for health promotion 2023 [in Japanese]. 2024. https://www.mhlw.go.jp/content/001194020.pdf (accessed July 20, 2024).
17. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: The population health science of sedentary behavior. *Exerc Sport Sci Rev* 2010; **38:** 105–113.
18. Bauman A, Ainsworth BE, Sallis JF, Hagströmer M, Craig CL, Bull FC, et al. The descriptive epidemiology of sitting: A 20-country comparison using the International Physical Activity Questionnaire (IPAQ). *Am J Prev Med* 2011; **41:** 228–235.
19. Biswas A, Oh PI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: A systematic review and meta-analysis. *Ann Intern Med* 2015; **162:** 123–132.
20. Patterson R, McNamara E, Tainio M, de Sá TH, Smith AD, Sharp SJ, et al. Sedentary behaviour and risk of all-cause, cardiovascular and cancer mortality, and incident type 2 diabetes: A systematic review and dose response meta-analysis. *Eur J Epidemiol* 2018; **33:** 811–829.
21. Osumi A, Kanejima Y, Ishihara K, Ikezawa N, Yoshihara R, Kitamura M, et al. Effects of sedentary behavior on the complications experienced by pregnant women: A systematic review. *Reprod Sci* 2024; **31:** 352–365.
22. Ekelund U, Steene-Johannessen J, Brown WJ, Fagerland MW, Owen N, Powell KE, et al.; Lancet Physical Activity Series 2 Executive Committe; Lancet Sedentary Behaviour Working Group. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality?: A harmonised meta-analysis of data from more than 1 million men and women. *Lancet* 2016; **388:** 1302–1310.
23. Dunstan DW, Dogra S, Carter SE, Owen N. Sit less and move more for cardiovascular health: Emerging insights and opportunities. *Nat Rev Cardiol* 2021; **18:** 637–648.
24. Carter S, Hartman Y, Holder S, Thijssen DH, Hopkins ND. Sedentary behavior and cardiovascular disease risk: Mediating mechanisms. *Exerc Sport Sci Rev* 2017; **45:** 80–86.
25. Pinto AJ, Bergouignan A, Dempsey PC, Roschel H, Owen N, Gualano B, et al. Physiology of sedentary behavior. *Physiol Rev* 2023; **103:** 2561–2622.
26. Welch SA, Ward RE, Beauchamp MK, Leveille SG, Travison T, Bean JF. The Short Physical Performance Battery (SPPB): A quick and useful tool for fall risk stratification among older primary care patients. *J Am Med Dir Assoc* 2021; **22:** 1646–1651.
27. Izawa KP, Kanejima Y, Kitamura M, Ishihara K, Ogura A, Kubo I, et al. Relation of sedentary behaviour to physical function in phase I cardiac rehabilitation. *Sci Rep* 2023; **13:** 9387.
28. Bakker EA, van Bakel BMA, Aengevaeren WRM, Meindersma EP, Snoek JA, Waskowsky WM, et al. Sedentary behaviour in cardiovascular disease patients: Risk group identification and the impact of cardiac rehabilitation. *Int J Cardiol* 2021; **326:** 194–201.
29. Izawa KP, Ishihara K, Kanejima Y, Kitamura M, Ogura A, Kubo I, et al. Sedentary behaviour may cause differences in physical outcomes and activities of daily living in older cardiovascular disease patients participating in phase I cardiac rehabilitation. *Sci Rep* 2024; **14:** 14037.
30. Siddarth P, Burggren AC, Eyre HA, Small GW, Merrill DA. Sedentary behavior associated with reduced medial temporal lobe thickness in middle-aged and older adults. *PLoS One* 2018; **13:** e0195549.
31. Ishihara K, Izawa KP, Kitamura M, Kanejima Y, Ogawa M, Yoshihara R, et al. Effects of cardiac rehabilitation on cognitive function in patients with acute coronary syndrome: A systematic review. *Heliyon* 2024; **10:** e32890.
32. Dempsey PC, Sacre JW, Larsen RN, Straznicky NE, Sethi P, Cohen ND, et al. Interrupting prolonged sitting with brief bouts of light walking or simple resistance activities reduces resting blood pressure and plasma noradrenaline in type 2 diabetes. *J Hypertens* 2016; **34:** 2376–2382.
33. Izawa KP, Watanabe S, Omiya K, Hirano Y, Oka K, Osada N, et al. Effect of the self-monitoring approach on exercise maintenance during cardiac rehabilitation: A randomized, controlled trial. *Am J Phys Med Rehabil* 2005; **84:** 313–321.
34. Izawa KP, Watanabe S, Hiraki K, Morio Y, Kasahara Y, Takeichi N, et al. Determination of the effectiveness of accelerometer use in the promotion of physical activity in cardiac patients: A randomized controlled trial. *Arch Phys Med Rehabil* 2012; **93:** 1896–1902.
35. Kanejima Y, Kitamura M, Izawa KP. Self-monitoring to increase physical activity in patients with cardiovascular disease: A systematic review and meta-analysis. *Aging Clin Exp Res* 2019; **31:** 163–173.
36. Kitamura M, Izawa KP, Nagasaki T, Yoshizawa T, Okamura S, Fujioka K, et al. Effects of self-monitoring using an accelerometer on physical activity of older people with long-term care insurance in Japan: A randomized controlled trial. *Eur Geriatr Med* 2024; **15:** 371–380.
37. Kroesen SH, van Bakel BMA, de Bruin M, Günal A, Scheepmaker A, Aengevaeren WRM, et al. A cardiac-rehab behaviour intervention to reduce sedentary time in coronary artery disease patients: The SIT LESS randomized controlled trial. *Int J Behav Nutr Phys Act* 2024; **21:** 90.
38. Yoshihara R, Kitamura M, Ishihara K, Kanejima Y, Izawa KP. Mobile health intervention reduces sedentary time and physical inactivity in patients with cardiovascular diseases after discharge: Systematic review and meta-analysis. *Heart Mind (Mumbai)* 2024, doi:10.4103/hm.HM-D-24-00005.