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Exploring the association between campus environment of higher education and student health: A systematic review of findings and measures

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Abstract

Numerous studies have investigated the relationship between the neighborhood environments and residents' health. However, other important settings, such as university campuses, have received little attention. This paper conducted a systematic review and synthesized existing empirical works examining the association between the university/college campuses built and natural environments and students' health. Following the PRISMA guidelines, we searched nine databases using keywords related to higher-education campuses and health-related outcomes. A total of 19 articles were identified, including fifteen cross-sectional studies, three experimental studies, and one longitudinal study. The majority of the studies were conducted in Asian countries and published in the past five years. The findings indicate that active transportation infrastructure, such as increased road intersections and better walkability, were found to be positively associated with students' physical activity. The natural environments, including perceived naturalness, blue space, and greenness was shown to support student's mental health and quality of life. Specifically, blue space was found to be the most preferred place for mental restoration, and scattered trees demonstrated a supportive effect in reducing depression symptoms. Even just viewing virtual trees had a restorative effect and feel less anxiety. Additionally, during the summer, tree shadows were identified as the most important factors for enhancing thermal comfort. This review emphasizes the crucial role of campus environments in promoting college students' health. Future longitudinal studies and investigations using multiple campuses would provide a more comprehensive understanding of this relationship. Such endeavors can contribute

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Yizhen Ding: Conceptualization, Methodology, Data extraction, Writing – original draft, Visualization. Chanam Lee: Supervision, Writing – review & editing. Xi Chen: Data collection. Yang Song: Writing – review & editing. Galen Newman: Writing – review & editing. Ryunjung Lee: Writing – review & editing. Sungmin Lee: Writing – review & editing. Wonmin Sohn: Writing – review & editing. Dongying Li: Writing – review & editing.

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to the development of evidence-based strategies for designing and planning healthy campus environments that optimize students' well-being.

Keywords

Built environments; Campus environments; Literature review; Natural environments; Students health

1. Introduction

1.1. Colleges and universities students' health

Entering colleges and universities can be a challenging transitional period for students. For many, it is their first time away from home and they face numerous challenges as they adjust to independent lifestyles, including academic, social, and financial pressures (Worsley et al., 2021). As such, they are more susceptible to negative behaviors and at higher risk of developing physical and mental health problems (Dyson and Renk, 2006). Although many campuses offer various resources, such as recreational centers and mental health counseling centers, their utilization rates among students remain insufficient. According to the NIRSA/NASPA Consortium Nationwide Survey, a mere 39% of surveyed students reported using the recreational center at least three times per week (Forrester, 2014). Similarly, the University of California, Berkeley found that only approximately 16% of enrolled students sought assistance from the campus counseling center (Prince, 2015). Thus, without more accessible resources and support systems, many students are at risk of physical and mental health issues.

To mitigate the potential influence of COVID-19 on students' health, we looked at 2019 and 2022 National College Health Assessment (NCHA), both of which revealed concerning trends. The two reports found that a significant portion of college students do not engage in sufficient physical activity, with less than 50% meeting the recommended guidelines for moderate or vigorous exercise (ACHA, 2019, ACHA, 2022). Furthermore, in 2019, only 32.4% of respondents reported experiencing no or low psychological distress, and this figure declined to 27.6% in 2022. More concerning, in 2019, over a third of students reported being diagnosed with at least one mental health issue, such as ADHD, anxiety, or depression. However, in 2022, this percentage surged by 10%, with 43% of college students being diagnosed with at least one mental health disorder (ACHA, 2019, ACHA, 2022). These findings suggest a severe deterioration in mental well-being, potentially exacerbated by the challenges posed by COVID-19, especially among vulnerable population (Browning et al., 2021). They also underscore the need for further research into effective strategies for supporting students' health and well-being.

1.2. Built or natural environments and human health

The idea that the built or natural environments can have a positive effect on health outcomes is widely established (Perdue et al., 2003). Many empirical studies have provided evidence to show the built or natural environments are associated with various health-related outcomes (Hartig et al., 2014). Being in nature has been linked to overall stress reduction

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(Jiang et al., 2014, Jimenez et al., 2021, Ulrich et al., 1991) as well as attention recovery and mental restoration (Kaplan and Kaplan, 1989, Ohly et al., 2016). The built environments also significantly influences people's level of physical activity (McCormack and Shiell, 2011). Furthermore, access to parks and recreational facilities, availability of sidewalks/walking paths and bike lanes, and access to healthy food contribute to health by reducing the risk of obesity, cardiovascular disease, diabetes, and certain types of cancer (An et al., 2019, Murtagh et al., 2010; WHO, 2012).

University campuses are the first environments many young adults encounter after leaving their parents' homes and they often spend a significant portion of their day within these surroundings. Thus, the university environment holds the potential to contribute to the well-being of students. However, although there are known benefits of built or natural environments, the effects of exposure to campus environments on young adult populations are not yet fully understood, especially considering their high health risks (Dzhambov et al., 2018, Gascon et al., 2015, Gascon et al., 2017). It's even more important to understand these connections for college students in the post-pandemic era (Larson et al., 2022).

As of fall 2022, nearly 18 million students were enrolled in U.S. colleges (Causey et al., 2022), making efforts to enhance college students' health an increasingly prevalent topic of discussion among contemporary planners, designers, and policymakers. While university campuses can have a positive impact on students' health and well-being, there is still a lack of research on how campus planning and design specifically support this. Prior research has highlighted the positive effects of time spent in campus green spaces on students' physical, social, and mental well-being (Foellmer et al., 2021, Liprini and Coetzee, 2017, Stepansky et al., 2022). Furthermore, a scoping review of 14 research papers suggests that spending as little as 10 min in natural settings can improve the mental health of college-aged individuals (Meredith et al., 2020). These studies underscore the need for integrating campus environments and students' health.

1.3. Research questions and aims

We aimed to conduct a systematic literature review of the relationship between campus environments and the health-related outcomes of university students. To guide our investigation, we established the following objectives:

1. Summarize and analyze the existing knowledge regarding the relationship between campus environments (built, natural, and virtual) and different dimensions of students' health (physical, physiological, psychological, etc.).
2. Summarize the research methodologies utilized in the study of campus environments-health relationships.
3. Identify significant gaps in current knowledge to guide future research in this field.

These objectives provide a clear roadmap of our study's goals and set the stage for the subsequent presentation of results.

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2. Methods

2.1. Eligibility criteria

Our search and selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, 2009). We selected studies that met the following five criteria: 1) built or natural environmental factors are measured within a university or college campus boundary; 2) outcome variables are health-related; 3) papers are quantitative studies that employed either cross-sectional and longitudinal data analysis methods or experimental designs; 4) study populations are higher-education students; and 5) papers are empirical studies that are peer-reviewed and written in English; 6) papers were published before 2023. We excluded qualitative studies from our review as they lack statistical analysis to conclude the environments' impact on students' health.

2.2. Search strategy

The initial database search was conducted at the end of 2022, and the final query search was performed on June 10th, 2023, to ensure that no papers published before 2023 were overlooked. A total of nine databases were searched, which included MEDLINE, PubMed, APA PsycInfo, ERIC, Environment Complete, CINAHL Complete, GreenFILE, Psychology and Behavioral Sciences Collection, and Urban Studies Abstracts. These databases were chosen based on their extensive collection of environmental and health-related publications relevant to the scope of this review. The keywords used for the search consisted of three parts: (1) colleges and universities campus (e.g. campus* OR universit* OR college* OR education* OR institut* OR school* OR academ*); (2) built or natural environment (e.g. environment* OR "natural environment*" OR "food environment*" OR "nutrition environment*" OR outdoor OR space* OR park* OR natur* OR green*); and (3) health, including overall well-being (e.g. wellness OR wellbeing OR well-being OR quality of life OR QoL), physical (e.g. obesity OR obese OR overweight OR "body weight" OR BMI OR "Body mass index" OR physical), mental (e.g. anxi* OR stress OR ADD OR ADHD OR attention OR disorder OR agoraphobia OR phobias), and behavior health (e.g. suicide OR "life satisfaction" OR "life expectancy" OR fear* OR restorati* OR ruminat* OR affect* OR agress*). The selection of these keywords was based on research questions and collaborative discussions among the authors. A complete list of keywords can be found in Appendix A.

To better facilitate the review process, the online tool Covidence was used, a web-based systematic review allowing multiple reviewers to work simultaneously (Babineau, 2014). The use of Covidence also helped remove duplicated studies based on the same title, year, volume, and author (Covidence, 2023). The remaining non-duplicate studies were screened based on their titles and abstracts. Two researchers (YD and XC) completed the titles and abstract screening process and independently reviewed the initial one-third of the articles to assess the inter-rater reliability of the review results. No inconsistencies were found in the results between the two reviewers, and therefore, the rest of the articles were reviewed by only one reviewer.

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2.3. Data extraction

The data extracted for this review encompassed various elements pertinent to its scope. These included general information about each study, such as the field of publication, publication year, study design, study location, and geographical settings. Additionally, details regarding the study participants were collected, including population, sample size, age range, and gender distribution. The methods employed in the studies, such as the measurement of environmental factors and outcome variables, as well as the statistical analysis conducted, were also documented. The findings of the studies, specifically the associations between environmental factors and health outcomes, were recorded. The limitations, conclusions, and contributions were included to facilitate the analysis of research gaps.

2.4. Quality assessment

The Effective Public Health Practice Project (EPHPP) was used for assessing the quality of selected studies (Thomas et al., 1999). This tool was developed to encompass a variety of research designs, including observational, cross-sectional, pre-post, cohort, and randomized controlled trial designs (Thomas et al., 2004), and has been used in a similar systematic review study assessing physical and psychological health outcomes of green space related exercise in children and adolescents (Mnich et al., 2019).

The EPHPP tool has six equally weighted categories that are combined to generate an overall rating of the study quality, including selection bias, study design, confounders/control variables, blinding, data collection methods, and withdrawals and dropouts (Appendix B). If the article was not an experimental/intervention study, blinding was considered “not applicable (N/A).” The withdrawal and dropout category is still applicable to cross-sectional studies, referring to the percentage of people who joined but did not complete the study. Data collection methods were considered reliable and valid if at least 50% of the measurement instruments used in the study were reported as valid and reliable. Each category received a strong, moderate, or weak rating, which added up to the overall rating of the study as strong (no weak ratings), moderate (one weak rating), or weak (two or more weak ratings) (Thomas et al., 1999).

2.5. Data analysis

Because the campus environments examined in the reviewed studies exhibit significant diversity, we categorized the environmental factors into categories to facilitate the interpretation of the relationship between these environments and associated health outcomes (Table 1). We established four primary categories for campus environments. These categories are 1) Both Built and Natural Environments, which incorporates environmental features representing both built and natural aspects, such as aesthetics and shaded areas; 2) Built Environments, meaning physical environments without nature related features; 3) Natural Environments, encompassing elements or features related to natural environments; and 4) Simulated Environments, the environments measured were derived from simulated methods like photos and virtual reality.

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Within these categories, we further subdivided measurements based on their characteristics: the Built and Natural Environments includes aesthetics, shaded areas (i.e. sky view factor), and different types of spaces involving green, grey, and blue space; the Built Environments involves attributes like the unhealthy food environments, presence of daily activities areas, accessibility to destinations, and active transportation compatibility; the Natural Environments addresses attributes such as naturalness perceptions and vegetation attributes such as aerial image derived vegetation index and vegetation characteristics (e.g. bush scrub, dense tree, and scattered tree); and the Simulated Environments are photo simulations, and virtual reality representations of the campus environments.

Health outcomes are grouped into five categories: Overall Health represents general health, or a combined measure of both mental and physical health, which were merged into a single health variable for analysis; Physiological Response are immediate bodily reactions such as heart rate, blood pressure, and brain wave; Psychological Wellbeing including anxiety, depression and restoration; Physical Health are physical activity levels, walking or biking behaviors, and Body Mass Index (BMI). Lastly, Quality of life (QoL), which refers to individuals' overall well-being and satisfaction with life.

This systematic categorization framework enables a more comprehensive understanding of the complex relationship between the campus environments and health outcomes Table 1. Classification of Environmental Factors and Domains.

3. Results

Out of 23,375 articles initially extracted from nine search databases, Covidence automatically removed 10,659 duplicates; and 12,649 irrelevant records were removed after the titles and abstract screening. The remaining 67 articles were determined eligible for the full-text review. After the full-text review, 48 articles were further excluded because they did not meet the inclusion criteria (e.g., students' preference towards campus environments as outcome, the campus environments are referring to social environments.). Finally, a total of 19 articles were included in the data extraction process (Fig. 1).

3.1. Quality assessment

Each article was independently evaluated by two researchers. In cases of inconsistent assessment results, the two researchers reviewed the paper again and reached a consensus through discussion. The results of the quality assessment are presented in (Appendix C). In summary, ten studies were rated as low quality, eight were moderate, and one was categorized as strong. Poor ratings were typically found in the categories of study design (n = 14) because of the inherent weaknesses of cross-sectional studies, which are common to this body of literature, and make it difficult to understand causal relationships among the study variables. The category of confounders/control variables also received a large number of weak ratings (n = 8). Those weak-rated studies failed to consider control variables adequately or did not report any confounder/control variables. The blinding category did not apply to most of the studies (n = 14) due to the common use of cross-sectional design.

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3.2. Study characteristics

Table 2 shows the summary of the general study characteristics. The results of this review revealed that the research on campus environments and college students' health has gained more attention in the last five years, as 13 (68.43%) out of the reviewed 19 papers were published since 2018 (Fig. 2a). Although those papers were published in a wide variety of journals, the journals' subject areas represented three major fields including environmental science, social science, and medicine (Fig. 2b). As for the study design (Fig. 2c), cross-sectional studies (78.95%) were the most common, followed by experimental studies (15.79%). Only one study used a longitudinal design to assess the impact of the built environments (Sun et al., 2014). The study locations of these publications were distributed globally, but more than half of them (52.6%) were in Asia, predominantly China, with one from Malaysia (Fig. 2d). The United States was the only country in North America represented in the reviewed studies, and it accounted for 31.6% (n = 6) of the total publications. Three papers (15.8%) performed their research in European countries including Germany and Austria. In one article, researchers conducted a cross-continent study in both the United States and Turkey. In terms of the number of campuses covered in the paper, 12 papers (63.16%) used one campus, while five papers (36.84%) involved more than one campus. Only one study, in China, conducted nationwide research including 90 campuses across the country (Yang et al., 2022).

3.3. Assessment of campus environments

Cross-sectional studies employed various measurement methods to assess environmental features, including questionnaires, environmental audits, and objective measures such as normalized difference vegetation index (NDVI) derived from satellite images (Table 3). 10 out of the 19 studies used self-reported questionnaires, three studies used audit tools, and two studies used NDVI to measure the natural environments of campus. The Neighborhood Environment Walkability Scale (NEWS) was the most frequently used validated questionnaire to measure the built or natural environments and was employed in three studies (M. Liu et al., 2022; Peachey and Baller, 2015; Teuber and Sudeck, 2021). Malekinezhad et al. (2020) used the Perceived Sensory Dimension (PSD) to measure campus greenness. Reed and Ainsworth (2007) used the South Carolina Environmental Supports for Physical Activity Questionnaire (SCESPAQ). As for measurement for perceived greenness, Loder's two studies adopted questions from the PHENOTYPE project (Nieuwenhuijsen et al., 2014) (Loder et al., 2020, Loder and van Poppel, 2019). Whereas Gulwadi et al. (2019) and Hipp et al. (2016) used the perceived greenness scale developed by Sugiyama et al. (2008) and (Leslie et al., 2010). Liu's two studies designed and validated a self-rated naturalness scale to measure the naturalness of the campus environments (Q. Liu et al., 2022; Liu et al., 2018). The environmental audit tools were used in three studies to measure the walking environments. They are the Center for Disease Control and Prevention's Healthier Worksite Initiative Walkability Audit for walkability (Horacek et al., 2018), the Walking and Biking Suitability Assessment (WABSA) (Sisson et al., 2008), and a location specific audit tool developed by the Campus Development Office of the Chinese University of Hong Kong (CUHK) accompanied with field surveys (Sun et al., 2014).

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3.4. Assessment of university students' health

Table 3 lists the health outcome variables and measures. The amount of physical activity was assessed using questionnaires such as the International Physical Activity Questionnaire and the European Health Interview Survey (Horacek et al., 2018, Loder et al., 2020, Loder and van Poppel, 2019, Peachey and Baller, 2015). Travel diaries were used to measure walking distance. Researchers transformed the self-recorded walking routes into Geographic Information Systems (GIS) to obtain the distance (Sisson et al., 2008, Sun et al., 2014). In addition, devices such as pedometers and accelerometers were used in experimental studies to measure physical activity levels/intensities (Sisson et al., 2008). Other than the amount of physical activity, BMI, calculated from height and weight (weight/height2), was used in two studies to indicate physical wellbeing (Horacek et al., 2018, Loder and van Poppel, 2019).

Restorativeness (n = 7) was the dominant psychological wellbeing outcome (Sun et al., 2021; Q. Liu et al., 2022; Liu et al., 2018; Wang et al., 2018; Gulwadi et al., 2019; Malekinezhad et al., 2020; Guo et al., 2019) and was measured using self-reported questionnaires such as the Perceived Restorativeness Scale (PRS). Two studies measured depression and anxiety. Yang et al., (2022) examined depression using the 9-item Patient Health Questionnaire (PHQ-9), and Guo et al., (2019) examined anxiety measured by the State-Trait Anxiety Inventory (STAI-S).

Physiological responses, including thermal symptoms, skin temperature, blood pressure, systolic pressure, heart rate, and brainwaves were measured using professional/clinical devices (Niu et al., 2020, Guo et al., 2019). Thermal symptoms were measured subjectively using questionnaires by asking participants if they felt or experienced heat related reactions (e.g., dizziness, profuse sweating, fast heartbeat) (Niu et al., 2020).

As for overall health, in Liu's two studies, researchers asked students to evaluate their own health, such as physical health, mental health and quality of life, in the past two weeks on a 7-point scale (Q. Liu et al., 2022; Liu et al., 2018). In addition, Gulwadi et al. (2019) and Hipp et al. (2016) measured students' quality of life using the World Health Organization quality of life questionnaire.

3.5. Associations between campus environments and students' health

Physical well-being and associated environmental factors: Among the nine studies that mentioned physical well-being, six studies showed built environmental factors, accessibility to destinations, and active transportation compatibility (e.g. road intersections, road condition, walkability/bikeability) were positively associated with physical activity intensity (e.g., moderate or high) or walking (e.g., walking distance, walking trips, and steps) (M. Liu et al., 2022; Sisson et al., 2008; Sun et al., 2014). Dead-end streets (cul-de-sacs) in a campus environment were negatively associated with physical activity. Sun et al., (2014) and Peachey and Baller (2015) examined land use, showing increased residential areas were associated with decreased walking distance. In Horacek et al., (2018) study, walkability/bikeability was shown to be negatively associated with BMI. Among the three studies (Loder and van Poppel, 2019, Peachey and Baller, 2015, Teuber and Sudeck, 2021)

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involving the natural environments (i.e. perceived naturalness, vegetation attributes), none showed significant associations with any of the physical wellbeing outcome.

3.5.1. Physiological responses and associated environmental factors—Niu et al. (2020) examined shaded areas and their associations with students' physiological responses. The results showed that students had lower skin temperature and thermal symptoms when doing physical activity in areas completely shaded by trees and/or pavilions and relatively lower blood pressure and heart rate under tree shaded places compared to non-shaded area, pavilion shaded or building shaded areas. Guo et al. (2019) showed college students VR street trees on campus and measured their heart rate and brain waves. The results indicated heart rate values were significantly reduced while viewing street trees. Brain wave activities also indicated the relaxing effect of viewing street trees.

3.5.2. Overall health and associated environmental factors—Liu's study (2022) indicates that accessibility and road conditions support student's mental and physical health, but the aesthetics of the environment do not. Liu et al. (2018)'s study suggested perceptions of natural attributes (i.e., a high amount of green area, large waterfront area, many wild plants, and animals, etc.) and perceptions of natural forms (e.g., hilly, meandering waterscape, winding road, etc.) were positively associated with students' self-rated overall health.

3.5.3. Psychological well-being and associated environmental factors—Nine studies investigated campus environments and students' mental health conditions as well as the level of depression, anxiety, and psychological restoration. Among those studies, Yang et al. (2022) focused on the environments within a 0.5 km, 1 km, and 2.5 km buffer of the campus and students' depression symptoms, indicating that campus neighborhoods with scattered trees (0.5 km), access to water (0.5, 1.0, and 2.5 km), and increased street intersections (1.0 and 2.5 km) were associated with decreased depression. However, bush scrub, dense trees, low plants, and NDVI were not associated with depression. In contrast, those living near higher densities of food outlets serving takeaway sweets and fast food (0.5, 1.0, and 2.5 km) were more susceptible to depression. Furthermore, Loder et al. (2020) examined the perceived greenness in the home and campus environments of 601 college students in Graz, Austria, and found that both were positively associated with better mental health.

Five studies examined the natural environment and students' psychological restoration. The supportive environmental factors reported in these studies include perceived naturalness, NDVI, perceived greenness, percentage of vegetation cover (photo simulated), and perceptions of the green environments. Additionally, Sun et al. (2021) observed restorative effects were ranked as follows: blue space (representing water features) had the greatest effect, followed by sports ground, then green space, showing that students had better restorative effects after experiencing a water feature. This result is similar to the study conducted by Lu and Fu (2019) showing that students prefer waterfront space followed by vegetation spaces, courtyard spaces, and squares for relaxation which can reflect the restorative effect of those spaces. The study found that students prefer formal, well-maintained gardens and lawns over naturalistic areas (Speake et al., 2013).

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Two studies exposed students to simulated natural environments to test their mental health outcomes. The study conducted by Guo et al. (2019) employed virtual reality (VR) techniques to investigate the restorative effects of various tree species on a university campus. The study found that viewing street trees had a positive impact on reducing student anxiety. In the study conducted by Wang et al. (2018), they manipulated images of campus environments to depict varying landscape features, such as the amount of vegetation coverage and the naturalness of water bodies. These altered images were then presented to students, and the findings indicated that the higher the presence of natural features in the photos, the more significant the improvement in students' restoration.

3.5.4. Quality of life and associated environmental factors—Two studies, Gulwadi et al. (2019) and Hipp et al. (2016) measured the mediating effect of restorativeness in the relationship between perceived/objective greenness and quality of life. Both demonstrated a positive correlation between perceived greenness and restorativeness, which contribute to the enhanced overall quality of life. Gulwadi et al. (2019) also showed higher NDVI values across the entire campus and in proximity to buildings were associated with better quality of life.

Based on Table 4, a clear pattern emerged. The built environments are primarily linked to physical health. T. On the other hand, the natural environments are predominantly connected to mental health and overall quality of life.

4. Discussion

Overall, studies related to campus environments and college students' health have increased in the last five years, indicating increased awareness of the campus environment's roles in promoting students' health and wellbeing. This line of research is more popular in Asian countries, especially in China, than in other countries. This could reflect that many Chinese campuses have been newly constructed or improved (Sharma, 2021), offering timely opportunities and motivations for researchers to evaluate the potential impact of the new or improved campus environments. However, this area of study remains under explore in Western countries. Furthermore, it is worth noting that the majority of studies in this field have focused on a single university campus. While these individual case studies provide valuable insights, there is a need for more research encompassing multiple campuses to gather additional and comparable evidence that can inform future research and practical applications in designing and managing campus environments to better support student health.

4.1. Methodologies in studying campus environments and students' health

Cross-sectional and survey-based observational studies were predominant in the reviewed studies on this topic. Our search identified only two experimental studies assessing the causal effects of specific interventions. One such study conducted by Guo et al. (2019) utilized virtual reality technology to expose students to different types of campus tree species. The other study by Wang et al. (2018) employed campus photos to simulate students' environmental exposure. Although these studies demonstrated varying effects of

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campus environments on students' psychological restoration, it is important to note that they were based on Simulated (photographed/simulated) environments.

Furthermore, there are other intervention studies beyond the scope of this review, such as forest exposure experiments conducted within campuses, that offer additional insights into the health benefits of nature exposure for college students (Bang et al., 2017, Chou and Hung, 2021, Kim et al., 2021, Kim et al., 2020). However, it is important to acknowledge that interventions tested in these studies typically involve nature-based programs specifically designed for the intervention studies themselves, rather than being part of students' normal daily routine. The potential causal impact of the campus environmental characteristics that students are naturally exposed to as part of their everyday life is still largely unknown, which can offer valuable additional insights into the full range of health-promoting potential of the campus environment.

4.2. Existing knowledge of campus environments and students' health

As for the environmental factors and their related health outcomes, the reviewed studies generally support the finding that physical activity is more closely related to the built environments, while mental health related outcomes are more strongly correlated with the natural environments (Table 4).

Nine out of 19 studies investigated college students' mental health outcomes. These studies covered four mental health aspects: overall mental health (n = 2), restoration (n = 7), depression (n = 1), and anxiety (n = 1). Among these outcomes, restoration was the most frequently examined mental health benefit, assessing how campus environments helped students recover from academic stress. Including additional mental health variables beyond psychological restoration in future studies, such as stress, resilience, and attention, could help improve our understanding of the campus environments on various mental health conditions common to college students (ACHA, 2019, ACHA, 2022). Additionally, it will be important to more completely capture the exposure to health features such as greenness at/around the home, work, and along travel routes in addition to campus. Emerging evidence from the environmental psychology literature suggests that such exposure has cumulative (i.e. quantitative association) and dose-response relationships (i.e. changes caused by differing levels of exposure) (Jiang et al., 2016). One of our reviewed studies by Loder and her colleagues (2020) also showed that perceived exposure to greenness at home versus at university campus was independently associated with mental health outcomes (Loder et al., 2020).

In terms of physical activity outcomes, six of the reviewed studies showed that the campus built environments are highly correlated with college students' physical activities (Horacek et al., 2018; M. Liu et al., 2022; Peachey and Baller, 2015; Reed and Ainsworth, 2007; Sisson et al., 2008; Sun et al., 2014). Although there was no clear association between the built environments and mental health, it is still important to note that increased physical activity was associated with better mental health (Saxena et al., 2005). In addition, unhealthy food environments, such as high fast-food restaurant density and take-away sweet shop density were correlated with an increased risk of depression. However, causal relationships between the two could not be established due to the cross-sectional nature of existing

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studies. Therefore, further research is needed to understand if there is a meaningful causal role that the food environments play in reducing the risk of depression or other health problems prevalent in student populations.

Built environments factors such as street connectivity and road conditions were shown to support college students' walking behaviors. The presence of dead-end streets (cul-de-secs) was a negative correlate with active transportation (Peachey and Baller, 2015). Dead-end streets reduce the overall connectivity of the street/path network, resulting in increased travel lengths due to the need to make detours to get to the desired destination. Such a condition is shown to discourage people's participation in active transportation, especially walking (Hochschild Jr, 2015). Health-promoting transportation infrastructure on campus should be better incorporated into the future campus planning/design/management decision-making process.

4.3. Knowledge gaps and future research needs

Overall, studies included in this review were conducted within a limited number of campuses, resulting in limited external validity. This leaves opportunities for future work involving multiple campuses to draw more generalizable insights. We also learned from this review that the current status of knowledge about the campus environments and student health relationship is dominated by correlational evidence. Thus, more experimental investigations using longitudinal and intervention studies are needed to examine their causal relationships. However, experimental studies in real world environments are always challenging due to multiple feasibility and ethical concerns. As an alternative approach, the use of technologies, such as VR, video, and photo simulations offers opportunities for future experimental studies in a more controlled environment (Guo et al., 2019, Wang et al., 2018).

For college students, peer and academic pressures can be stressful, and green space can reduce and/or help them cope with such stress. While this review confirms the significant benefits of environmental factors on students' health outcomes in general, we found limited empirical studies that specifically target campus green space and its roles in stress reduction. According to the attention restoration theory, the natural environments can help students restore attention (Kaplan, 1995), and being able to pay attention is a key to academic success. Additionally, some research has documented links between greenspace and academic performance, and more of this work is needed on college campuses specifically with outdoor classrooms, etc. (Browning and Rigolon, 2019, Hodson and Sander, 2017, Wyatt et al., 2017). Overall, health problems that are particularly prevalent among college students, such as stress and sedentary behavior, require further examinations regarding their relationships with campus environments, and this might be done more effectively with targeted interventions (i.e., specific programs) and subsequent evaluations.

Additionally, during the peak of the COVID-19 pandemic, college students reported significant reductions in walking and overall physical activity (López-Valenciano, Suárez-Iglesias, Sanchez-Lastra, and Ayán, 2021) and prolonged indoor and sedentary times increasing the risks of various health problems (Romero-Blanco et al., 2020). However, a study involving 132 college students from a mid-sized U.S. university indicated an increased use of outdoor spaces for in-person interactions during the pandemic, and these interactions

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were perceived as meaningful by the students (Barankevich and Loebach, 2022). Campus built and natural environments can serve as an accessible solution to relieve college students' emotional problems and promote their physical activities during times of crisis (e.g., the COVID-19 pandemic) (Larson et al., 2022).

5. Conclusion

In conclusion, the findings of this review demonstrate that the built and natural environments of the university/college campus are and can be beneficial to students' health. The results suggest that aesthetics, transportation (road intersections and conditions, presence of sidewalks), natural features, and greenness are important factors that can lead to improved student health outcomes. Trees are especially important, which scattered plantings, shade conditions, and certain species showing positive associations with students' physical activity and mental health outcomes. However, the number of existing articles examining campus environments and students' health is relatively small. These studies are predominately cross-sectional and conducted in a single campus setting. Further, the number of health outcomes assessed is limited. For example, mental health outcomes are limited only to restoration. Thus, many opportunities remain for future research on this topic, especially those involving multiple campuses, employing longitudinal and intervention methods, and targeting the specific health problems prevalent among college students. Additionally, future literature reviews can conduct a meta-analysis to provide more precise and conclusive results, and to develop a framework for a healthy campus infrastructure.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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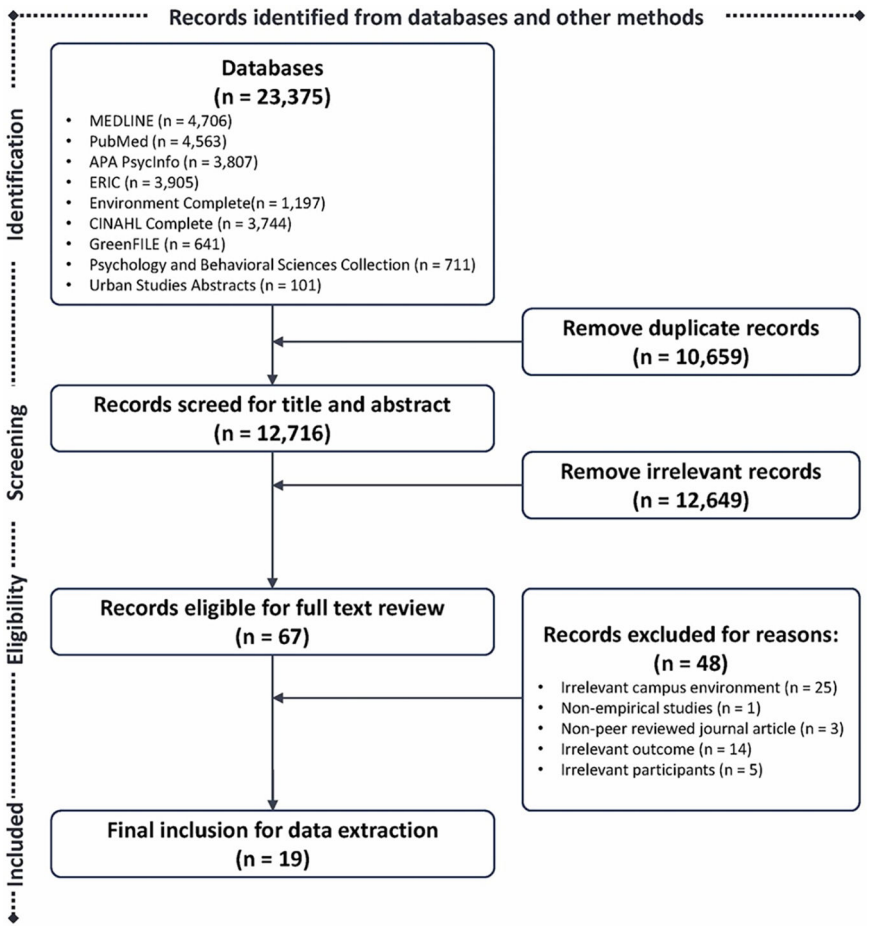

Fig. 1.
PRISMA Diagram.

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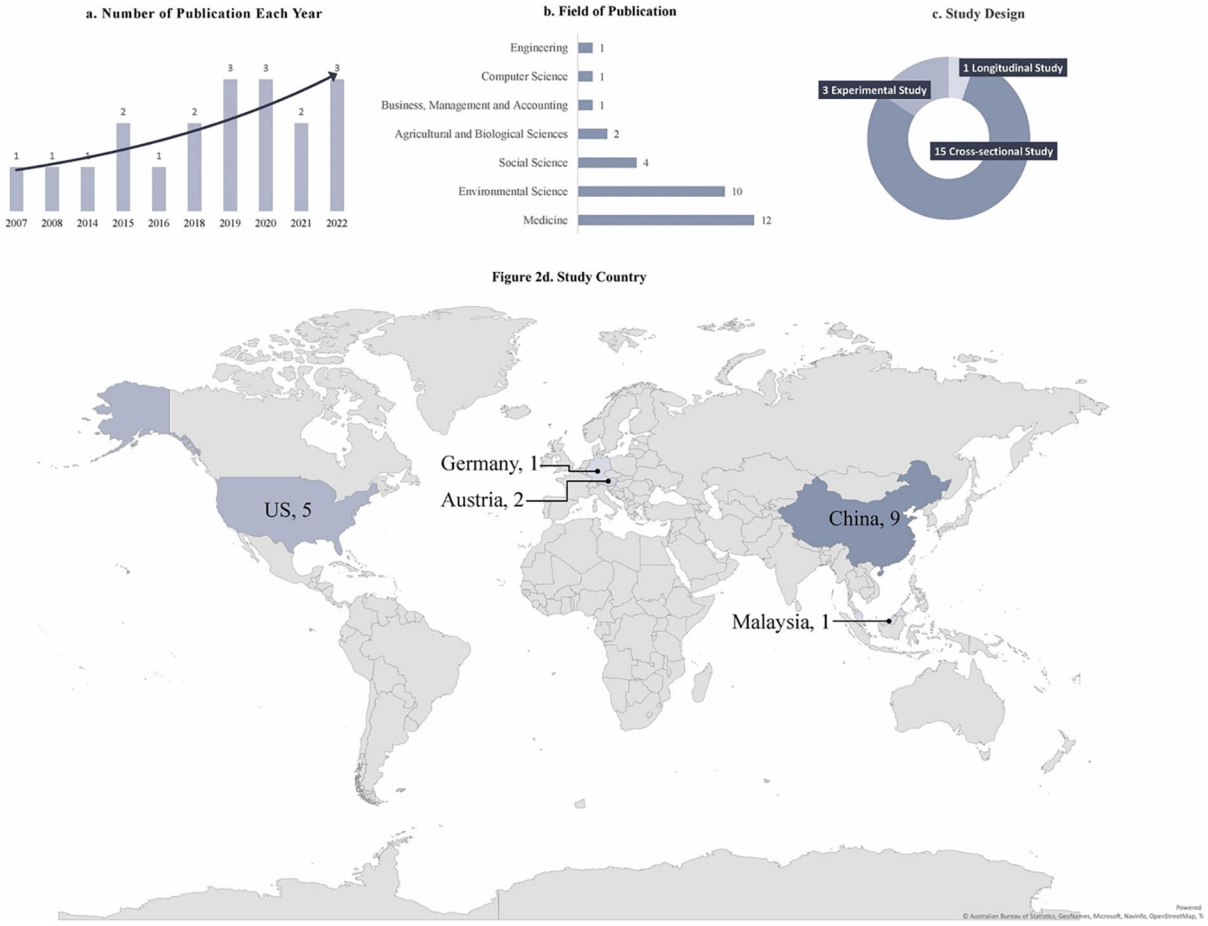

Fig. 2.
Study Characteristics.

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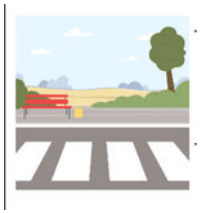
Table 1.

Classification of Environmental Factors and Domains

Built Environment & Natural Environment			Built Environment		
	Aesthetics	• Aesthetics (M. Liu et al., 2022; Peachey & Baller, 2015; Teuber & Sudeck, 2021)		Un-healthy food environment	• Fast-food restaurant density (Yang et al., 2022) • Take-away sweet shops density (Yang et al., 2022)
				Presence of daily activities areas	• Residential (Peachey & Baller, 2015) • Life area (Sun et al., 2014) • Work area (Sun et al., 2014) • Parking area (Peachey & Baller, 2015)
	Shaded area	• Sky view factor (Niu et al., 2020)		Accessibility to destinations	• Accessibility (M. Liu et al., 2022; Peachey & Baller, 2015) • Connectivity (Peachey & Baller, 2015; Teuber & Sudeck, 2021)
	Type of space	Blue space, sports ground, green space, grey space (Sun et al., 2021)		Active transportation	• Intersections (Sun et al., 2014; Yang et al., 2022) • Cul-de-sacs (Peachey & Baller, 2015) • Road condition (M. Liu et al., 2022; Reed & Ainsworth, 2007) • Walkability/ Bikeability (Horacek et al., 2018; Peachey & Baller, 2015; Sisson et al., 2008) • Sidewalk presence (Reed & Ainsworth, 2007)
Natural Environment			**Simulated Environment**		
	Naturalness	• Hilliness (Peachey & Baller, 2015; Teuber & Sudeck, 2021) • Water (Yang et al., 2022) • Perceived naturalness (Q. Liu et al., 2022; Liu et al., 2018) • Perception of natural attribute (Liu et al., 2018) • Perception of natural form (Liu et al., 2018)		Virtual reality trees	• View of street trees (Guo et al., 2019) • Tree species (Guo et al., 2019)
	Vegetation attributes	• Bush scrub (Yang et al., 2022) • Dense trees (Yang et al., 2022) • Low plants (Yang et al., 2022) • Scattered trees (Yang et al., 2022) • Satellite-derived vegetation index (Gulwadi et al., 2019; Yang et al., 2022) • Perceived greenness (Gulwadi et al., 2019;		Photo simulated environment	• Visual naturalness of water (Wang et al., 2018) • Percentage of land covered by vegetation (Wang et al., 2018)

		Hipp et al., 2016; Loder et al., 2020; Loder & van Poppel, 2019; Malekinezhad et al., 2020)

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Table 2.

Summary of Overall Study Characteristics

#	Study	Field of Publication	Study location (Continent; Country)	Study design	Number of samples (N=number of schools; n=number of participants	Participants characteristics (G=gender; A=age)
1	Guo 2019	Environmental Science, Medicine	Asia; China	Experiment	N=1, n=150	G: female = 50%, male = 50%; A: m=23.75, SD=1.01
2	Gulwadi 2019	Environmental Science, Social science	Europe and North America; Turkey and US	Cross-sectional	N=4, n = 1079(Overall), n=358(Turkey University A), n=255(US University B), n=164 (Turkey University C), n=302(US University D)	G: not provided A: m=21.5
3	Hipp 2015	Environmental Science	North America; US	Cross-sectional	N=3, n=439 (308, 69.8% from University A; 85, 19.3% from University B; and 46, 10.4% from University C)	G: female=78.2%; A: m=23.6
4	Horacek 2016	Medicine, Social Sciences	North America; US	Cross-sectional	N=13, n=1384	G: female=68.4%, male=31.6% (437); A: m=19.33, SD=1.07
5	Loder 2019	Environmental Science, Medicine	Europe; Austria	Cross-sectional	N=1, n=601	G: female=465 (77%), male=125 (21%); A: m=24, SD=7
6	Loder 2020	Medicine	Europe; Austria	Cross-sectional	N=1, n=601	G: female=465 (77%), male=125 (21%); A:24 years (SD=7)
7	Liu 2018	Agricultural and Biological Sciences, Environmental Science	Asia; China	Cross-sectional	N=8, n=2550	G: female=49.14% (1253), male=50.86% (1297); A:16–28 (m=22.06, SD=2.20)
8	Liu 2022	Social Sciences	Asia; China	Cross-sectional	N=1, n=802	G: male:female= 2:1; A:not provided
9	Liu 2022	Agricultural and Biological Sciences, Environmental Science	Asia; China	Cross-sectional	N=1, n=897	G: female 447 (49.83 %), male = 450 (50.17%); A:m=22.29, SD =2.56
10	Malekinezhad 2020	Medicine	Asia; Malaysia	Cross-sectional	N=5, n=444	G: female=300, male=144; A:19–30
11	Niu 2020	Environmental Science	Asia; China	Experiment	N=1, n=54	G: female = 50%, male = 50%; A:19–25
12	Peachey 2015	Medicine	North America; US	Cross-sectional	N=1, n=829	G: female =70.9%, male=29.1%; A: not provided
13	Reed 2007	Medicine	North America; US	Cross-sectional	N=1, n=560	G: female=392 (70%), male=168 (30%); A: not provided
14	Sisson 2008;	Medicine	North America; US	Experiment	M=Convenience Sampling; N=2; n= 20(ASU-Polytechnic), n= 20(ASU-Tempe)	G: male=33%(ASU-Polytechnic), male=60% (ASU-Tempe); A: female m=23.5, male m=24.9 (ASU-Polytechnic), female m=

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#	Study	Field of Publication	Study location (Continent; Country)	Study design	Number of samples (N=number of schools; n=number of participants	Participants characteristics (G=gender; A=age)
						18.4, male m=18.6 (ASU-Tempe)
15	Sun 2014	Business, Management and Accounting Computer Science, Medicine	Asia; China	Longitudinal	M=Convenience Sampling; N=1; n=198(March 2012), n=169(same cohort December 2012)	G: baseline female=109 (56%), male=89 (45%), follow-up female=96 (55%), male=74(44%); A: m=18.7, SD=1.2(Baseline)
16	Sun 2021;	Environmental Science, Medicine	Asia; China	Cross-sectional	N=1; n=819	G: female=469(57%), male=350(43%); A: not provided
17	Teuber 2021	Environmental Science, Medicine	Europe; Germany	Cross-sectional	N=1; n=997	G: female=718 (72%), male=232 (23.3%), not provide=47 (4.7%); A: 18–42(m:23.4, sd:3.45)
18	Wang 2018	Engineering Environmental Science, Social Sciences	Asia; China	Experiment	N=1; n=323	G: female=188, male=135; A: m=23.1
19	Yang 2022	Medicine	Asia; China	Cross-sectional	N=89, n=22,009	G: male =9,779 (44.43%); A: m=20.01, SD=1.75

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Table 3.

The Campus Environments in Relation to Students' Health Outcomes and their Corresponding Measures

	Independent variables and measurement	Outcome and measurement
Research that examined built and natural environment		
Liu 2022	Accessibility, Road condition, Aesthetics • Neighborhood Environment Walkability Scale-Abbreviated (NEWS-A)	Walking behavior, Physical and mental state • Walking behavior: number of walking trips. • Self-reported physical and mental state
Niu 2020	Sky view factor • Sky view factor	Physiological changes (skin temperature, blood pressure and heart rate), Thermal responses • Physiological changes: Skin temperature: iButton DS1922L, Blood pressure and heart rate: OMRON HEM–7211) • Thermal response: ask if the respondent felt or experienced feeble, dizziness, nausea, profuse sweating, chest tightness, headache, fast heartbeat or dysphoria
Sun 2021	Type of space: blue space, green space, grey space, and sports ground • Participants expose to different type of space	Rstorativeness • Perceived Restorativeness Scale (PRS)
Yang 2022	Objective greenness, landcover feature, food environments • Objective greenness: NDVI: Sentinal-2 satellite data with a high spatial resolution (10 × 10m) in 2018. • Landcover feature: 30m Landsat 8 level 1 image of land cover according to the 2018 local climate zone map provided by the Hong Kong University through the mapping on the World Urban Database and Access Portal Tools. • Food environment: The count of each food outlet was retrieved from points of interest (POIs) data from the Gaode map	Depression • 9-item Patient Health Questionnaire (PHQ-9)
Research that examined natural environment		
	•	•
	•	•
Gulwadi 2019	Objective greenness, Perceived greenness • Objective greenness: NDVI • Perceived greeness: Leslie et al. (2010) 17 item perceived greenness (PG) scale	Restorativeness, Quality of life • Restorativeness: 26 item perceived restorativeness (PRS) scale. • Quality of life: 6 item World Health Organization quality of life short survey (WHOQOL-BREF) scale.
Hipp 2015	Perceived greenness • Sugiyama et al. (2008) 11-item perceived greenness scale	Quality of life • World Health Organization's Quality of Life Brief survey with 26 items
Loder 2019	Perceived greenness • Questions from the PHENOTYPE project	BMI, Physical activity, Sedentariness • BMI: Self-reported weight and height • Physical Activity and Sedentariness: German version of the short form of the International Physical Activity Questionnaire (IPAQ)
Loder 2020	Perceived greenness • Questions from PHENOTYPE project	Mental health • German version of the WHO (Five) Well-Being-Index (World Health Organization)
Liu 2018	Perceived naturalness • Self-rated naturalness scale (SRNS)	Restorativeness, Self-reported health • Self-rated restoration. • Self-reported health: students' own perceived health during the last two weeks
Liu 2022	Perceived naturalness • Self-rated naturalness scale, adopted from Liu et al. (2018)	Restorativeness, overall health • Self-rated restoration scale • Self-reported health
Malekinezhad 2020	Perceptions of campus outdoor green space qualities • Perceived Sensory Dimension (PSD)	Restoration experience and perceived restorativeness • Restoration experience: Restorative Outcome Scale (ROS-6 items)

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	Independent variables and measurement	Outcome and measurement
		• Perceived restorativeness: Restorative Components Scale (RCS-22 items)
Research that examined built environment		
Horacek 2016	Walkability/bikeability • 12-item Center for Disease Control and Prevention's Healthier Worksite Initiative Walkability Audit for walkability/bikeability	BMI, Physical activity • BMI: Anthropometrics • Physical activity: 7-item International Physical Activity Questionnaire (IPAQ).
Peachey 2015	WalkabilityNeighborhood Environment Walkability Scale-Abbreviated (NEWS-A)	Physical activityInternational Physical Activity Questionnaire Long Form (IPAQ)
Sisson 2008	Walkability • Walking and Biking Suitability Assessment (WABSA)	Physical activity • steps, distance: university-issued campus maps to record daily campus walking trips for 7 consecutive days. Pedometer and accelerometer.
Reed 2007	Environmental Supports for Physical Activity • South Carolina Environmental Supports for Physical Activity Questionnaire (SCESPAQ)	Physical activity • 4 of the National College Health Risk Behavior Survey (NCHRBS) PA module items.
Teuber 2021	Perceived PA-Friendliness of the Study Environment • German version of the Neighborhood Environment Walkability Scale (NEWS)	Physical Activity • European Health Interview Survey (EHISPAQ)
Sun 2014	Changes to land use, Changes to pedestrian network • Campus Development Office of CUHK and field surveys.	Walking behavior • Walking diary
Research that examined simulated campus environments		
Guo 2019	Viewing campus street trees and different tree species • Virtual Reality simulated street trees and different tree species.	Heart rate, Brain wave, Anxiety, RestorativenessHeart rate: R-R interval monitor. • Brain wave: Portable MindWave-EEG headset. • Anxiety: State-Trait Anxiety Inventory (STAI-S) Restorativeness: • Restorativeness: The Perceived Restorativeness Scale (PRS)
Wang 2018	Campus environment with different landscape characteristics • Simulated Campus environment using campus photo and were measured using scale of landscape characteristics which was developed based on published literature, not standardized.	Restorativeness • Short-version Revised Restoration Scale (SRRS), which includes eight of the PRS items with a focus on the physiological perspective.

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Table 4.

Summary of Current Research Regarding Relationships Between Campus Environments and Students' Health

Environmental factors / Health related outcomes		Both Built and Natural Environment			Built Environment				Natural Environment		Simulated Environment	
		Aesthetics	Shaded Areas	Type of space	Unhealthy Food Environment	Presence of Daily Activities Areas	Accessibility to Destinations	Active Transportation Infrastructure	Naturalness	Vegetation Attributes	Viewing Virtual Reality Trees	Photo Simulated Environment
Overall health	Overall Health	–					↑	↑	↑			
Physical health	Walking	–				↓	↑	↑				
	Biking	–						–				
	Physical Activity	↑				–	↑	↑	–			
	BMI							↑	–			
	Sedentary Behavior								–			
Mental health	Restoration			↑/↓					↑		↑	↑/↓
	Depression				↓			↑	↑	↑		
	Mental Health								↑			
	Anxiety										↑	
Physiological changes	Thermal Symptom		↑/↓									
	Brain Wave											↑/↓
	Heart Rate		↑/↓									↑/↓
	Blood Pressure		↑/↓									
	Skin Temperature		↑/↓									
Quality of life	Quality of Life								↑			

– The results are not significant.
↑ Health-promoting factors.
↓ Health risk factors.
↑/↓ Mixed results.