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Review of Advances in Sedentary Behavior in Patients with Chronic Heart Failure

Xuan Lian[1], Yeping Wu[1], Ying Yu[1], Juan Ge[2]*

[1]Shanghai Sipo Polytechnic, Shanghai 201300, China
[2]Shanghai Jian Qiao University, Shanghai 201306, China

**Corresponding author: Juan Ge, gejian198907@163.com*

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Abstract: This paper systematically reviews the concept and assessment methods of sedentary behavior, summarizes the current status of sedentary behavior in patients with chronic heart failure (CHF) and its impact on adverse health outcomes, and synthesizes the potential mechanisms linking sedentary behavior to CHF as well as current intervention strategies. It aims to provide a reference for future research on sedentary behavior in CHF patients in China.

Keywords: Heart failure; Sedentary behavior; Mechanism; Intervention; Review

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1. Introduction

Heart failure (HF) is a complex clinical syndrome caused by various etiologies leading to structural and/or functional abnormalities of the heart, resulting in impaired ventricular systolic and/or diastolic function. It is characterized by high rates of rehospitalization and mortality. Based on the disease course, HF can be classified into chronic heart failure (CHF) and acute heart failure. Most patients with acute HF transition to a chronic course after partial symptom relief through hospitalization. CHF patients often experience acute exacerbations due to various triggers, requiring repeated hospitalizations [1]. The Report on Cardiovascular Health and Diseases in China 2023 Summary estimates that there are 8.9 million HF patients in China [2]. In recent years, with the deepening of comprehensive HF management, the role of behavioral factors in disease prognosis has gained increasing attention. HF disease management is complex, and studies have shown that guiding CHF patients in regular aerobic exercise helps improve their clinical symptoms [3]. Sedentary behavior (SB) is an independent risk factor for the incidence of cardiovascular diseases, is prevalent among CHF patients, and may be related to the complex symptoms of HF, leading to decreased physical activity capacity and increased sedentary time [4]. Therefore, closely monitoring SB in CHF patients and implementing effective interventions to promote their physical activity are of great significance for improving patients' quality of life and survival rates.

2. Definition and assessment of sedentary behavior

2.1. Definition of sedentary behavior

In 2012, the Sedentary Behaviour Research Network (SBRN), composed of researchers and health professionals interested in SB from various countries, first defined SB, emphasizing the distinction between "sedentary behavior" and "physical inactivity" [5]. In 2017, SBRN further clarified the definition of SB [6] as any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting, reclining, or lying posture. This includes watching television, playing games, using computers (collectively termed screen time), sitting in a car, and reading [7]. Recently, with in-depth research on different patterns of SB (e.g., prolonged uninterrupted sitting versus interrupted sitting), some scholars suggest that besides total sedentary time, the duration of sedentary bouts and the frequency of interruptions are also important health influencers [4]. Current standards for classifying prolonged sitting duration vary; some scholars consider daily sitting exceeding 4 hours as the threshold, while others propose 6, 7, or even 8 hours. The latest perspective tends to suggest that, regardless of total duration, prolonged uninterrupted sitting is more detrimental to health.

2.2. Assessment of sedentary behavior

Current assessment methods for SB are subjective and objective. Common subjective assessment methods include: (1) The International Physical Activity Questionnaire (IPAQ) [8], widely used domestically and internationally, applicable to various populations. Study results indicate its reliability is approximately 0.80 and validity approximately 0.30 [9]; (2) The Sedentary Behavior Questionnaire (SBQ) [10], which includes 9 types of sedentary behaviors (TV viewing, computer use, listening to music, talking on the phone, reading, etc.) and assesses time spent in SB by recalling weekdays and weekends. The intraclass correlation coefficients for each item and the entire questionnaire range from 0.51 to 0.93. In recent years, some simplified questionnaires for specific populations or contexts have also emerged. Objective measurement tools include accelerometer sensors, electronic devices worn on the wrist or anterior thigh to collect participant data, which is then exported and analyzed using specific software [4]. New-generation accelerometers and multi-sensor devices combining heart rate monitoring, electrodermal activity, and other physiological parameters can more accurately identify postures and distinguish low-intensity activities, improving the accuracy of objective assessment. Subjective questionnaires are more suitable for representative and generalizable study samples, are simple to administer, low-cost, and facilitate easy data collection, but suffer from lower reliability and validity. Conversely, objective measurements offer higher data accuracy but require equipment, funding, may experience data loss, and demand higher participant compliance. A combination of subjective and objective methods can be used to assess SB when necessary. Currently, using machine learning algorithms to analyze accelerometer data for automatic identification and classification of SB patterns is a research hotspot in this field.

3. Current status of sedentary behavior in heart failure patients

A cross-sectional study by Yavari *et al.* [11] found, using objective tools, that HF patients spent approximately 80% of their waking time sedentary. Another cross-sectional study in an elderly HF population, assessing SB via questionnaire, showed that elderly HF patients averaged up to 7 hours of daily sedentary time [12]. However, a study by Haedtke *et al.* [13] found that among hospitalized HF patients, self-reported mean sedentary time (253 ± 156 min/day) was significantly lower compared to accelerometer-measured sedentary time (392 ± 104 min/day). Despite differences in assessment tools, the daily sedentary time of HF patients remains high.

Chronic heart failure patients generally exhibit prolonged sedentary time, which may be related to their decreased exercise capacity and fear of physical activity due to concerns about their heart condition. Additionally, discrepancies between subjective and objective assessment methods may also lead to inconsistent results. Therefore, it is necessary to provide individualized exercise guidance based on the patient's specific situation, address their concerns, and select appropriate sedentary behavior assessment methods. Recent research emphasizes that when assessing sedentary behavior in heart failure patients, attention should be paid simultaneously to the total sedentary time, the duration of prolonged sedentary bouts, and the frequency of interruptions, as these indicators may have independent predictive value for health outcomes [14].

4. Impact of sedentary behavior on adverse health outcomes in HF patients

4.1. Increased mortality

Current research shows that SB and lack of physical activity are major risk factors for global cardiovascular disease and all-cause mortality, emphasizing SB as a key factor in cardiovascular disease among the elderly [15]. The American Heart Association recently issued a scientific advisory highlighting the harmful association between SB and heart disease incidence and mortality [16]. A 36-month follow-up study by Rami *et al.* [17], determining SB based on TV viewing time in HF patients, indicated that sedentary time increased its impact on mortality. A study by Linda *et al.* [18] found a 20% mortality rate among rural HF patients within a two-year follow-up, confirming that SB was associated with all-cause mortality, increasing the risk of death by over 80%. A meta-analysis of a large-scale cohort study by Freene *et al.* [19] further strengthened this association, noting that SB remained an independent predictor of mortality in HF patients even after adjusting for moderate-to-vigorous physical activity.

Healthcare professionals should pay close attention to the hazards of SB and consider incorporating it into patient life expectancy assessment systems to improve the quality of care for HF patients. Integrating SB reduction into comprehensive management plans for HF patients has become a focus in recent clinical practice guideline updates.

4.2. Reduced quality of life

In one meta-analysis, SB was associated with health-related quality of life (HRQL) in the elderly [20]. A study using objective tools to measure SB found that SB (increase of 1 min/day) was associated with poorer HRQL ($\beta = 0.004$; 95% CI: 0.0004–0.007; $P = 0.03$) [21]. Another study using both subjective and objective methods to assess SB found inconsistent results; partial correlation analysis showed that objectively measured sedentary time was not correlated with HRQL [13]. Recent studies have begun focusing on the relationship between SB patterns and quality of life, with preliminary evidence suggesting that frequent interruptions of sedentary time may positively impact the quality of life, particularly in the physical function domain, of CHF patients [22].

Current research on the impact of SB on the quality of life of HF patients is relatively scarce, and different assessment methods may lead to divergent results. Future studies need to establish uniform assessment standards. Healthcare professionals should implement early assessment, prevention, and management of SB in HF patients and adopt targeted interventions to improve their quality of life. Future research should focus more on exploring the interventional effects of changing SB patterns (e.g., increasing interruptions) on improving quality of life.

4.3. Induction of depression

Sedentary behavior can lead to depression in patients with heart failure. A cross-sectional study in India, which assessed sedentary behavior via questionnaire, confirmed that sedentary behavior is a risk factor for depression in heart failure patients [23]. A cross-sectional study in the United States, also using questionnaires to assess sedentary behavior, found that depression was an independent factor affecting physical activity in heart failure patients, and reducing sedentary time could improve depressive symptoms [12]. Compared to heart failure patients with shorter sedentary times, those with longer sedentary times had significantly increased depression levels at baseline, while their anxiety and depression symptoms showed improvement at 3 and 6 months post-discharge compared to baseline ($P < 0.001$) [24]. Current research preliminarily suggests that reducing sedentary behavior, particularly by increasing light-intensity activity to interrupt sitting, may be beneficial for alleviating depressive symptoms in heart failure patients. However, the causal relationship and specific pathways involved still require further clarification [25].

The association between SB and depression in HF patients remains debated. Current research on SB and depression in HF is limited, and most studies are cross-sectional. Future large-scale cohort studies are needed to determine if these associations are causal. Furthermore, exploring the mechanisms through which SB affects depressive mood via physiological pathways such as inflammation and neuroendocrinology is an important future research direction.

5. Potential mechanisms by which sedentary behavior affects heart failure

5.1. Chronic inflammation

SB is associated with inflammation. Some studies have found that higher levels of SB are associated with higher levels of inflammatory markers; increased sedentary time leads to increases in interleukin-6 and C-reactive protein [26]. Inflammatory cytokines can further activate the production of reactive oxygen species (ROS), which are important components in the pathogenesis of HF [27]. Systemic inflammation can drive cardiac hypertrophy and fibrosis, ultimately leading to the worsening of HF [28]. Recent studies have also found that SB may exacerbate systemic low-grade inflammation by affecting adipose tissue function and promoting the release of pro-inflammatory adipokines [29].

5.2. Metabolic markers

A link exists between SB and metabolism. Prolonged sitting, causing the loss of muscle contraction stimulation, impairs skeletal muscle metabolism of lipids and glucose [7], leading to adverse changes in blood insulin and glucose levels. The effects of hyperglycemia occur through various mechanisms, including increased ROS production, increased formation of advanced glycation end products, and activation of protein kinase C, ultimately leading to oxidative stress, apoptosis, and increased vascular permeability [30], thereby aggravating HF. Interrupting SB through physical activity can increase the expression of genes related to carbohydrate metabolism regulation in skeletal muscle and improve glucose metabolism [31]. Research has further revealed the negative effects of SB on mitochondrial function and the activity of enzymes related to skeletal muscle lipid metabolism, which may participate in the metabolic disorders of HF [32].

5.3. Hemodynamics

Current research has found that SB is associated with aortic wall stiffening, decreased arterial distensibility, increased left ventricular mass and mass-to-volume ratio, decreased left ventricular compliance, and impaired systolic and diastolic blood pressure [33,34]. SB leads to reduced skeletal muscle metabolism and decreased vasodilatory metabolites, resulting in further reduced blood flow. Reduced arterial blood flow and shear stress lead to the uncoupling of endogenous nitric oxide synthase from nitric oxide production and increased secretion of endothelin by endothelial cells, promoting vasoconstriction. Over time, this leads to increased total peripheral resistance, elevated systemic blood pressure, and increased left ventricular afterload, thereby exacerbating HF [35]. When sitting, muscle activity decreases (especially in lower limb weight-bearing muscles), subsequently reducing energy demand and leading to decreased peripheral blood flow and shear stress. This, in turn, increases vasoconstriction, leading to vascular dysfunction. Furthermore, sitting increases lower limb hydrostatic pressure, which may increase muscle sympathetic nerve activity and blood viscosity, thereby altering blood flow and shear stress [36]. Recent studies using high-frequency ultrasound and other techniques have more precisely demonstrated the immediate deterioration of femoral artery blood flow and endothelial function during acute sitting and found that regularly interrupting sitting can partially reverse this adverse effect [37].

5.4. Nervous system

SB is also associated with increased sympathetic nervous system activity. Elevated blood pressure after sitting may cause cerebral vasoconstriction to increase resistance, thereby maintaining constant blood flow. Increased vascular resistance leads to reduced arterial lumen size, potentially decreasing cerebral blood flow over time [38]. Higher sympathetic tone exacerbates vasoconstriction and leads to reduced renal blood flow and glomerular filtration rate, as well as increased renin and aldosterone activity, thereby increasing cardiac afterload and left ventricular myocardial stress, further worsening HF [35]. Recent studies indicate that SB may also disrupt the neurohumoral balance in HF patients by affecting baroreceptor sensitivity and cardiac autonomic regulation (e.g., reduced heart rate variability) [39].

5.5. Other potential mechanisms

In recent years, scholars have begun to focus on other potential mediating pathways. For example, SB may indirectly affect systemic inflammation and metabolic status, thereby participating in HF pathophysiology, by altering gut microbiota structure and the production of metabolites like short-chain fatty acids [40]. Additionally, epigenetic modifications (e.g., DNA methylation) are also considered an emerging mechanistic area through which SB affects cardiovascular health [41].

6. Exercise intervention strategies

Since 2003, there have been over 30 controlled intervention trials targeting SB reduction. Current main intervention measures include: (1) Environmental interventions: such as setting up “standing workstations” in workplaces, which can reduce sedentary time by an average of 40.6 minutes per day; home environment modifications, like using height-adjustable desks, also show potential for reducing sedentary time in HF patients; (2) Educational and motivational interventions targeting individual behavior: such as smartphone applications and educational programs, which can reduce sedentary time by 23.8 minutes per day; personalized feedback and goal setting based on behavior change theories (e.g., Behavior Change Wheel, Self-Determination Theory) are supported by increasing evidence; A study in the Republic of Korea suggested that most CHF patients have low exercise self-efficacy and should be guided to engage in more physical activity, with their confidence levels boosted through various means including lectures, discussions, goal setting, and support [42]; (3) Multi-component interventions: combining environmental and educational or motivational measures, which can reduce sedentary time by 35.5 minutes per day [43]. The World Health Organization's *Guidelines on Physical Activity and Sedentary Behaviour* recommend that adults engage in at least 150 minutes of moderate-intensity aerobic physical activity or at least 75 minutes of vigorous-intensity aerobic physical activity (or an equivalent combination) per week, while limiting sedentary time and increasing time spent in light-intensity physical activity [44]. Currently, interventions specifically aimed at interrupting and reducing SB in HF patients require further research. Some studies found that interventions specifically targeting SB are more effective than those simultaneously addressing both SB and physical activity. App-based interventions utilizing self-monitoring and multiple behavior change techniques show promise in reducing SB [45]. Recent research particularly emphasizes the importance of "sedentary interruption" (i.e., frequently and briefly interrupting prolonged sitting with low-intensity activity), suggesting that even very short periods (e.g., 2–5 minutes) of standing or slow walking may positively impact metabolic and vascular function. Telehealth guidance and wearable device reminders are feasible means to achieve effective sedentary interruption.

7. Conclusion and prospects

SB seriously endangers the physical and mental health of HF patients. Currently, research on SB in HF patients in China is still in its infancy. Through literature review, this article summarizes the main hazards of SB for HF patients, including increased mortality risk, reduced quality of life, and elevated depression risk. Its potential impact mechanisms involve chronic inflammation, abnormal metabolic markers, hemodynamic changes, and nervous system regulatory imbalance. In recent years, attention to SB patterns (e.g., prolonged sedentary bouts vs. interruptions), emerging mechanisms (e.g., gut microbiota, epigenetics), and digital intervention strategies has injected new research vitality into this field. Based on previous research, this article proposes the following suggestions for domestic scholars conducting future related research: First, there is a need to standardize the assessment methods for SB in HF patients, adopting a combination of subjective and objective strategies when necessary, and promoting the standardized measurement and reporting of SB pattern indicators; Second, in-depth exploration of the specific mechanisms by which SB affects HF is needed, particularly from multi-omics perspectives (e.g., metabolomics, metagenomics) to find new biomarkers and pathways; Third, large-scale cohort studies should be conducted to clarify causal relationships, utilizing methods like Mendelian randomization to assist causal inference; Fourth, interventional research should be strengthened to develop and validate SB intervention strategies suitable for Chinese HF patients, particularly feasible intervention plans centered on "sedentary interruption" combined with mobile health technology and personalized feedback, to effectively guide patients in reducing or interrupting SB. Fifth, attention should be paid to the differential responses to SB and its interventions among different HF patient subgroups (e.g., different ejection fraction types, comorbidities) to achieve precise intervention.

Disclosure statement

The authors declare no conflict of interest.

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