

Behavioral and psychosocial correlates of multisite musculoskeletal symptoms in university students: green-space use, physical activity, and perceived stress

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ABSTRACT

Aims: This study examined behavioral, psychosocial, and environmental correlates of recent multisite musculoskeletal symptom burden among university students, with particular attention to green-space access and use, physical activity, and perceived stress.

Methods: This cross-sectional study included 619 students aged 18–30 years at Selçuk University in Konya, Türkiye. Data were collected in March–April 2026 using an anonymous online questionnaire. The primary outcome was the number of anatomical regions with symptoms during the previous 4 weeks. Perceived green-space access was assessed using a four-item composite, and recent green-space use was measured as the number of visit days during the previous 7 days. Direct associations were evaluated using negative binomial regression, with zero-inflated negative binomial models as sensitivity analyses. Exploratory pathway-oriented analyses estimated indirect statistical associations through physical activity and perceived stress.

Results: Overall, 353 students (57.0%) reported at least one 4-week musculoskeletal symptom. The neck (34.6%), low back (24.7%), shoulders (23.7%), and upper back (23.4%) were the most frequently affected regions. Neither perceived green-space access nor visit frequency was directly associated with symptom burden. Green-space visit frequency was positively associated with log-transformed total physical activity ($\beta=0.296$; $p<0.001$). Log-transformed physical activity (incidence rate ratio (IRR)=1.11; $p=0.002$) and perceived stress (IRR=1.05; $p<0.001$) were positively associated with symptom burden. A positive indirect statistical association through physical activity was observed (estimate=0.0306; 95% confidence interval (CI), 0.0114–0.0538; $p<0.001$), whereas the indirect association through perceived stress was not significant.

Conclusion: Multisite musculoskeletal symptom burden was common among university students. Green-space access and visit frequency were not directly associated with symptom burden, whereas physical activity and perceived stress showed positive cross-sectional associations. Given the cross-sectional design, these findings do not establish causal relationships or the direction of the observed associations. Student musculoskeletal health assessments should therefore consider activity context and psychosocial factors rather than assume a direct protective effect of green-space access or use.

Keywords: Young adult, pain, environment, cross-sectional studies, health behavior

INTRODUCTION

Musculoskeletal conditions are major contributors to pain, disability, functional limitation, and reduced participation across the life course.¹ University students are an important population for early preventive assessment because prolonged sitting, intensive screen use, study-related postural demands, irregular physical activity, poor sleep, and academic stress may contribute to musculoskeletal symptoms.^{2–4} These symptoms commonly involve the neck, low back, shoulders, and other anatomical sites.^{3,4} Environmental and contextual determinants are also relevant.⁵ Study, living, and transportation environments may influence activity opportunities, sedentary time, psychological restoration, and exposure to postural or mechanical strain.^{6–8} Such factors frequently coexist in university life.^{4,5,8}

Green spaces, including parks, gardens, and campus green areas, may support walking, recreation, social participation, and psychological recovery.^{7,9} However, their relationship with musculoskeletal outcomes is less established than their association with general health and well-being.⁷ Musculoskeletal implications may depend on whether visits involve sitting, walking, vigorous exercise, sport, uneven terrain, or repeated mechanical loading.⁸ Physical activity has a complex relationship with musculoskeletal symptoms.^{10,11} Regular aerobic and muscle-strengthening activities are recommended for health and musculoskeletal function.¹² Observational evidence indicates that associations between physical activity and musculoskeletal symptoms may vary according to activity level, domain, and loading context.^{10,11}

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Physical activity may therefore provide preventive or rehabilitative benefits but may contribute to muscular pain when excessive, repetitive, or poorly matched to recovery capacity.¹¹ Measuring green-space use only as visit frequency cannot capture differences in activity type, terrain, intensity, and recovery context.^{13,14}

Psychosocial stress is another correlate of multisite musculoskeletal symptoms.¹⁵⁻¹⁷ Stress, non-restorative sleep, and physical inactivity may increase later chronic pain risk, while perceived stress has been associated with musculoskeletal pain among students.^{15,16} Stress and pain may reinforce each other through physiological, cognitive, behavioral, and social mechanisms, with sleep disturbance further influencing pain sensitivity and recovery.^{17,18} Nature exposure may support stress reduction, mental health, and psychological restoration.^{7,19,20} However, the potential involvement of perceived stress in associations between green-space exposure and musculoskeletal symptoms remains unclear.^{7,21} Green-space exposure is also multidimensional.^{13,21} Perceived access reflects whether nearby spaces are considered available, reachable, safe, and usable, whereas recent use reflects behavioral engagement.²² These dimensions may represent environmental opportunity and actual green-space-related behavior, respectively.^{13,22} They should therefore be distinguished when examining musculoskeletal symptom burden.^{13,21}

Limited evidence has examined perceived green-space access and recent use together with physical activity and perceived stress in relation to multisite musculoskeletal symptoms among university students. This study therefore aimed to examine behavioral, psychosocial, and environmental correlates of 4-week multisite musculoskeletal symptom burden, with particular attention to perceived green-space access, recent green-space use, physical activity, and perceived stress. Secondary objectives were to describe the regional distribution of symptoms, explore indirect statistical associations through physical activity and perceived stress, and evaluate associations after adjustment for relevant demographic and lifestyle-related factors.

METHODS

Ethics

The study complied with the Declaration of Helsinki and was approved by the Selçuk University Faculty of Health Sciences Non-interventional Clinical Researches Ethics Committee (Date: 04.02.2026, Decision No: 2026/89). All participants provided electronic informed consent. Participation was voluntary and anonymous.

Study Design and Setting

This cross-sectional observational study was conducted among undergraduate and associate-degree students at Selçuk University in Konya, Türkiye. Data were collected between 20 March and 20 April 2026 using a self-administered online questionnaire prepared in Google Forms. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.²³

Participants and Procedure

Students were recruited through voluntary convenience sampling, with the survey link distributed via student WhatsApp groups used for academic communication. The number of students who received or opened the invitation was not recorded; therefore, a formal response rate could not be calculated. No academic credit, financial payment, or other incentive was provided.

Eligible participants were actively enrolled undergraduate or associate-degree students aged 18–30 years who provided electronic informed consent. Students were excluded if they reported rheumatic or inflammatory disease, fibromyalgia, major trauma or orthopedic surgery, neurological disorders, or chronic systemic diseases with substantial musculoskeletal involvement. These conditions were self-reported and not verified through medical records.

Before accessing the questionnaire, participants received information about the study purpose, voluntary participation, anonymity, and absence of incentives. They proceeded only after providing electronic consent. No names, student numbers, telephone numbers, institutional email addresses, or other direct identifiers were collected. All questionnaire items were mandatory.

Sample Size

The minimum sample size was calculated using the single-population proportion formula. A conservative expected musculoskeletal symptom prevalence of 50% was selected because it maximizes the required sample when prevalence is uncertain.^{24,25} At a 95% confidence level and 5% absolute precision, 385 participants were required. Allowing for 20% potentially unusable records increased the target to 482. This calculation was intended to provide adequate precision for prevalence estimation rather than to detect prespecified regression or indirect-association effect sizes; the latter analyses were therefore considered exploratory.

Measures

Sociodemographic and lifestyle variables: Recorded variables included age, gender, faculty group, class year, housing type, self-reported height and weight, daily sitting, screen and study time, smoking, regular exercise, and current paid employment. Body-mass index was calculated as weight in kilograms divided by height in meters squared. Faculty programs were grouped as health sciences; social, administrative, legal, and communication sciences; science, engineering, technical, and agricultural fields; arts, design, tourism, and sports; or other. Regular exercise was defined as exercising at least twice weekly.

Green-space access and use: Perceived green-space access was assessed using four study-specific items covering availability within walking distance, ease of access, safety, and everyday usability. Each item was rated from 1, strongly disagree, to 5, strongly agree. The composite score was the mean of the four items, with higher scores indicating more favorable perceived access. Full item wording is provided in **Supplementary Table S1**.

Recent green-space use was measured as the number of days participants visited outdoor natural or semi-natural spaces,

Supplementary Table S1. Study-specific perceived green-space access items

Item no	Dimension assessed	Item wording
1	Availability within walking distance	There is a green space, such as a park or garden, within walking distance of where I live, including my home or dormitory.
2	Ease of access	It is easy for me to reach green spaces.
3	Perceived safety	Green spaces are sufficiently safe for use.
4	Everyday accessibility	Green spaces in the area where I live are accessible in my daily life.

Notes: Items were translated from Turkish and rated from 1 (strongly disagree) to 5 (strongly agree). The composite was calculated as their mean; higher scores indicate more favorable access. Cronbach's α was 0.930.

including parks, gardens, and campus green areas, during the previous 7 days. The primary environmental exposures were perceived access and visit days. Additional descriptive questions addressed visit duration, approximate distance, and active and passive use days.

Musculoskeletal symptoms: Musculoskeletal symptoms were assessed using the Turkish Extended Nordic Musculoskeletal Questionnaire, which records pain or discomfort in the neck, shoulders, upper back, elbows, wrists/hands, low back, hips/thighs, knees, and ankles/feet.²⁶ Symptoms were recorded for the previous 12 months and 4 weeks. Multisite symptom counts were calculated by summing symptomatic regions for each period. The primary outcome was the number of symptomatic regions during the previous 4 weeks; regional prevalence and the presence of any 4-week symptom were secondary descriptive outcomes.

Perceived stress: Perceived stress was assessed using the 10-item Perceived Stress Scale (PSS-10).²⁷ The Turkish version has demonstrated acceptable validity and reliability.²⁸ Items are scored from 0, never, to 4, very often; four positively worded items are reverse-coded. Total scores range from 0 to 40, with higher scores indicating greater perceived stress.

Physical activity and sitting time: Physical activity was assessed using the International Physical Activity Questionnaire–Short Form, which has demonstrated acceptable validity and reliability in Turkish populations.²⁹ Participants reported vigorous and moderate activity and walking during the previous 7 days. Total physical activity was calculated in MET-min/week using standard coefficients and scoring criteria.³⁰ Sitting time was recorded separately and was not included in the total physical activity score.

Data management and quality control: Responses were screened for eligibility, out-of-range values, internal inconsistencies, implausible anthropometric or physical activity values, and exact duplicate response patterns. Scores were calculated according to the specified instrument rules. Exact duplicate response patterns were removed. Because all items were mandatory, the final dataset contained no item-level missing data.

Statistical Analysis

Analyses were performed using R version 4.5.3. Data were summarized as mean and standard deviation, median and interquartile range, or number and percentage, as appropriate. The internal consistency of the perceived green-space access composite was evaluated using Cronbach's alpha.

Because the primary outcome—the 4-week symptomatic-region count—was overdispersed, negative binomial regression was used. Perceived green-space access and visit frequency were examined in separate crude and adjusted models, with incidence rate ratios and 95% confidence intervals reported. Adjusted models included age, gender, body-mass index, faculty group, class year, housing type, daily screen and study time, smoking, and current paid employment. Covariates were selected a priori based on their relevance to the exposures, intermediate variables, or outcome. Multicollinearity was assessed using variance inflation factors.

Model evaluation included overdispersion, Akaike information criterion, and simulation-based residual diagnostics. Because 43.0% of participants reported no symptomatic region, zero-inflated negative binomial models were examined as sensitivity analyses. Although these models yielded lower AIC values, simulation-based diagnostics indicated no problematic residual dispersion or zero inflation in the negative binomial models, and substantive conclusions were unchanged. Negative binomial regression was therefore retained as the more parsimonious primary model.

Exploratory pathway-oriented analyses evaluated indirect statistical associations through physical activity and perceived stress. Total physical activity was transformed as $\ln(\text{MET-min/week}+1)$, and indirect associations were estimated using 5,000 bootstrap resamples. An additional exploratory negative binomial model simultaneously examined walking, moderate-intensity, and vigorous-intensity physical activity, each transformed as $\ln(\text{MET-min/week}+1)$, with adjustment for green-space visit frequency and the prespecified covariates. Analyses were restricted to participants reporting female or male gender because other responses were too few for stable estimation. Green-space visits and physical activity referred to the previous 7 days, whereas musculoskeletal symptoms referred to the previous 4 weeks. Because these recall periods did not fully overlap, some reported symptoms may have preceded the measured exposures. Consequently, temporal ordering could not be established, and the exploratory indirect statistical associations were not interpreted as evidence of causal mediation. All tests were two-sided, with $p < 0.05$ considered statistically significant.

RESULTS

Participant Flow and Sample Characteristics

A total of 698 submitted records were screened. Of these, 78 records were excluded based on the predefined eligibility criteria: 76 participants reported at least one exclusionary clinical condition, and three were outside the eligible age range of 18–30 years, with one participant meeting both exclusion criteria. Consequently, 620 records remained eligible. One record with an exact duplicate response pattern across questionnaire items was subsequently removed, yielding a final analytic sample of 619 students.

The sample was predominantly female and mainly comprised students from health sciences programs. Perceived green-space access was generally high, whereas more than one-third of participants were classified as physically inactive according to IPAQ categories. The four perceived green-space

access items showed high internal consistency (Cronbach's $\alpha=0.930$). The median weekly physical activity was 495 MET-min/week (IQR: 247.5-924) for walking, 4 MET-min/week (IQR: 0-240) for moderate-intensity activity, and 0 MET-min/week (IQR: 0-320) for vigorous-intensity activity. Participant characteristics are summarized in **Table 1**. Regarding daily lifestyle characteristics, the most frequently reported screen time was 5-7 hours/day (49.8%, $n=308$), study time was 1-2 hours/day (46.0%, $n=285$), and sitting time was 4-6 hours/day (42.6%, $n=264$).

Table 1. Participant characteristics, green-space variables, physical activity, perceived stress, and musculoskeletal symptom burden

Characteristic	Value
Final analytic sample, n	619
Age, years, mean $\pm$ SD	20.71 $\pm$ 2.01
Height, cm, mean $\pm$ SD	167.23 $\pm$ 8.80
Weight, kg, mean $\pm$ SD	63.96 $\pm$ 13.97
BMI, kg/m ² , mean $\pm$ SD	22.73 $\pm$ 3.72
Perceived green-space access, mean $\pm$ SD	3.85 $\pm$ 1.10
Green-space visit days in previous 7 days, median (IQR)	3.00 (2.00–4.00)
PSS-10 total score, mean $\pm$ SD	21.49 $\pm$ 5.88
IPAQ total physical activity, MET-min/week, median (IQR)	822.0 (396.0–1642.5)
4-week musculoskeletal region count, mean $\pm$ SD	1.39 $\pm$ 1.67
12-month musculoskeletal region count, mean $\pm$ SD	1.51 $\pm$ 1.72
Female, n (%)	472 (76.3)
Male, n (%)	139 (22.5)
Prefer not to say, n (%)	8 (1.3)
Health sciences, n (%)	451 (72.9)
Social/administrative/legal/communication sciences, n (%)	81 (13.1)
Science/engineering/technical/agricultural fields, n (%)	36 (5.8)
Arts/design/tourism/sports, n (%)	38 (6.1)
Other faculty/program group, n (%)	13 (2.1)
Dormitory housing, n (%)	331 (53.5)
Shared student house, n (%)	16 (2.6)
Living alone, n (%)	20 (3.2)
With family, n (%)	252 (40.7)
Smoking, yes, n (%)	159 (25.7)
Regular exercise, yes, n (%)	194 (31.3)
Current paid employment, yes, n (%)	98 (15.8)
IPAQ inactive, n (%)	234 (37.8)
IPAQ minimally active, n (%)	321 (51.9)
IPAQ very active, n (%)	64 (10.3)
Any 4-week musculoskeletal symptom, n (%)	353 (57.0)
Cronbach's alpha for perceived green-space access items	0.930

Abbreviations: SD: Standard deviation, BMI: Body-mass index, IPAQ: International Physical Activity Questionnaire, IQR: Interquartile range, MET: Metabolic equivalent of task, PSS-10: 10-item Perceived Stress Scale, Min: Minute

Musculoskeletal Symptom Burden and Regional Distribution

More than half of the participants reported at least one musculoskeletal symptom region during the previous 4

weeks. The distribution of the 4-week musculoskeletal region count was overdispersed, supporting the use of count models that allow for overdispersion. The most frequently reported 4-week symptom regions were the neck (34.6%), low back (24.7%), shoulders (23.7%), and upper back (23.4%). The corresponding 12-month prevalence values were 38.4% for the neck, 27.8% for the low back, 25.0% for the shoulders, and 23.9% for the upper back (**Figure 1**). Detailed regional prevalence estimates for all anatomical regions are presented in **Supplementary Table S2**.

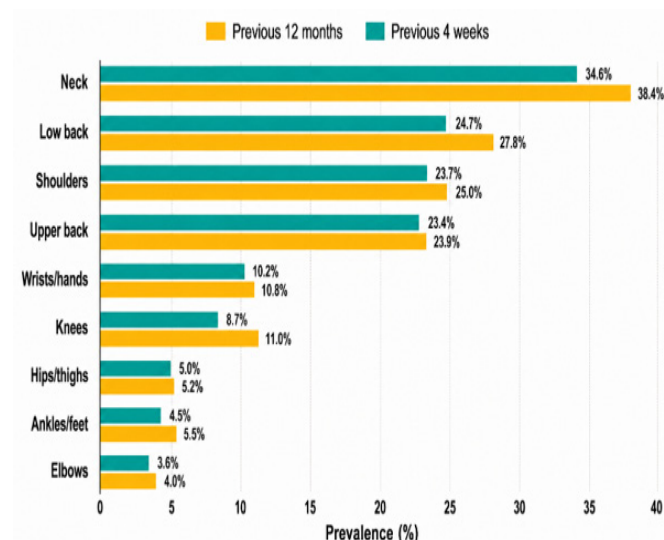


Figure 1. Regional prevalence of musculoskeletal symptoms during the previous 12 months and previous 4 weeks ($n=619$).

Supplementary Table S2. Regional prevalence of musculoskeletal symptoms during the previous 12 months and previous 4 weeks

Region	12-month symptoms, n (%)	4-week symptoms, n (%)
Neck	238 (38.4)	214 (34.6)
Low back	172 (27.8)	153 (24.7)
Shoulders	155 (25.0)	147 (23.7)
Upper back	148 (23.9)	145 (23.4)
Wrists/hands	67 (10.8)	63 (10.2)
Knees	68 (11.0)	54 (8.7)
Hips/thighs	32 (5.2)	31 (5.0)
Ankles/feet	34 (5.5)	28 (4.5)
Elbows	25 (4.0)	22 (3.6)

Notes: Percentages are based on the final analytic sample ($n=619$).

Direct Associations with Multisite Musculoskeletal Symptom Burden

Poisson models showed evidence of overdispersion, and negative binomial models were therefore used as the primary models. Multicollinearity diagnostics did not indicate problematic collinearity.

In crude and adjusted negative binomial models, neither perceived green-space access nor green-space visit frequency was significantly associated with 4-week multisite musculoskeletal symptom burden. Because 43.0% of participants had no symptomatic region during the previous 4 weeks, zero-inflated negative binomial models were additionally examined as sensitivity analyses. These

models did not change the substantive conclusions. The direct association estimates are presented in **Table 2**. Model diagnostics and zero-inflated negative binomial sensitivity analyses are presented in **Supplementary Table S3**.

Table 2. Direct associations of green-space variables with 4-week multisite musculoskeletal symptom burden

Exposure	Model	IRR	95% CI	p value
Perceived green-space access	Crude negative binomial	1.07	0.971–1.18	0.160
Perceived green-space access	Adjusted negative binomial	1.06	0.964–1.17	0.214
Perceived green-space access	ZINB, count component	1.03	0.943–1.12	0.521
Green-space visit days, previous 7 days	Crude negative binomial	1.03	0.980–1.08	0.259
Green-space visit days, previous 7 days	Adjusted negative binomial	1.02	0.968–1.07	0.520
Green-space visit days, previous 7 days	ZINB, count component	1.03	0.989–1.07	0.157

Notes: Adjusted and ZINB models included the prespecified covariates. Abbreviations: IRR: Incidence rate ratio, CI: Confidence interval, ZINB: Zero-inflated negative binomial

Supplementary Table S3. Diagnostics for adjusted negative binomial models and zero-inflated negative binomial sensitivity analyses

Diagnostic	Perceived green-space access model	Green-space visit frequency model
Outcome mean	1.394	1.394
Outcome variance	2.773	2.773
Variance-to-mean ratio	1.989	1.989
Poisson overdispersion ratio	1.916	1.914
Poisson overdispersion p value	<0.001	<0.001
Poisson AIC	2171.500	2173.240
Negative binomial AIC	2024.696	2025.790
ZINB AIC	2003.054	2001.496
Observed zero counts, n (%)	266 (43.0)	266 (43.0)
Expected zero counts under negative binomial model, n (%)	251.0 (40.6)	251.0 (40.6)
Expected zero counts under ZINB model, n (%)	266.0 (43.0)	267.0 (43.1)
Vuong test, raw p value	0.0145	0.0093
Vuong test, AIC-corrected p value	0.0228	0.0149
Vuong test, BIC-corrected p value	0.0559	0.0377
DHARMA dispersion test p value for negative binomial model	0.164	0.172
DHARMA zero-inflation test p value for negative binomial model	0.242	0.242
DHARMA KS uniformity test p value for negative binomial model	0.174	0.554

Notes: Negative binomial models were retained as primary because residual diagnostics were acceptable and conclusions were unchanged in ZINB analyses. Abbreviations: AIC: Akaike information criterion, ZINB: Zero-inflated negative binomial, BIC: Bayesian information criterion, KS: Kolmogorov-Smirnov

Exploratory Pathway-Oriented Analyses

Exploratory pathway-oriented analyses were conducted among participants reporting female or male gender because the very small number of responses outside these categories led to unstable model estimates. The analytic sample for these models included 611 participants.

Perceived green-space access was not significantly associated with log-transformed total physical activity or perceived

stress. In the corresponding outcome model, perceived green-space access was not significantly associated with musculoskeletal symptom burden, whereas both log-transformed total physical activity and perceived stress were positively associated with symptom burden.

Green-space visit frequency was positively associated with log-transformed total physical activity, but it was not associated with perceived stress. In the outcome model, green-space visit frequency was not directly associated with musculoskeletal symptom burden. However, log-transformed total physical activity and perceived stress were both positively associated with musculoskeletal symptom burden. Bootstrap analyses suggested a positive indirect statistical association between green-space visit frequency and musculoskeletal symptom burden through physical activity, whereas the indirect statistical association through perceived stress was not significant. The pathway-oriented estimates are summarized in **Table 3**, detailed bootstrap direct and indirect statistical association estimates are presented in **Supplementary Table S4**, and the exploratory statistical associations involving green-space visit frequency, physical activity, perceived stress, and musculoskeletal symptom burden are illustrated in **Figure 2**.

In an additional exploratory negative binomial regression model simultaneously examining walking, moderate-intensity, and vigorous-intensity physical activity, walking-related activity was positively associated with musculoskeletal symptom burden (IRR=1.09, 95% CI 1.02-1.16; p=0.008), whereas moderate-intensity (IRR=1.01, 95% CI 0.97-1.05; p=0.605) and vigorous-intensity activity (IRR=0.98, 95% CI 0.94-1.01; p=0.203) were not significantly associated with symptom burden. All three components were entered simultaneously as log-transformed MET-min/week values, with adjustment for the prespecified covariates.

DISCUSSION

This study found that recent multisite musculoskeletal symptom burden was common among university students, with the neck, low back, shoulders, and upper back being the most frequently affected regions. Neither perceived green-space access nor recent visit frequency was directly associated with symptom burden. Green-space visit frequency was positively associated with physical activity, while physical activity and perceived stress were positively associated with symptom burden in the exploratory pathway-oriented models. A positive indirect statistical association through physical activity was also observed; however, the cross-sectional design does not establish temporal ordering, the direction of associations, or causal mediation.

The absence of a direct association between broad green-space indicators and musculoskeletal symptom burden is noteworthy. Green-space exposure has been associated with general health, well-being, physical activity, stress reduction, and psychological restoration.^{7,9,19,20} Musculoskeletal symptoms are also influenced by mechanical loading, posture, sedentary exposure, recovery, sleep, stress, and previous or ongoing pain.^{2-5,8,15-18} Perceived access may therefore be too distal to demonstrate a direct association with symptom burden. Access indicates environmental opportunity but does not determine whether students visit green spaces or whether

Table 3. Exploratory pathway-oriented analyses for 4-week multisite musculoskeletal symptom burden

Exposure	Path or effect	Estimate	95% CI or bootstrap CI	p value
Perceived green-space access	Access → log total physical activity, β	0.108	−0.0262 to 0.243	0.114
Perceived green-space access	Access → PSS-10 total score, β	0.0784	−0.363 to 0.520	0.728
Perceived green-space access model	Perceived green-space access → symptom burden, IRR	1.04	0.944 to 1.14	0.429
Perceived green-space access model	Log total physical activity → symptom burden, IRR	1.10	1.04 to 1.18	0.002
Perceived green-space access model	PSS-10 total score → symptom burden, IRR	1.05	1.03 to 1.07	<0.001
Perceived green-space access	Indirect association through physical activity	0.0106	−0.00213 to 0.0280	0.112
Perceived green-space access	Indirect association through perceived stress	0.00387	−0.0187 to 0.0236	0.759
Green-space visit days	Visit days → log total physical activity, β	0.296	0.230 to 0.363	<0.001
Green-space visit days	Visit days → PSS-10 total score, β	0.0248	−0.207 to 0.256	0.834
Green-space visit frequency model	Green-space visit days → symptom burden, IRR	0.992	0.943 to 1.04	0.760
Green-space visit frequency model	Log total physical activity → symptom burden, IRR	1.11	1.04 to 1.18	0.002
Green-space visit frequency model	PSS-10 total score → symptom burden, IRR	1.05	1.03 to 1.07	<0.001
Green-space visit days	Indirect association through physical activity	0.0306	0.0114 to 0.0538	<0.001
Green-space visit days	Indirect association through perceived stress	0.00123	−0.0126 to 0.0146	0.842
Green-space visit days	Total indirect association	0.0318	0.00693 to 0.0593	0.013

Notes: Analyses included 611 participants and were adjusted for the prespecified covariates. Indirect estimates were calculated on the log-count scale using 5,000 bootstrap resamples and do not indicate causal mediation. Abbreviations: β : Regression coefficient, CI: Confidence interval, IRR: Incidence rate ratio, MET: Metabolic equivalent of task, PSS-10: 10-item Perceived Stress Scale

Supplementary Table S4. Bootstrap direct and indirect statistical association estimates

Exposure	Effect	Estimate	95% bootstrap CI	p value
Perceived green-space access	Indirect association through physical activity	0.0106	−0.00213 to 0.0280	0.112
Perceived green-space access	Indirect association through perceived stress	0.00387	−0.0187 to 0.0236	0.759
Perceived green-space access	Total indirect association	0.0144	−0.0129 to 0.0411	0.296
Perceived green-space access	Direct association	0.0380	−0.0533 to 0.149	0.363
Green-space visit days	Indirect association through physical activity	0.0306	0.0114 to 0.0538	0.0004
Green-space visit days	Indirect association through perceived stress	0.00123	−0.0126 to 0.0146	0.842
Green-space visit days	Total indirect association	0.0318	0.00693 to 0.0593	0.0132
Green-space visit days	Direct association	−0.00784	−0.0570 to 0.0423	0.745

Notes: Analyses included 611 participants and were adjusted for prespecified covariates. Bootstrap estimates are presented on the log-count scale and do not indicate causal mediation. Abbreviations: CI: Confidence interval

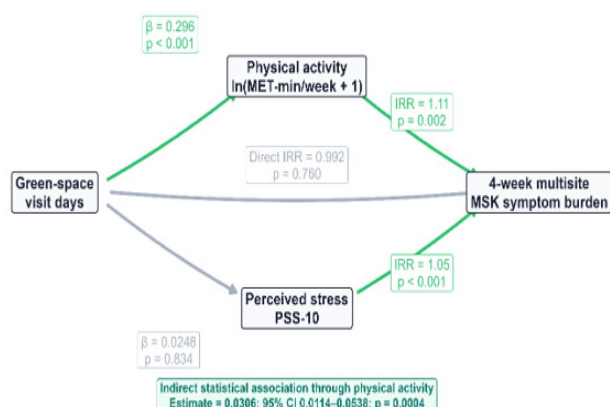


Figure 2. Pathways linking green-space visits to symptom burden. Green and gray lines indicate significant and nonsignificant associations, respectively. IRR: Incidence rate ratio, MET: Metabolic equivalent of task, MSK: Musculoskeletal, PSS-10: 10-item Perceived Stress Scale, Min: Minute

visits involve sitting, walking, exercise, social activity, or recovery.

Green-space exposure is multidimensional. Perceived access, objective proximity, safety, quality, aesthetics, restorative potential, and actual use represent related but distinct dimensions.^{13,21} In this study, perceived access reflected the subjective availability and usability of nearby green

spaces, whereas visit frequency reflected recent behavioral engagement. Frequent visits may involve diverse activities ranging from quiet sitting to active transportation, vigorous exercise, or sport. This heterogeneity may partly explain why perceived access and visit frequency were not directly associated with symptom burden.

The positive association between green-space visit frequency and physical activity supports the view that green spaces may enable movement, recreation, and active transportation.^{6,7,9,13,14} Nevertheless, the musculoskeletal implications of activity depend on its type, intensity, duration, mechanical demands, and recovery context. Regular physical activity is beneficial for health and musculoskeletal function.¹² However, associations between physical activity and pain may vary according to activity level, domain, and loading context.^{10,11} The present findings should therefore not be interpreted as indicating that physical activity or green-space use is harmful. One possible explanation is that students who visit green spaces more frequently are also more active and consequently experience greater movement- or load-related exposure. Reverse directionality is also possible because students with symptoms may use green spaces for walking, coping, or recovery. Furthermore, the observed positive association may differ according to activity type and intensity. Vigorous exercise, sports participation, repetitive mechanical

loading, and sports-related injuries may contribute to musculoskeletal symptom reporting in some students. These explanations remain speculative because detailed sports participation, injury history, and activity context were not assessed. In the additional exploratory analysis, the positive association was observed for walking-related activity but not for moderate- or vigorous-intensity activity. This finding may reflect differences in activity patterns or symptom-related changes in walking behavior rather than a harmful effect of walking. Given the cross-sectional design and differing recall periods, this association should be interpreted cautiously.

Interpretation is further limited by the IPAQ-SF, which estimates overall activity volume but does not distinguish leisure walking, structured exercise, sport, commuting, muscle-strengthening activity, terrain-related loading, or activity performed despite pain. Moderate and appropriately progressed activity may support function, whereas abrupt increases, repetitive loading, inadequate recovery, or activity performed in the presence of symptoms may contribute to symptom reporting.^{10,11} More detailed assessment of activity context is therefore needed.

Perceived stress was positively associated with multisite symptom burden, consistent with evidence that stress and pain may reinforce each other through physiological, cognitive, behavioral, and social mechanisms.^{15,17} Increased muscle tension, altered pain sensitivity, sleep disturbance, reduced recovery, and greater attention to bodily discomfort may contribute to this relationship.^{15,17,18} Green-space exposure has been associated with restorative and stress-related benefits.^{7,19,20} However, perceived stress did not show a significant indirect statistical association between green-space variables and symptom burden. Simple access and visit-frequency measures may not capture whether a green-space experience is safe, quiet, comfortable, restorative, or socially supportive.^{13,21,22}

The regional pattern was consistent with previous university-student studies identifying the neck, low back, upper back, and shoulders as frequent symptom sites.^{2-5,16} Research involving university students in Türkiye has also addressed internet-based education and its implications for student health, as well as sleep quality and musculoskeletal pain.^{31,32} A recent study by Güler et al.³³ identified associations between digital burnout, academic procrastination, and neck and low back pain among university students. Similarly, Bayraktar and Mohammadzadeh³⁴ reported associations of screen time, sitting time, and physical activity with multisite musculoskeletal pain, supporting the importance of considering multiple behavioral factors in this population. These symptoms should be considered within a multifactorial framework that includes behavioral, ergonomic, psychosocial, and recovery-related factors. Recent research comparing academic and examination periods has also highlighted the relevance of physical activity, sleep quality, and musculoskeletal discomfort among university students, further supporting the need to consider academic and lifestyle contexts when interpreting symptom-related associations.³⁵ The present findings do not demonstrate that specific modifications to campus green spaces would reduce musculoskeletal symptoms. Instead, they support further investigation of how green-space quality, activity

type, sedentary accumulation, ergonomics, recovery opportunities, and psychosocial context jointly relate to student musculoskeletal health.

The study addressed an underexplored topic, evaluated multisite rather than single-region symptoms, distinguished perceived green-space access from recent use, and applied established measures of musculoskeletal symptoms, perceived stress, and physical activity. The use of negative binomial regression with simulation-based diagnostics and zero-inflated sensitivity analyses also strengthened the analytical approach.

Future research should use longitudinal, multi-campus designs combining objective and subjective green-space measures with device-based physical activity, sedentary-time, and posture assessments. Detailed measures of green-space quality, restorative experience, activity type, symptom severity, disability, sleep, ergonomics, and recovery may clarify when green-space use is beneficial, neutral, or associated with greater symptom reporting.

Limitations

Several limitations should be considered. The cross-sectional design prevents conclusions about temporality, directionality, or causal mediation. An additional methodological limitation arises from the differing recall periods of the principal variables. Green-space visits and physical activity were assessed over the previous 7 days, whereas musculoskeletal symptoms were assessed over the previous 4 weeks. Thus, symptoms reported during the first 3 weeks of the symptom recall period may have occurred before the measured green-space visits and physical activity. This temporal mismatch limits the interpretation of the observed associations, particularly the exploratory indirect statistical associations, which should not be regarded as evidence of causal pathways. Convenience sampling from a single university, the predominance of female students (76.3%) and health sciences students (72.9%), and the unavailable response rate limit the generalizability of the findings, particularly to students from other universities, academic disciplines, and demographic backgrounds. Participants were recruited through student WhatsApp groups, which may have introduced selection bias. Eligibility and exclusion criteria were based on self-reported information without verification through medical records, potentially leading to misclassification of participants' eligibility. Musculoskeletal symptoms were also self-reported and not clinically verified. Pain intensity, disability, treatment seeking, and detailed symptom duration were not assessed. The four-item perceived green-space access measure was developed specifically for this study and has not undergone comprehensive psychometric validation. Although the composite demonstrated high internal consistency (Cronbach's $\alpha=0.930$), its construct validity, test-retest reliability, and measurement properties across different student populations have not been established. Accordingly, the findings involving perceived green-space access should be interpreted cautiously. The quality and specific characteristics of green spaces, including maintenance, aesthetics, vegetation, and available recreational facilities, were not systematically assessed. Furthermore, the purpose of visits, objective environmental exposure, and activity context were

not comprehensively measured, limiting the interpretation of green-space-related associations. The sample-size calculation was designed for prevalence estimation rather than prespecified regression or indirect-association effect sizes. Residual confounding from ergonomics, sleep, academic workload, mental health, previous injury, and seasonal conditions also remains possible.

CONCLUSION

Recent multisite musculoskeletal symptom burden was common among university students, particularly in the neck, low back, shoulders, and upper back. Perceived green-space access and recent visit frequency were not directly associated with symptom burden. Green-space visit frequency was positively associated with physical activity, while physical activity and perceived stress were positively associated with symptom burden in exploratory pathway-oriented models. Because of the cross-sectional design, the observed associations cannot establish causality or temporal direction, and the indirect statistical association through physical activity should not be interpreted as evidence of causal mediation. Longitudinal studies using more detailed measures of green-space use, activity context, ergonomics, recovery, and symptom severity are needed to clarify these relationships.

ETHICAL DECLARATIONS

Ethics Committee Approval

Approved by the Selçuk University Faculty of Health Sciences Non-interventional Clinical Researches Ethics Committee (Date: 04.02.2026, Decision No: 2026/89).

Informed Consent

Electronic informed consent was obtained from all participants through Google Forms before they accessed the anonymous online questionnaire. Participants were informed about the study aims, procedures, and voluntary nature of participation. Only participants who provided electronic consent proceeded to the questionnaire. No handwritten signatures were obtained.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

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Author Contributions

Concept: MAG, MBG; Design: MAG, MBG; Control: MAG; Resources: MAG, MBG; Data Collection and/or Processing: MAG, MBG; Analysis and/or Interpretation: MAG, MBG; Literature Review: MAG, MBG; Writing the Article: MAG, MBG; Critical Review: MAG, MBG; Final Approval of the Manuscript: MAG, MBG; Visualization: MAG.

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