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Research Article



Characteristics and cardiometabolic profiles in patients with spinal cord injury in the UK

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ABSTRACT

Objective: Cardiovascular disease (CVD) is the leading cause of mortality in individuals with spinal cord injury (SCI). This study examined patient characteristics, SCI-specific factors, and biochemical parameters associated with CVD risk.

Methods: A retrospective secondary analysis was conducted on 421 patients admitted between January and December 2017. Demographic, clinical, and biochemical data were recorded within 7 days of admission. CVD risk was estimated using the QRISK-2 score. Between-group differences were examined using Chi-square and Kruskal – Wallis tests. Logistic regression with multiple imputation was performed to identify predictors of CVD risk.

Results: Most patients were male (73%), aged <65 years (74%), and had traumatic SCI (68%). Over half (56%) were at medium/high CVD risk. Common biochemical abnormalities included vitamin D deficiency/insufficiency (56%), hypoalbuminemia (46%), anemia (42%), elevated C-reactive protein (CRP) (48%), low creatinine (55%), overweight/obesity (49%), high cholesterol (40%), low high-density lipoprotein cholesterol (43%), and high cholesterol/HDL ratio (28%). Univariate regression identified higher creatinine (OR 1.02), CRP (OR 1.01), and hypoalbuminemia (OR 0.923) as independent predictors of increased CVD risk, alongside traditional factors (male sex, older age, high total cholesterol, low HDL, elevated cholesterol/HDL ratio). Multivariate analysis confirmed significant associations of serum albumin (negative) and creatinine (positive) with CVD risk. No significant associations were found with injury level, onset, or nutritional risk scores.

Conclusion: Patients with SCI often present at admission with high rates of CVD risk and biochemical abnormalities. A more systematic approach with clear clinical guidance for routine CVD risk assessment at admission is required, alongside tailored early interventions.

KEYWORDS

Spinal cord injury;
Cardiovascular disease risk;
Dyslipidaemia; Creatinine;
Albumin

Introduction

Cardiovascular disease (CVD) is the leading cause of mortality among individuals with spinal cord injury (SCI) (1). Consequently, patients with SCI are now recognized as a distinct risk group for CVD (2). Previous observational studies have demonstrated that CVD risk factors, including central obesity, dyslipidaemia, type 2 diabetes mellitus, and elevated C-reactive protein (CRP), are more prevalent in patients with SCI than in the general population (1, 3). A Canadian study reported a prevalence of stroke of 5.7% and heart disease of 17.1% among individuals with SCI, compared with 1.1% and 4.9%, respectively, in those without SCI (4). This elevated CVD risk is largely attributed to obesity due to markedly reduced daily energy expenditure resulting from motor dysfunction, as well as autonomic dysfunction leading to abnormalities in blood pressure, heart rate variability, arrhythmias, and a blunted cardiovascular response to exercise (3, 5, 6).

Early identification and management of CVD risk factors are crucial in this group to prevent the development of cardiovascular complications (5). The present study aimed to investigate the characteristics of CVD risk and explore SCI-specific factors at the admission stage in a UK tertiary SCI center. The findings are intended to support clinical professionals in implementing early risk management strategies for patients with SCI.

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Methods

This was a one-year, retrospective secondary data analysis collected between January and December 2017. Formal ethical approval was not required by the institutional ethics committee as the study did not involve active patient participation. Details of the data collection have been reported elsewhere (7). All data and biochemical tests were recorded or conducted within 7 days of hospital admission.

A total of 421 patients with SCI were included. Due to missing information in some cases, the sample size varied across measures. Only measures that had data from 180 or more patients (which aligns with the number of patients who had CVD risk scores) were included in the analysis. Patients were categorized as low (<10), medium (10–20), or high risk (>20) of CVD according to their CVD risk score, calculated using the QRISK-2 scoring system (8). Variables incorporated into the score included age, sex, ethnicity, blood pressure, cholesterol levels, body mass index (BMI), smoking status, and alcohol intake. Of note, QRISK-2 allows for CVD risk estimation even when some information is unavailable.

Categorical variables are presented as frequency (*n*) and percentage (%), including sex, age group, level of injury, cause of SCI, the American Spinal Injury Association Impairment Scale (AIS), pressure ulcer, onset of SCI, nutrition risk, and CVD risk. AIS was dichotomized as complete (no motor or sensory function preserved in the sacral segments S4 – S5) or incomplete (all other SCI classifications) (9). The nutrition risk was assessed by using the Spinal Nutrition Screening Tool (SNST) score and categorized as normal (≤ 10) or malnourished (> 11) (10). Continuous variables are presented as mean (standard deviation, SD) or median (interquartile range, IQR) if non-normally distributed. This included age, BMI, time since SCI onset (days), total cholesterol, high-density lipoprotein cholesterol (HDL), cholesterol/HDL ratio, albumin, C-reactive protein (CRP), potassium, sodium, urea, creatinine, white cell count, hemoglobin, hematocrit, and 25(OH)D concentration.

Comparisons across low-, medium-, and high-risk groups were performed using the Pearson Chi-square test for categorical variables, and one-way ANOVA or Kruskal–Wallis tests for continuous variables, with *post hoc* analyses adjusted using Bonferroni corrections. Statistical significance was set at $P \leq 0.05$ (two-tailed).

Logistic regression analyses were conducted with CVD risk (low vs. medium/high; $n = 180$) as the dependent variable. A series of univariate analyses were first performed for each categorical and continuous variable (including the variables used to calculate the CVD risk scores by QRISK2), prioritizing categorical predictors. The multivariate regression was conducted only on independent variables that were significant in the univariate regression analysis, excluding the variables used to calculate the CVD risk scores by QRISK2. For these, we utilized the Multiple Imputation then Deletion (MID) approach which argues that cases with imputed dependent variables add no information to regression estimates and may increase bias (11). Therefore, the missing predictor data were imputed 10 times using the SPSS MI PMM function with the larger dataset ($n = 421$), and the logistic regressions were then run on each imputed dataset (using an unimputed dependent variable, but imputed predictors resulting in $n = 180$). Results were pooled using Rubin's rules (12) to account for uncertainty introduced by imputation. Results were interpreted as standard logistic regression outputs. Variables significant in univariate analyses ($P < 0.05$) were included in the multivariate logistic regression, where significance was set at $P < 0.01$.

Results

Characteristics of patients with SCI

A total of 421 patients with SCI were included in the analysis. Table 1 shows the characteristics (categorical variables) of the patients with SCI. Most of the patients were male (73.2%), adults <65 y (73.9%), traumatic injury (67.8%), without pressure ulcers (83.1%), chronic onset (>180 days) (72.7%), and nourished (77.2%). Around half had complete injury (49.2%), tetraplegic injury (46.8%), a serum 25(OH)D concentration <50 nmol/L (56.3%), and medium or high CVD risk (55.6%). A list of continuous variables and missing number included in the study can be found in Appendix 1.

Table 2 shows the categories of the biochemical parameters according to the normal range of individual measures (Appendix 2). Nearly half of the patients were overweight or obese (48.5%), had high total cholesterol (40%), low HDL (42.8%), low albumin (46%), low hemoglobin (42%), low hematocrit (49%) and high CRP (48%) concentrations. Around one-third of patients had a higher cholesterol/HDL ratio, and 23% had a low

Table 1. Descriptive characteristics of the SCI patients (total number of 421).

Categorical variables		Recorded % (n)	Missing number
Sex	Total number	414	7
	Female	26.8% (111)	
	Male	73.2% (303)	
Age	Total number	421	0
	<65 y	73.9% (311)	
	≥65 y	26.1% (110)	
Level of injury	Total number	389	32
	Tetraplegic	46.8% (182)	
	Paraplegic	53.2% (207)	
Cause of SCI	Total number	367	54
	Traumatic	67.8% (249)	
	Non-traumatic	32.2% (118)	
AIS	Total number	378	43
	Complete	49.2% (186)	
	Non-complete	50.8% (192)	
Pressure ulcer	Total number	260	161
	Yes	16.9% (44)	
	No	83.1% (216)	
Onset of SCI	Total number	366	55
	<180 days	27.3% (115)	
	≥180 days	72.7% (306)	
Nutrition risk (SNST score)	Total number	149	272
	Normal (score 0-10)	77.2% (115)	
	Malnourished (score ≥ 11)	22.8% (34)	
CVD risk score	Total number	180	241
	<10%	44.4% (80)	
	10–20%	36.7% (66)	
	>20%	18.9% (34)	

AIS, ASIA impairment scale (ASIA, American Spinal Injury Association); CVD, cardiovascular disease; SCI, spinal cord injury; SNST, spinal nutrition screening tool.

Table 2. Categories of biochemical and metabolic parameters.

Parameters	Categories	Recorded % (n)	Parameters	Categories	Recorded % (n)
BMI (kg/m²)	Total number	47.0% (198)	Urea (mmol/L)	Total number	357
	Underweight	6.1% (12)		Low	7.6% (27)
	Normal weight	48.5% (93)		Normal	85.7% (306)
	Overweight/obesity	48.5% (93)		High	6.7% (24)
Total cholesterol (mmol/L)	Total number	42.5% (179)	CRP (mg/L)	Total number	347
	Normal	60.0% (107)		Normal	52.2% (181)
	High	40.0% (72)		High	47.8% (166)
HDL cholesterol (mmol/L)	Total number	180	Cholesterol/HDL ratio	Total number	180
	Normal	57.2% (103)		Normal (<6)	72.2% (130)
	Low	42.8% (77)		High (≥6)	27.8% (50)
Albumin (g/L)	Total number	324	Creatinine (μmol/L)	Total number	357
	Low	46.0% (149)		Low	55.2% (197)
	Normal	54.0% (175)		Normal	42.6% (152)
	High	0		High	2.2% (8)
Potassium (mmol/L)	Number	352	White cell count (10⁹/L)	Total number	361
	Low	2.6% (9)		Low	2.8% (10)
	Normal	97.2% (342)		Normal	81.2% (293)
	High	0.2% (1)		High	16.0% (58)
Sodium (mmol/L)	Total number	357	Hemoglobin (g/L)	Total number	361
	Low	23.2% (83)		Low	42.3% (153)
	Normal	76.2% (272)		Normal	57.1% (206)
	High	0.6% (2)		High	0.6% (2)
Serum 25(OH)D (nmol/L)	Total number	197	Hematocrit (%)	Total number	361
	Deficiency	22.8% (47)		Low	48.8% (176)
	Insufficiency	33.5% (64)		Normal	51.2% (185)
	Sufficiency	43.7% (86)		High	0

BMI, body mass index; CRP, C-reactive protein; HDL, high-density lipoprotein cholesterol; 25(OH)D, 25-hydroxy vitamin D.

sodium concentration, or vitamin D deficiency (serum 25(OH)D concentration <25 nmol/L). More than half of the patients (55%) had a low serum creatinine level.

Comparisons of categorical and continuous variables between low-, medium- and high-CVD risk groups

There was no significant difference in AIS, cause of SCI, level of SCI, onset of SCI, nutrition risk or pressure ulcer between different CVD risk categories (Table 3).

Table 4 shows comparisons of various continuous variables between low, medium and high-risk groups. Patients in high-risk groups had a significant higher BMI compared with the low-risk group ($P = 0.007$). The total cholesterol was significantly higher in medium-risk group compared with low-risk group ($P = 0.04$). The HDL cholesterol levels were significantly different between any two risk groups (all $P < 0.001$). The cholesterol/HDL ratio was significantly higher in medium and high-risk groups compared with that in low-risk group ($P < 0.001$ respectively), and in high-risk group compared with medium risk group ($P < 0.001$). The serum albumin concentration was significantly lower in medium- and high-risk groups compared with the low-risk group ($P = 0.029$ and $P = 0.025$ respectively). CRP levels were significantly higher in high-risk group compared with that in low-risk group ($P = 0.026$). Serum potassium concentration was significantly

Table 3. Association of categorical variables with cardiovascular risks.

CVD risk		Low % (n)	Medium % (n)	High % (n)	P value*
All patients		44.4% (80)	36.7% (66)	18.9% (34)	–
Level of SCI	Tetraplegic	42.0% (34)	37.0% (30)	21.0% (17)	0.867
	Paraplegic	43.3% (39)	38.9% (35)	17.8% (16)	
AIS	Complete	42.3% (30)	40.8% (29)	16.9% (12)	0.735
	Non-complete	41.8% (41)	36.7% (36)	21.4% (21)	
Cause of SCI	Traumatic	42.9% (42)	35.7% (35)	21.4% (21)	0.786
	Non-traumatic	47.8% (32)	34.3% (23)	17.9% (12)	
Onset of SCI	<180days	44.0% (40)	35.1% (32)	20.9% (19)	0.775
	≥180days	44.9% (40)	38.2% (34)	16.9% (15)	
Nutrition risk (SNST score)	≤10	40.9% (27)	34.8% (23)	24.2% (16)	0.374
	≥11	46.5% (53)	37.7% (43)	15.8% (18)	
Pressure ulcer	Yes	25.0% (4)	43.8% (7)	31.3% (5)	0.148
	No	49.5% (46)	34.4% (32)	16.1% (15)	

AIS, ASIA impairment scale (ASIA, American Spinal Injury Association); CVD, cardiovascular disease; SCI, spinal cord injury; SNST, spinal nutrition screening tool; *Pearson Chi-Square test.

Table 4. Association of biochemical parameters with cardiovascular risks.

Parameters	CVD risk groups			P value
	Low	Medium	High	
All patients % (n)	44.4% (80)	36.7% (66)	18.9% (34)	–
BMI	24.0 (20.0, 29.0) (71)	24.0 (21.2, 26.8) (32)	27.5 (24.0, 32.8) (24)	0.014a
Total cholesterol (mmol/L)	4.4 (3.9, 5.1) (80)	5.0 (4.0, 5.9) (65)	4.8 (3.8, 5.7) (34)	0.089b
HDL cholesterol (mmol/L)	1.1 (1.0, 1.4) (80)	0.9 (0.7, 1.1) (66)	0.7 (0.6, 0.8) (34)	0.001c
Cholesterol/HDL ratio	3.7 (3.0, 4.7) (88)	5.1 (4.4, 6.5) (66)	6.4 (5.5, 7.6) (34)	0.001d
Albumin (g/L)	34.9 (5.4) (73)	32.3 (6.6) (66)	31.6 (6.2) (34)	0.008e
CRP (mg/L)	7.1 (2.1, 25.5) (77)	12.0 (4.4, 31.0) (65)	18 (5.5, 40.0) (34)	0.047f
Potassium (mmol/L)	4.2 (4.0, 4.5) (76)	4.2 (4.0, 4.5) (65)	4.1 (3.8, 4.4) (33)	0.053g
Sodium (mmol/L)	139.0 (136.8, 140.2) (78)	138.0 (135.0, 139.0) (65)	140.0 (138.0, 142.0) (33)	0.005h
Urea (mmol/L)	4.3 (3.5, 5.1) (78)	4.4 (3.5, 5.3) (65)	5.1 (4.5, 5.5) (33)	0.279
Creatinine (μmol/L)	49.5 (38.0, 63.0) (78)	53.0 (42.5, 62.8) (65)	60.0 (45.5, 70.5) (33)	0.054i
White cell count (10 ⁹ /L)	7.9 (6.2, 9.6) (78)	8.4 (6.5, 10.1) (65)	7.4 (6.2, 9.0) (34)	0.850
Hemoglobin (g/L)	124.9 (19.3) (78)	125.2 (22.7) (65)	124.5 (22.7) (34)	0.988
Haematocrit	0.38 (0.05) (78)	0.38 (0.06) (65)	0.38 (0.06) (34)	0.650
25(OH)D (nmol/L)	43.1 (25.9, 70.8) (69)	39.0 (20.0, 73.5) (54)	33.3 (23.9, 56.8) (32)	0.627

Notes: Data were presented as mean (SD) (n) or median (IQR) (n). CRP, C-reactive protein; CVD, Cardiovascular disease; 25(OH)D, 25-hydroxy vitamin D; a, $P = 0.007$ between low and high risk group, $P = 0.008$ between medium and high risk groups; b, $P = 0.04$ between low and medium risk groups; c, $P < 0.001$ between any two groups; d, $P < 0.001$ between any two groups; e, $P = 0.028$ between low and medium risk groups, $P = 0.025$ between low and high-risk groups; f, $P = 0.026$ between low and high-risk groups; g, $P = 0.048$ between medium and high-risk groups; h, $P = 0.004$ between medium and high-risk groups; i, $P = 0.049$ between low and high-risk groups. Kruskal-Wallis test adjusted by the Bonferroni corrections.

lower in high-risk group compared with medium risk group ($P = 0.048$), and sodium concentration was significantly higher in high-risk than in medium-risk group ($P = 0.004$). In addition, creatinine concentration was significantly higher in the high-risk group than in the low-risk group ($P = 0.049$). There was no significant difference in serum urea, white blood cell count, hemoglobin, hematocrit and 25(OH)D between different CVD risk groups.

Logistic regression

Table 5 shows the outcome of the univariable binary logistic regression of various categorical predictors of low and medium-high CVD risk. The sex and age group are significant predictors of CVD risk of patients with SCI ($P < 0.001$ and $P = 0.043$ respectively). The predictors including level of SCI, cause of SCI, AIS complete level, pressure ulcers, onset of SCI and nutritional status are all insignificant. The odds ratio (OR) for sex (male) is 4.660 (95% CI 2.304, 9.426) and for age group (≥ 65 y) the corresponding figures are 1.968 (95% CI 1.023, 3.786).

Table 6 shows the outcome of the univariable binary logistic regression of various continuous predictors of low and medium-high CVD risk. There is a significant positive correlation of age ($P < 0.001$), total cholesterol ($P = 0.024$), HDL cholesterol ($P < 0.001$), cholesterol/HDL ($P < 0.001$), CRP ($P = 0.042$) and creatinine ($P = 0.042$) with the CVD risk, while HDL and albumin show a significant negative correlation with CVD risks ($P < 0.001$ and $P = 0.003$ respectively). The odds ratio (OR) for age is 1.051 (95% CI 1.030, 1.072, $P < 0.001$), total cholesterol 1.357 (95% CI 1.040, 1.770, $P = 0.024$), HDL 0.020 (95% CI 0.005 0.078, $P < 0.001$), cholesterol/HDL 3.023 (95% CI 2.151, 4.248, $P < 0.001$), CRP 0.010 (95% CI 1.000, 1.019, $P = 0.042$), albumin 0.923 (95% CI 0.876, 0.972, $P = 0.003$), and creatinine 1.018 (95% CI 1.001, 1.035, $P = 0.042$).

Table 5. Univariate logistic regression for categorical predictors of CVD risks.

Categorical predictors of low vs medium and high CVD risk	B	SE	Sig.	Exp(B)	95% CI for Exp(B)	
					Lower	Upper
Sex (Male vs Female)	1.539	0.359	0.000	4.660	2.304	9.426
Age Groups (≥ 65 y vs < 65 y)	0.677	0.334	0.043	1.968	1.023	3.786
Level of SCI (Cervical vs Others)	0.114	0.308	0.712	1.120	0.612	2.051
Cause of SCI (Traumatic vs Non-traumatic)	0.218	0.321	0.498	1.244	0.662	2.336
AIS complete (Complete vs non-complete)	-0.023	0.315	0.941	0.977	0.527	1.812
Pressure ulcers (Yes vs No)	0.928	0.502	0.065	2.530	0.943	6.789
Onset SCI (< 180 days vs ≥ 180 days)	-0.079	0.316	0.802	0.924	0.497	1.716
SNST (Normal vs Malnourished)	0.256	0.428	0.550	1.292	0.554	3.016

B, estimated coefficients; SE, standard error; Sig., P value; Exp(B), odds ratio; 95% CI, 95% confidence interval; AIS, ASIA impairment scale (ASIA, American Spinal Injury Association); CVD, cardiovascular disease; SCI, spinal cord injury; SNST, spinal nutrition screening tool.

Table 6. Univariate logistic regression for continuous predictors of CVD risks.

Continuous predictors for low vs medium and high CVD risk	B	SE	Sig.	Exp(B)	95% CI for EXP(B)	
					Lower	Upper
Age (years)	0.050	0.010	0.000	1.051	1.030	1.072
BMI (kg/m^2)	0.028	0.029	0.343	1.028	0.971	1.089
Onset of SCI (days)	0.000	0.000	0.604	1.000	1.000	1.000
Total cholesterol (mmol/L)	0.305	0.136	0.024	1.357	1.040	1.770
HDL (mmol/L)	-3.896	0.686	0.000	0.020	0.005	0.078
Cholesterol/HDL ratio	1.106	0.174	0.000	3.023	2.151	4.248
Albumin (g/L)	-0.081	0.027	0.003	0.923	0.876	0.972
CRP (mg/L)	0.010	0.005	0.042	1.010	1.000	1.019
Sodium (mmol/L)	-0.004	0.037	0.905	0.996	0.926	1.071
Potassium (mmol/L)	0.176	0.382	0.644	1.193	0.564	2.522
Urea (mmol/L)	0.127	0.084	0.130	1.135	0.963	1.337
Creatinine ($\mu\text{mol}/\text{L}$)	0.018	0.009	0.042	1.018	1.001	1.035
Haematocrit	-2.244	2.811	0.425	0.106	0.000	26.178
Haemoglobin (g/L)	0.000	0.007	0.981	1.000	0.986	1.014
White Cell Count ($10^9/\text{L}$)	0.004	0.015	0.814	1.004	0.975	1.033
vitamin D (nmol/L)	-0.004	0.005	0.373	0.996	0.986	1.005

B, estimated coefficients; SE, standard error; Sig., P value; Exp(B), odds ratio; 95% CI, 95% confidence interval; BMI, body mass index; CRP, C-reactive protein; HDL, high-density lipoprotein cholesterol.

Table 7. Multivariate analysis with only univariate significant predictors excluding variables that were used for CVD risk scores.

Low vs medium and high CVD risk	<i>B</i>	S.E.	Sig.	Exp(<i>B</i>)	95% CI for EXP(<i>B</i>)	
					Lower	Upper
Albumin	−0.092	0.034	0.006	0.912	0.854	0.974
CRP	0.003	0.005	0.490	1.003	0.994	1.013
Creatinine	0.029	0.011	0.006	1.029	1.008	1.051
Constant	1.682	1.166	0.149	5.377	0.547	52.872

B, estimated coefficients; SE, standard error; Sig., *P* value; Exp(*B*), odds ratio; 95% CI, 95% confidence interval; CRP, C-reactive protein.

Since the variables including age, sex, BMI, cholesterol, cholesterol/HDL ratio have already been accounted for the CVD risk score, the final model of the MVA mode only includes the other variables that were shown significant in the univariate analysis, which is presented in Table 7. The MVA shows that serum albumin (OR 0.912, 95% CI 0.854, 0.974, $P = 0.006$) was negatively associated with CVD risks, while creatinine (OR 1.029, 95% CI 1.008, 1.051, $P = 0.006$) was positively associated. There was no significant association between CRPs and the CVD risks.

Discussion

This secondary data analysis found more than half of patients with SCI were at medium or high risk of CVD using the QRISK2 assessment tool on admission to the SCI center. The multivariate analysis showed that serum albumin (negative) and creatinine (positive) concentrations have a significant association with increased CVD risks.

Our results show that 18.9% of patients with SCI had high CVD risk using QRISK2 scoring system (a risk score greater than 20%), which is much higher than 10.5% ($n = 2,012,000$) of the general population aged 40–74 years in the UK using the same scoring tool. This trend aligns with the finding that the prevalence of heart disease was 17.1% in patients with SCI compared to 4.9% in individuals without SCI according to a cross-sectional study on 60,000 Canadian individuals (4). Our results also demonstrated that higher risk of CVDs in patients with SCI was underpinned by nearly half of patients being overweight or obese, around 40% having higher total cholesterol or lower HDL levels, and 28% having high cholesterol/HDL ratios (≥ 6).

Apart from the traditional risk factors, patients have SCI-specific risk factors that contribute to the increased risk of CVDs, which include autonomic dysfunction, chronic inflammation, altered metabolic homeostasis, physical deconditioning, and sarcopenia (13). These factors, particularly the autonomic dysfunction, not only lead to obesity (specifically neurogenic obesity) due to positive energy balance via reduced energy expenditure and basal metabolic rate, and a delayed sense of satiety after eating, but also depress baseline heart rate and metabolism (13) and cause peripheral artery disease (2).

The time since injury was reported to be positively associated with higher risk of CVDs in patients with SCI. A cross-sectional study of 257 patients with long-term SCI living in the Netherlands (14) found that the duration of the spinal injury was positively associated with the increased CVD risk following SCI. However, we did not observe the above results in our study. This might be because our study focused on patients at the admission stage, while the other studies focused on patients with chronic (≥ 10 years) SCI. In addition, the Netherlands study used a different CVD risk assessment tool, the Framingham risk score (FRS) from the current study, QRISK2, and different risk factors are included in the two risk assessment tools (15). However, it was unclear whether the relationships between the time since injury and CVD risk are related to advancing age and/or a direct impact on CVD risk (14). Nevertheless, while the time living with SCI is unmodifiable, it is likely a key indicator of accumulated risk supporting a higher index of CVD suspicion which may cue clinicians to undertake assessment/treatment of modifiable factors.

In a systematic review and meta-analysis (16) investigating the association of the neurological level of SCI and CVD risk factors, 47 studies including 3878 patients with SCI were included. The results show that the serum triglycerides and total cholesterol levels were lower in tetraplegia as compared to paraplegia, indicating that in SCI individuals, the level of injury may be an additional non-modifiable cardiovascular risk factor. However, our results found that patients with cervical SCI had similar risks of CVDs to those of patients with non-cervical SCI ($n = 180$, $P = 0.867$). This might be due to the fact that we used a scoring system (QRISK-2) (8) to estimate the CVD risk by considering multiple factors instead of individual factors.

Our study found that serum CRP concentrations are significantly and positively associated with CVD risk in the univariate regression model, which agrees with other literature that inflammation is one of the important risk factors for CVD in patients with SCI (13, 17). Inflammation is part of a complex physiological response to injury or harmful stimuli induced by mechanical, chemical, or immunological agents in acute and chronic SCI (17). However, the significance disappeared in the MVA model, indicating CRPs are likely correlated with other significant variables included in the multivariate model, rather than being a truly independent predictor.

The serum albumin has traditionally been considered a useful biochemical parameter of nutrition status (17). Our results indicate that patients with higher risk of CVDs had significantly lower serum albumin, however, there was no significant difference in SNST scores among low-, medium- or high-risk groups. Evidence has shown that lower albumin was a consequence of inflammation rather than malnutrition, because inflammation usually exists in both critical illness and chronic illness and would cause hepatic reprioritization of protein synthesis, resulting in lower serum concentrations of albumin and redistribution of serum proteins because of an increase in capillary permeability (18). Based on this, the association between low albumin and high CVD risk in patients with SCI is likely mediated by inflammation rather than nutritional status because no significant difference in nutrition status between low-, medium- and high-risk groups was observed in the current research. This finding is supported by Tong *et al.* (19) who concluded that hypoalbuminemia observed in patients with SCI is a reflection of the prolonged state of inflammation (a known risk for CVDs in patients with SCI), which limits neurological recovery.

A positive association between serum creatinine and CVD risk was observed in the present study, consistent with findings from previous studies. For example, evidence shows that serum creatinine was associated with several traditional cardiovascular risk factors and the 10-year cardiovascular risk in 9978 Chinese hypertensive patients (20), and moderately elevated plasma creatinine was significantly associated with increased risk of myocardial infarction and ischemic heart disease in 10,489 individuals from the Danish general population based on a prospective general population study, the Copenhagen City Heart Study, during 32 years of follow-up (21). The observed relationship between serum creatinine and CVD risk may be explained by renal dysfunction, a recognized risk factor for CVD (22), due to reduced creatinine clearance through the renal glomerulus. Creatinine is therefore widely used as a biomarker of renal function (23). However, it is worth noting that using serum creatinine levels to predict renal functions is questionable in SCI patients (24). Serum creatinine levels depend on both muscle mass and kidney clearance, and they provide an inaccurate measure for kidney function in patients with SCI. This is because patients with SCI have low serum creatinine levels (25) as well as observed in the current study (55% of patients had low serum creatinine) due to having significantly decreased muscle mass (muscle wasting) caused by prolonged disuse (24–26). Consequently, patients with SCI who appear to have “normal” serum creatinine may in fact be at increased risk of renal dysfunction (27). This highlights the need for SCI-specific serum creatinine thresholds, which should be established in future research rather than relying on cut-offs derived from the general population.

It is worth noting that the QRISK2 tool was developed and validated using general-population data and has not been validated to use in patients with SCI who present with distinctive physiological alterations that can undermine the validity of QRISK-2. Autonomic dysfunction, altered metabolism, and profound sarcopenia produce cardiovascular and metabolic profiles that differ substantially from those of the population in which QRISK-2 was derived and validated. Although these factors contribute to the heightened CVD risk in people with SCI, they may also lead to the underestimation of certain risk components of QRISK-2. For example, SCI is associated with accelerated loss of lean body mass and increased fat mass; therefore, a “normal” BMI may correspond to a disproportionately high body fat percentage. This limits the use of BMI as a predictor of CVD risk in SCI, suggesting that body fat percentage and/or waist-to-hip ratio may be more appropriate alternatives. Blood pressure provides another challenge. Patients with lesions at or above T6 often cannot regulate blood pressure and heart rate normally, making conventional measures less reflective of their true hemodynamic status. Additionally, QRISK2 does not account for inflammatory markers, despite inflammation being an independent CVD risk factor and significantly elevated in patients with SCI in the current study and others (13, 17).

Taken together, these limitations indicate that QRISK2 may underestimate CVD risk in individuals with SCI, therefore, fundamentally limits the precision of the study's primary outcome. This underscores the need for a tailored CVD risk-prediction tool designed specifically for the SCI population.

Several other limitations should be acknowledged. First, although the overall sample size was relatively large ($n = 421$), fewer than half of the patients (42.8%, $n = 180$) had complete CVD risk profiles, and other important parameters such as BMI and lipid profiles were also incomplete. The diabetic marker, HbA1c, a recognized CVD risk factor in patients with SCI (1) (Chopra *et al.*, 2018), was available for only 14 patients, indicating that cardiovascular risk assessment was not prioritized or systematically undertaken at admission. This represents a substantial limitation of the dataset. This high volume of missing data suggests potential selection bias in the 180 patients whose complete profiles were used for the risk score calculation and subsequent multivariate analysis. Patients with complete risk profiles may differ clinically from those who did not undergo comprehensive cardiovascular assessment. Second, the cross-sectional design limits the ability to establish causal relationships. Finally, although data were collected within seven days of hospital admission, this timeframe does not necessarily reflect the acute phase of SCI, as some patients may experience long delays, sometimes months or years, before seeking medical care, a pattern reflected in the prolonged onset period observed in this study. This heterogeneity indicates that the metabolic profiles represent a mix of acute physiological stress and established chronic metabolic changes, limiting the interpretation of these findings as indicators of cardiovascular risk at an early stage of SCI.

Conclusion

Our study provides new evidence on cardiovascular disease (CVD) risk among patients with spinal cord injury (SCI) assessed at the time of admission, complementing existing literature that has largely focused on chronic SCI (16). The findings underscore the importance of initiating cardiometabolic risk and metabolic syndrome surveillance during the acute or early admission phase and maintaining annual monitoring thereafter to mitigate CVD risk. Particular attention should be directed toward patients presenting with dyslipidaemia, inflammation, elevated serum creatinine, or low serum albumin. However, because several key CVD risk factors were either uncollected or incompletely recorded in this study (including ethnicity, HbA1c, blood pressure, BMI, and lipid profiles), a more systematic approach or clear clinical guidance is needed to strengthen the assessment of CVD risk in patients with SCI. Meanwhile, the development of tailored CVD risk assessment tools for this unique population is warranted.

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Contributions SW and HD conceptualized the research. HD prepared the manuscript. SPH, HD and SW analyzed the data. SW, IG and AG provided the patient's data. All authors reviewed and agreed with the final version of the manuscript.

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Conflicts of interest Authors have no conflict of interests to declare.

Data availability The study data can be requested and will be available upon receiving approval from the hospital who approved the use of the data in this paper.

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Appendices

Appendix 1. Continuous variables in patients with SCI

Continuous variables	Number recorded	Median (IQR) or Mean (SD)	Range
Age (years)	421	52.0 (38.0, 66.0)	18–90
BMI (kg/m ²)	198	24.0 (21.0, 29.0)	15.0–60.0
Onset of SCI (days)	366	1826.5 (1111.0, 9015.0)	6.0–22135
Cholesterol (mmol/L)	179	4.5 (3.9, 5.5)	2.2–8.5
HDL (mmol/L)	180	1.0 (0.8, 1.2)	0.3–2.5
Cholesterol/HDL ratio	180	4.8 (3.7, 6.0)	0.9–14.3
Albumin (g/L)	324	35.0 (30, 39)	15–48
CRP (mg/L)	347	9.0 (2.7, 27.5)	1–316
Potassium (mmol/L)	352	4.1 (3.9, 4.4)	3.1–5.8
Sodium (mmol/L)	357	139 (136, 140)	114–147
Urea (mmol/L)	357	4.4 (3.4, 5.3)	1.6–55.0
Creatinine (μmol/L)	357	52.0 (39, 65)	16–262
White cell count (10 ⁹ /L)	361	9.3 (10.4)	1.5–145.0
Hemoglobin (g/L)	361	127.3 (20.2)	72–226
Hematocrit	362	0.39 (0.05)	0.22–0.54
25(OH)D (nmol/L)	197	43 (25.5, 70.6)	20–226

Data were presented as mean (SD) for normally distributed data or media (IQR) for non-normally distributed data. CRP, C-reactive protein; HDL, high-density lipoprotein; SCI, spinal cord injury; 25(OH)D, 25-hydroxy vitamin D.

Appendix 2. Criteria for categorizing the continuous parameters

Parameters	Categories	Recorded % (n)
BMI (kg/m ²)	Total number	198
	Underweight <18.9	6.1% (12)
	Normal weight 18.9–24.9	48.5% (93)
	Overweight/obesity ≥ 25.0	48.5% (93)
Total cholesterol (mmol/L)	Total number	179
	Normal < 5 mmol/L	60.0% (107)
	High ≥ 5 mmol/L	40.0% (72)
HDL cholesterol (mmol/L)	Total number	180
	Low (M < 1.2, F < 1.0)	57.2% (103)
	High (M ≥ 1.2, F ≥ 1.0)	42.8% (77)
Cholesterol/HDL ratio	Total number	180
	Normal (<6)	72.2% (130)
	High (≥6)	27.8% (50)
Potassium (mmol/L)	Total number	352
	<3.5	2.6% (9)
	3.5–5.0 (normal)	97.2% (342)
	>5.0	0.2% (1)
Urea (mmol/L)	Total number	357
	<2.5	7.6% (27)
	2.5–7.8 (normal)	85.7% (306)
	>7.8	6.7% (24)
Creatinine (μmol/L)	Total number	357
	<45 (female)	55.2% (197)
	<59 (male)	
	45–84 (female) (normal)	42.6 (152)
	59–104 (male) (normal)	
	> 84 (female)	2.2% (8)
	> 104 (male)	
Sodium (mmol/L)	Total number	357
	<135	23.2% (83)
	135–145 (normal)	76.2% (272)
	>145	0.6% (2)
White cell count (10 ⁹ /L)	Total number	361
	<4.5 × 10 ⁹ /L	2.8% (10)
	4.5–11.0 × 10 ⁹ /L (normal)	81.2% (293)
	>11.0 × 10 ⁹ /L	16.0% (58)
Hemoglobin (g/L)	Total number	361
	<115 (female)	42.3% (153)
	<130 (male)	
	115–165 (female) (normal)	57.1% (206)
	130–180 (male) (normal)	
	>165 (female)	0.6% (2)
	>180 (male)	
Hematocrit	Total number	361
	<0.37 (female)	48.8% (176)
	<0.40 (male)	
	0.37–0.47 (female) (normal)	51.2% (185)
	0.40–0.54 (male) (normal)	
	>0.47 (female)	0
	>0.54 (male)	
Albumin (g/L)	Total number	324
	<35	46.0% (149)
	35–55 (normal)	54.0% (175)
	>55	0
CRP (mg/L)	Total number	347
	<10 (normal)	52.2% (181)
	≥10	47.8% (166)
Serum 25(OH)D (nmol/L)	Total number	197
	<25 (deficiency)	22.8% (47)
	25–50 (insufficiency)	33.5% (64)
	>50 (sufficiency)	43.7% (86)

BMI, body mass index; CRP, C-reactive protein; HDL, high-density lipoprotein cholesterol, 25(OH)D, 25-hydroxy vitamin D.