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# Exploring Risk Factors and Preventive Strategies for Cardiovascular Dysfunction Following Spinal Cord Injuries: A Comprehensive Literature Review

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## ABSTRACT

This paper reviews the increased cardiovascular risks associated with spinal cord injury (SCI), focusing on the pathophysiological mechanisms, clinical manifestations, and both immediate and long-term effects. It identifies several potential risk factors for cardiovascular diseases post-SCI, including reduced physical activity, low HDL cholesterol levels, higher body fat percentage, poor glucose tolerance, insulin resistance, psychosocial influences, and emerging risk factors associated with SCI. Appropriate nutritional counseling and intervention are critical because individuals with SCI often consume insufficient nutrition. Screening for cardiovascular risk factors and assessing the global risk for coronary heart disease are essential steps in prevention. Research suggests that people with chronic SCI are more likely to experience poor glucose tolerance, insulin resistance, and hyperinsulinemia. Key management strategies for these patients involve weight control, dietary changes, physical activity, and blood sugar management. Successful prevention of cardiovascular disease requires the active involvement of both patients and healthcare providers.

**Keywords:** Cardiovascular diseases, Spinal cord injury, Risk factors, Prevention

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**Introduction**

Spinal cord injury (SCI) results in significant impairment of sensory, motor, and autonomic functions, leading to profound changes in the patient’s condition [1, 2]. Both the initial injury and its long-term effects can be life-threatening and require continuous medical attention [3]. Annually, around 12,500 cases of SCI are reported in the United States [4], with a global incidence ranging from 133,000 to 226,000 cases [5]. The economic impact of SCI is substantial, with lifetime costs for care ranging from $1.5 million to $4.7 million. The majority of SCI cases are due to traumatic accidents, with road traffic incidents being the leading cause in developing countries. Despite changes in demographics, men still account for 80% of new SCI diagnoses [5].

The primary cause of SCI is typically a deformity or compression in the spine. Secondary injury occurs after the initial damage, leading to a series of biochemical and cellular responses like electrolyte imbalances, free radical production, swelling, ischemia, and inflammation [6, 7]. These secondary injuries are classified into acute, subacute, and chronic phases. In the acute phase (within 48 hours), bleeding and lack of blood flow lead to inflammation and changes in ion balance. The subacute phase (up to two weeks) involves the activation of immune responses and astrocyte proliferation, resulting in scar tissue that hinders nerve regeneration. The chronic phase, which lasts beyond six months, marks the healing process [2].

For patients with SCI at or above the sixth thoracic vertebra (T6), there is often a failure to properly control the sympathetic nervous system, which regulates blood pressure, heart rate, and blood flow to various regions of the body [8, 9].

This paper examines the increased cardiovascular risks associated with spinal cord injury, focusing on the pathophysiological mechanisms, clinical manifestations, and both immediate and long-term effects.

**Results and Discussion**

*Physiological Mechanisms of SCI*

Orthostatic hypotension, a common cardiovascular issue following SCI, occurs because of the absence of reflex vasoconstriction mediated by the sympathetic nervous system. This leads to blood pooling in the lower extremities and a decrease in venous return, which lowers blood pressure [10, 11].

A decrease in blood volume returned to the heart results in lower filling pressures, increasing the likelihood of ischemic stroke. Tachycardia may also occur due to reduced vagal inhibition, but it does not compensate for the reduced sympathetic activity [12]. Patients with cervical SCI tend to experience more severe orthostatic hypotension than those with thoracic SCI. In addition, orthostatic hypotension is more frequent in patients with traumatic SCI compared to non-traumatic SCI. However, it may improve over time, and other vascular adjustments may help maintain blood pressure [13].

Arenas such as the kidney can further trigger compensatory mechanisms, like activating the renin-angiotensin-aldosterone system, which impacts fluid balance and blood pressure regulation [13]. Over time, some SCI patients adapt to these postural blood pressure changes, primarily through mechanisms regulating blood flow to the brain. Overall, SCI can cause a range of cardiovascular complications, including low blood pressure, arrhythmias, and venous thromboembolism [14, 15].

*Symptoms and Impacts of Cardiovascular Dysfunction in SCI*

Many symptoms of orthostatic hypotension, such as dizziness, fainting, and visual disturbances (e.g., scotomas and tunnel vision), are caused by inadequate blood supply to the brain. Other symptoms can include pallor, generalized weakness, and mental sluggishness. Overheating above the injury site is also common. If uncontrolled, blood pressure fluctuations can severely affect the patient’s recovery and overall quality of life [16, 17].

Orthostatic hypotension can be a significant barrier to rehabilitation. A study of acute SCI patients showed that 43% reported that these symptoms limited their ability to participate in rehabilitation activities. Persistent hypotension in SCI patients has also been linked to cognitive decline, such as memory and attention deficits [18].

Various factors, including prolonged bed rest, sudden changes in posture, and even dehydration, can exacerbate postural hypotension. Large meals, physical exertion, alcohol, or heat may also worsen symptoms. Certain medications, including tricyclic antidepressants, antihypertensives, and narcotics, may contribute to or intensify orthostatic hypotension [19, 20].

This paper focuses on evaluating the cardiovascular risks that may be heightened following spinal cord injury (SCI).

*Risk Factors and Prevention Approaches for Cardiovascular Dysfunction in SCI*

A wealth of studies has outlined the common cardiovascular risk factors for conditions like atherosclerosis and coronary heart disease in the general population. These risk factors have been the subject of numerous epidemiological investigations, including well-known studies like Framingham [21-23]. Some non-modifiable risk factors include advancing age, male gender, and a family history of coronary heart disease. Special attention should be given to individuals with first-degree relatives who have experienced early-onset coronary artery disease, as these individuals require early screening and intervention.

On the other hand, modifiable risk factors that contribute to cardiovascular diseases include hypertension, smoking, lipid imbalances (elevated LDL and decreased HDL), physical inactivity, obesity, and conditions such as diabetes or pre-diabetes [23]. These risk factors are generally manageable with appropriate interventions.

In addition to these widely recognized risk factors, new and emerging risks are being actively studied, especially in the context of SCI. Research has shown that individuals with SCI may experience a higher incidence of various cardiovascular risk factors compared to the general population (see **Table 1**) [24]. This has raised concerns that traditional cardiovascular risk assessment methods may not adequately capture the unique risks faced by individuals with chronic SCI, potentially leading to an underestimation of their cardiovascular risk [25, 26].

Chronic spinal cord injury (SCI) has been linked to an increased risk of cardiovascular problems, as supported by several studies [25, 26].

**Table 1.** Potential cardiovascular risk factors following SCI

| Cardiovascular risk factor |
|---|
| Reduced physical activity |
| Low levels of HDL cholesterol |
| Higher body fat percentage |
| Impaired glucose regulation and insulin resistance |
| Psychological factors (such as depression and isolation) |
| Possible impact on emerging risks (inflammation and platelet function) |

To effectively reduce the risk of coronary heart disease (CHD), both patient and doctor motivation are essential. The initial steps in prevention involve identifying key risk factors and assessing the overall risk for CHD. Below are the primary goals for prevention (**Table 2**).

**Table 2.** Major prevention targets for coronary heart disease

| Prevention target |
|---|
| Smoking cessation |
| Targeted lipid management |
| Blood pressure regulation |
| Weight control |
| Regular physical activity |
| Diabetes management |
| Intervention |
| Antiplatelet therapy (e.g., aspirin) |
| Anticoagulation therapy |
| Blockers of the renin-angiotensin-aldosterone system |
| Use of beta-blockers |

*Hypertension*

Blood pressure (BP) levels are closely linked to cardiovascular disease, and evidence suggests that controlling hypertension can lower the risks of heart disease and related deaths [17]. In individuals with spinal cord injury (SCI), low blood pressure is more common than high blood pressure, particularly in those with complete tetraplegia or high-level paraplegia. However, some studies report a notably higher incidence of hypertension in these patients. While this may be the case in certain instances, the hypertension is often idiopathic and not associated with kidney problems. The prevalence of hypertension varies widely in studies, influenced by factors such as age, sex, ethnicity, veteran status, and the characteristics of the SCI, including its severity, complexity, and cause [27]. Tetraplegics generally have a lower incidence of hypertension than paraplegics, especially those with lower levels of paraplegia (T7 and below). When considering factors such as age, demographics, and comorbidities, those with non-traumatic SCI are more likely to develop hypertension compared to those with traumatic SCI. Hypertension is also common in SCI patients who have aortic disease or complications from aortic surgery. Blood pressure fluctuations due to autonomic instability and posture should be considered when diagnosing hypertension in SCI patients. People with SCI, particularly quadriplegics, may experience changes in blood pressure depending on their posture [28]. If a quadriplegic patient is sitting when BP is measured, supine hypertension might not be detected. Autonomic instability can lead to significant BP variability in SCI patients. Coexisting conditions like autonomic dysreflexia and orthostatic hypotension, especially in quadriplegics, can make diagnosis more challenging. Autonomic dysreflexia is clinically distinct from essential hypertension in its presentation, progression, and episodic nature. To improve the diagnosis of hypertension in SCI patients, it's recommended to take multiple BP measurements over time, both in seated and supine positions. Key lifestyle changes like reducing salt intake, avoiding alcohol, increasing physical activity, and managing weight are important for controlling hypertension [29]. Adhering to prescribed medication is essential for effective management. For patients with BP readings of 130/80 mmHg or higher, lifestyle modifications should be considered. For most adults, medication is typically started when BP reaches 140/90 mmHg. It remains unclear whether SCI patients should have different target BP ranges than the general population. Medication choices may be influenced by SCI-specific factors. For example, thiazide diuretics, which are commonly recommended for the general population [29], might not be suitable for SCI patients who require intermittent catheterization.

*Smoking*

Smoking is well-known to contribute to coronary heart disease, and the risk of myocardial infarction drops significantly soon after quitting. It is crucial to systematically identify smokers. Successful smoking cessation relies on regular individual interventions or participation in support groups. It is important that smoking cessation efforts are permanent and that patients remain engaged in counseling programs. Doctors should ask about smoking habits during every visit, encourage quitting, provide counseling, assist in creating a quitting plan, and consider referring patients to specialized programs or offering pharmacotherapy, such as nicotine replacement therapy or bupropion. Options like nicotine gum, patches, sprays, lozenges, and inhalers can be helpful. Clinicians should proactively contact smokers who have relapsed to discuss new treatment options and additional counseling resources [30]. Since nicotine dependence often involves relapses and remissions, patients should be encouraged to limit exposure to secondhand smoke at home and in the workplace.

*Lipid Abnormalities*

High LDL (low-density lipoprotein) levels are a well-established risk factor for coronary heart disease, and significant evidence supports the idea that lowering LDL can slow the progression of coronary artery disease. Conversely, high HDL (high-density lipoprotein) levels are linked to a reduced risk of coronary heart disease, acting as a protective factor. Research suggests that individuals with chronic SCI tend to have lower HDL levels compared to the general population [31]. While only 10% of the general population has an HDL level < 35 mg/dL, the figure rises to 24% to 40% in SCI patients [32].

The first step in managing lipid disorders is evaluating the patient's overall risk to guide treatment decisions [27]. Although there is no universal agreement on screening guidelines, experts generally recommend that screenings should be based on assessing the patient's total cardiovascular risk [33, 34]. While studies in healthy adults may offer insights, they may not fully apply to SCI patients due to physiological differences. It is recommended that individuals with SCI undergo a fasting lipid profile at least every five years, and more frequently for those at higher risk or showing signs of lipid imbalances [32].

Conditions such as diabetes, hypothyroidism, and medications like anabolic steroids can cause secondary dyslipidemia, and these should be ruled out in patients with abnormal lipid levels. Treatment plans should be customized based on each patient's risk level. Given the lack of consensus on the best medication for low HDL, lifestyle interventions are essential. These include smoking cessation, weight management in overweight individuals, and increased physical activity for those who are sedentary. A heart-healthy lifestyle is encouraged for all patients. While niacin has been shown to raise HDL, including in SCI patients, it is no longer recommended due to its lack of proven benefit on cardiovascular outcomes and its higher risk of side effects when used alone or with statins [30].

Statins are the primary medication used to lower LDL and cholesterol levels [35]. Statins not only lower triglycerides, total cholesterol, and LDL cholesterol, but they also have anti-inflammatory and plaque-stabilizing properties. The American College of Cardiology (ACC) and the American Heart Association (AHA) strongly recommend statins for secondary prevention in patients with clinically atherosclerotic cardiovascular disease, primary prevention in individuals with LDL ≥ 190 mg/dL, and primary prevention in people with diabetes aged 40-75 years who have LDL levels between 70-189 mg/dL. They also recommend statins for individuals without diabetes but with an estimated 10-year risk of developing cardiovascular disease. Fixed-dose statin therapy is preferred, using either a high-intensity regimen (lowering LDL by about 50% or more) or a moderate regimen (reducing LDL by 30-50%) [27]. This approach is considered superior to targeting specific LDL-C goals [36, 37]. The guidelines suggest that creatine kinase (CK) testing should only be done if a patient experiences muscle symptoms such as weakness or soreness while taking statins. However, because SCI patients may not present these symptoms clearly, more frequent CK monitoring could be necessary in this group. Though most studies on statins were done with non-SCI populations, a small retrospective study in SCI patients found that statin use was linked to lower mortality [35].

*Physical Activity*

Sedentary behavior is a recognized risk factor for coronary heart disease [23]. Physical activity offers multiple cardiovascular benefits, including enhanced endothelial function, reduced systemic inflammation, better insulin sensitivity, improved oxygen utilization by the heart, lowered blood pressure, and positive effects on platelet aggregation and blood viscosity [21].

Individuals with spinal cord injury (SCI) often face challenges in staying active due to mobility limitations, inadequate exercise options, access barriers, and the physical toll of musculoskeletal injuries. Additionally, SCI alters the body's physiological response to exercise due to muscle loss and autonomic dysfunction [37]. Ordinary daily movements are insufficient to achieve cardiovascular fitness for SCI patients.

Aerobic exercises, such as upper body aerobic activities, strengthening routines, and options like wheelchair ergometry, swimming, or electrical stimulation-based exercises like cycling and rowing, can help SCI patients improve cardiovascular health. However, there is limited research on the most effective exercise regimens or how exercise impacts cardiovascular risk for people with SCI [35].

The Department of Health and Human Services suggests that adults with disabilities should engage in at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity exercise each week. This can be complemented with strength training exercises targeting all major muscle groups at least twice a week. For those unable to meet these recommendations, it's still important to stay active to the best of their ability, with guidance from healthcare professionals [38, 39].

*Obesity and Overweight*

Obesity is a major factor in worsening heart health, increasing the risk of coronary heart disease, and contributing to cardiovascular disease risk on its own. People with SCI often consume fewer calories than the general population after the acute injury phase, which can lead to weight gain [39]. SCI patients, particularly those with quadriplegia, have a higher body fat percentage and lower muscle mass, which increases the risk of heart disease and insulin resistance [40].

Standard methods of measuring obesity, like weight or BMI, may not be accurate in people with SCI because these individuals have reduced muscle mass and an elevated fat percentage. As a result, determining obesity prevalence is more complex. Individuals with SCI should reduce their calorie intake as energy needs typically decrease post-injury. Nutritional counseling becomes vital as individuals with SCI may follow suboptimal diets. Depending on injury severity, energy requirements may be reduced by 10-25% compared to healthy individuals. For optimal health, the recommended body weight for SCI individuals is often 10-20 kg lower than for the general population due to decreased muscle mass [41, 42].

*Diabetes Mellitus, Impaired Glucose Tolerance, and Hyperinsulinemia*

People with diabetes mellitus (DM) are at an elevated risk of developing coronary heart disease. While lipid imbalances play a significant role, elevated blood sugar and insulin levels also contribute independently to cardiovascular risk [43]. The presence of abdominal obesity, atherogenic dyslipidemia, high blood pressure, insulin resistance, and proinflammatory states is all part of the metabolic syndrome, which increases cardiovascular disease risk. SCI patients with diabetes have higher rates of coronary heart disease and related conditions such as myocardial infarction [43].

Although the data is not consistent and is influenced by demographic factors, individuals with chronic SCI are more likely to experience conditions like impaired glucose tolerance, insulin resistance, and hyperinsulinemia. For example, veterans with SCI had higher rates of diabetes compared to the general population, but their rates were consistent with other veterans, suggesting that demographic factors may play a significant role in this finding. Factors such as age, ethnicity, family history, and military service can increase the risk of insulin resistance. For those with SCI and diabetes, managing weight, improving diet, increasing physical activity, and controlling blood sugar are essential treatment strategies. Specialized attention to diabetes management can significantly improve the quality of life and overall health outcomes for individuals with SCI [44].

*Psychosocial Factors*

Psychosocial elements have been shown to increase the risk of coronary heart disease. Research highlights depression, social isolation, and chronic stress as key contributors to this risk [45]. Studies indicate that the severity of depression is closely linked to a higher likelihood of coronary events, with depression being a known independent risk factor for both heart attacks and mortality [46-48].

Two potential mechanisms that explain the connection between depression and heart disease include platelet dysfunction and hormonal changes, such as higher cortisol levels, which may contribute to atherosclerosis. Social isolation, marked by the absence of regular social interactions or emotional support, is also a risk factor. After a heart attack, individuals who lack strong social networks are at a higher risk of experiencing recurrent cardiac events [45].

People with spinal cord injuries (SCI) may be at a greater risk for depression and social isolation compared to the general population, although prevalence rates can vary [45]. Therefore, addressing depression and enhancing social support should be integral to the treatment and care of SCI patients.

*Emerging Risk Factors*

Beyond the well-established risk factors, studies have identified a range of emerging factors that may contribute to coronary heart disease. However, much of the research on these factors is still preliminary, and further investigation is needed to determine their significance. These emerging factors include oxidative stress, platelet activation, increased plasma homocysteine levels, certain lipoproteins, and inflammatory markers like high-sensitivity C-reactive protein (CRP) [49].

While there is some research specifically focusing on SCI, most studies on coronary artery disease are based on the general population. In SCI patients, some research has highlighted abnormalities in platelet function, such as altered aggregation and resistance to certain inhibitors [40]. The importance of these abnormalities in the context of SCI and heart disease remains unclear. Additionally, studies have found higher CRP levels in SCI patients, but these inflammatory markers can be elevated due to other conditions like urinary tract infections or pressure sores, making it difficult to link them directly to cardiovascular disease risk in SCI patients [50].

**Conclusion**

Spinal cord injuries are more common and often more severe in males, with the risk of cervical spinal cord injury increasing with age, especially in individuals over 65. SCI can have significant effects on the cardiovascular system, including reduced mean blood pressure and heart rate. People with chronic SCI are more likely to experience glucose intolerance, insulin resistance, and hyperinsulinemia. Effective management for these individuals includes controlling weight, modifying the diet, increasing physical activity, and managing blood sugar levels. Preventing coronary heart disease in SCI patients requires a collaborative effort from both patients and healthcare providers.

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