

A Meta-Analysis of Evidence Synthesis for a Healthy Campus Built Environment by Adopting Active Design Approaches to Promote Physical Activity

Sweyda Abdullah Azeez ¹, Faris Ali Mustafa ^{1,*} and Rizgar Maghded Ahmed ²

¹ Department of Architecture, College of Engineering, Salahaddin University—Erbil, Erbil 44002, Iraq; sweyda.aziz@su.edu.krd

² Department of Statistics and Informatics, College of Administration and Economics, Salahaddin University—Erbil, Erbil 44002, Iraq; rizgar.ahmed@su.edu.krd

* Correspondence: faris.mustafa@su.edu.krd; Tel.: +964-0750-4524659

Abstract: The spread of chronic diseases, particularly obesity, has become a significant social issue on a global level concerning human inactivity and unhealthy behavior. The new approach to active design introduced by AIA and Sport England to increase human activity through physical activity in the built environment includes certifications such as Fitwell and LEED. An active design is any design feature that encourages physical activity, thus encouraging the user to be physically, mentally, and socially active in the built environment. This study aims to assemble evidence on the active design approach through physical activity in the campus built environment by using a meta-analysis approach and statistical analyses. There were 1993 papers identified during the search; following the screening, eligibility, and inclusion stages, 10 studies that addressed physical activity in colleges and universities were chosen. Findings indicate that physical activity has a positive impact on human health in the built environment. I^2 is (96.38%), which indicates considerable heterogeneity with $p < 0.0001$ and an absence of publication bias. Accordingly, a model was designed to integrate an active design approach and healthy behavior theories for future research. Overall, the evidence shows the importance of active design and physical activity for a healthy built environment to achieve healthy social behavior.

Keywords: active design; physical activity; healthy campus environment; healthy behavior theory; meta-analyses; heterogeneity



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1. Introduction

Physical inactivity contributes to the second, third, and fourth leading causes of death—obesity, high blood pressure, and high blood glucose, respectively [1,2]. The physical activity approach was introduced by Sport England and AIA to increase physical inactivity around the world. In 2007, David Burney announced that the city would lead efforts to improve its buildings and streets with the creation of the active design guidelines [3]. The active design guidelines (ADG) are a manual of evidence-based and best-practice strategies to increase physical activity in the design and construction of neighborhoods, streets, and buildings. There has been accumulating evidence, particularly over the last two decades, of the important role that the built (or human-made) environment—our buildings, streets, neighborhoods, and their amenities—plays in increasing or inhibiting physical activity [4,5]. Other design guidelines that influence and stimulate physical activity are attributes of the built landscape, green components, etc. [6–8].

The US Centers for Disease Control and Prevention (CDC) concluded that there are sufficient to strong levels of scientific evidence for several environmental policies and approaches to increase physical activity, including the use of stairway signage in decision points such as elevators and escalators, the creation or promotion of access to places for

physical activity [9], and urban design policies and interventions at the community and street scale [10]. The active design guidelines (ADG) would be the next step in the process to promote the design and construction of public and private sector projects focused on active living in New York City [11].

In the UK, an active design has been commissioned by Sport England [5,12] to promote new environments that offer opportunities for communities to be naturally active as part of their daily lives. In promoting physical activity, walking, and cycling (referred to as active travel) [13], the active design integrates several converging agendas: the first is “the design agenda—the promotion of high-quality inclusive design of buildings and public spaces is a key principle of the planning system”; the second is “the health agenda—physical activity is fundamental to the public health and wellbeing of the nation and is central to arresting increasing trends in obesity among adults and children” [9]; and the third and last one is “the transport agenda—the promotion of active travel modes reflects government transport policy seeking to promote more sustainable and environmentally friendly modes of transport”.

The body of evidence shows that there are multiple definitions of active design but with the same meaning [3,5,12,14–20]. The evidence concludes that an active design is defined as any design element that promotes physical activity to create a healthy environment and achieve a healthy community. Therefore, physical activity is the main variable of active design; thus, according to the definition in [21], physical activity involves being physically active (moving, acting, and performing) to achieve physical wellness, mentally active (influenced by a unique array of interests, emotions, and ideas) to achieve mental health, and, finally, socially active (within culturally defined spaces and context) to achieve social well-being.

Human healthy lifestyle behaviors are determined by socioeconomic, cultural, and environmental factors [22–24]. The fundamental objectives of environmental design are to create a setting that encourages physical activity, provides opportunities for society to move physically, and inspire people to do so [25]. Thus, the built environment has a crucial role in formulating human behavior and public health, and healthy built environment outcomes require healthy behavior [2,26–28]. Most students spend their time on campus; a healthy campus is described as a location that actively promotes good health outcomes and supports each student as a whole—a united bio-psycho-social entity [29,30]. Therefore, a campus built environment plays an important role in shaping students’ behavior [31–33]. Unfortunately, a great deal of students experience significant levels of stress during their time in college and stop being physically active [7,29,34–36]. The campus built environment could promote physical activity [37]. To solve this issue, theories are crucial because they are the cornerstone of professional practice; they help us to formulate solutions and interventions that will best enable us to deliver the services in practice to achieve healthy behavior in a built environment and develop research with theoretical support [38].

Many methods have been used in this field; meta-analysis is a quantitative method used to combine the findings of multiple research works into a single conclusion. The term “meta-analysis” was first coined by Gene Glass in 1976 as the statistical analysis of a large collection of analysis results from individual studies to integrate the findings [39]. The current study combines the results and findings of earlier studies that were used in this work to demonstrate the impact of physical activity on students’ health in campus built environments. It uses an active design approach to increase physical activity per a few studies that include statistical analyses, and it ultimately aims to propose a theory of encouraging healthy behavior in a built environment.

Evidence gathered from various sources demonstrates a close relationship between active design, physical activity, and the campus built environment in achieving healthy behavior and lifestyles among students. To solve this issue, this paper conducts a review to identify the best ways to achieve a healthy built environment and healthy behavior through active design approaches and theories. Based on the review, active design approaches enhance physical activity, and we aim to identify a physical activity categorization and to propose a theory for each case. Finally, throughout this meta-analysis, a model is developed

based on healthy behavior theory and active design, focused on enhancing physical activity by obtaining a healthy built environment to promote healthy behavior outcomes.

2. Materials and Methods

2.1. Search Strategy

An exhaustive search strategy was implemented. The authors searched Scopus, Google Scholar, the Web of Science citation database, the PubMed database, the Global Health Database, Web of Science, governmental publications, and conference proceedings. This set of databases has been selected to ensure a comprehensive search across disciplines. Active design keywords are mostly related to human energy from body movements applied to a building layout and site, creating a positive human experience, as well as contributing to human health to achieve physical activity, thus including public health. On the contrary, keywords mostly related to fitness, exercise, and campus design relate to human comfort. In addition, in research works that combine the concept of physical activity with active design, the keywords mention active living concerning healthy lifestyles for public health and environments; strategies, policies, and guidelines to achieve an active lifestyle; living; and built environments for public health. In contrast to research works on education campuses and physical activity, it was noted that exercise, fitness, aerobics, and leisure time were the factors that kept users physically active, as seen in Figure 1. The search results were collated in an online systematic review platform, Covidence (www.covidence.org; accessed on 14 January 2023), in which search terms were searched using keywords. The study complied with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statements [40].

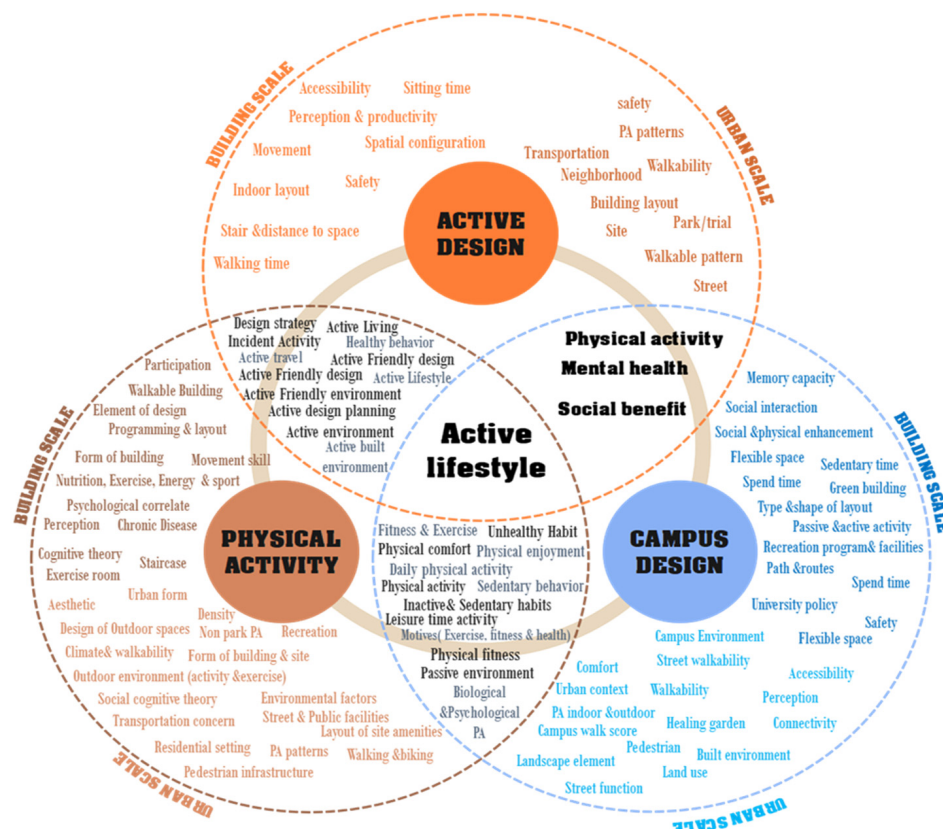


Figure 1. Active design, physical activity, and campus design as keywords included in the meta-analysis.

2.2. Inclusion and Exclusion Criteria (Selection of Studies)

The primary question of our research refers to the role of the campus built environment within the educational sector (school campus, university campus, college campus, and elementary school campus) in promoting active behavior among students. Students spend

the majority of their time on campus, where they develop their behavior either positively or negatively. Moreover, students are an essential part of both the nation and the world. Therefore, we searched for both longitudinal and cross-sectional studies dealing with an active design (which has a potential role in promoting physical activity) leading to (healthy behavior). Accordingly, we included studies that looked into healthy behavior through each type of physical activity (physically active, mentally active, and socially active) that impacts human health and results in a healthy lifestyle [41–46]. For this reason, searching involved cross-sectional studies that investigated physical activity levels in subjects with human health compared to control groups. As for the inclusion criteria, original articles dealing with the study of active design (promoting physical activity), human health, healthy behavior, and a control group composed of students who engaged in healthy exercise, as well as studies on the educational sector (the built environment) with statistical analyses that reported on physical activity, were included. Meanwhile, the exclusion criteria covered studies that did not mention physical activity, such as walking, physical fitness, recreational programs, aerobic exercise, swimming, etc., or other types of buildings and environments, as well as those that did not contain statistical analyses, which were excluded.

2.3. Quality Assessment and Data Extraction

There are different tools used to assess the quality of meta-research studies. The methodological quality of the included articles was assessed according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist. The STROBE checklist can be found at <https://www.strobe-statement.org/index.php?id=available-checklists>, accessed on 3 November 2022. STROBE is a tool that assists researchers in the fundamental step of quality assessment. It consists of a 22-item checklist, related to the manuscript title/abstract, introduction, methods, findings, discussion, and findings. Eighteen items are related to cohort studies, case–control studies, and cross-sectional studies, whereas four are specific to each of the three study designs (cohort studies, case–control studies, and cross-sectional studies). STROBE provides general reporting recommendations for descriptive observational studies and studies that investigate associations between exposures and health outcomes [47–49]. In addition, it represents the direct demonstration of its adaptability to different types of research areas. The advantages of STROBE are that it is a useful tool for double-checking if all the points required by an observational study are included in the manuscript and gives a more detailed explanation about items that could be used for different interventions and comparisons between them.

Quality assessment was completed before data extraction began. Data were extracted from full-text research, while quantitative results were extracted from the text and tables, including (participants, sector, methodologies, measurement, statistical analyses of physical activity types, variables, and results). The outcome indicates whether physical activity has a positive or negative effect on human health. For research without an exact size, the gap was filled via the methods introduced by [50]. This study develops a novel meta-analytic procedure that combines the evidence on physical activity and health behavior theory, making it possible to adjust for the effects of extraneous factors in all studies and bridging the gap between control group studies and other types of studies.

2.4. Statistical Analyses

Analyses were performed using the MedCalc Statistical Software, Version 20.218 (MedCalc Software Ltd., Ostend, Belgium; <https://www.medcalc.org>; accessed on 4 November 2022). Meta-analyses were performed (n , mean, SD) and assessed for both interventions and control groups of studies, with the weight (%) (fixed and random), 95% confidence intervals (CI), and SE calculated for studies. The heterogeneity test among studies (significant at $p < 0.05$) was assessed, and the I^2 test [51] was applied to indicate the amount of heterogeneity. For the publication bias, Egger's test and Begg's test were used for calculation (intercept, 95% CI, Kendall's Tau, and significance level).

3. Results

3.1. Literature and Research

A rapid literature review was conducted to collect all evidence for active design focused on physical activity (general), assembling all evidence for physical activity on campus (educational sector), and statistical methods demonstrating outcome effects of physical activity on human health (public health). Search terms used in the systematic review are “active design”, “physical activity”, “university campus”, “healthy built environment”, and “healthy behavior”. For screening, a total of 1850 articles were identified, and 143 additional records were added. Other resources were deemed irrelevant and duplicates were removed, leaving 1450; after the exclusion of 805 articles due to irrelevancy, as a result of keywords and related topics, 645 full-text articles were assessed for relevancy, depending on keywords. The sources assessed for eligibility totaled 191; duplicates of the same methodology that were excluded totaled 454; exclusion criteria included no relevant interventions with no control group, unrelated outcomes, full text not available, and theses. The studies were human studies (students), English language articles, interventions or exposures involving a healthy built environment (building and urban scale), interventions or exposures for active design, physical activity, and college campus (educational sector), outcome(s) involving perceived or actual physical activity, walkability, movement, health, well-being at a university campus, all study types (including conference papers, case studies, and commentaries, systematic review, research papers), and full-text (papers available), and the impact on health. In total, 23 active design records were selected with a focus on students. Of these, 10 documents related to research on physical activity with statistical analyses were used for data extraction and meta-analyses, and 13 documents related to active design achievement strategies to promote physical activity without statistical analyses were excluded, as shown in Figure 2.

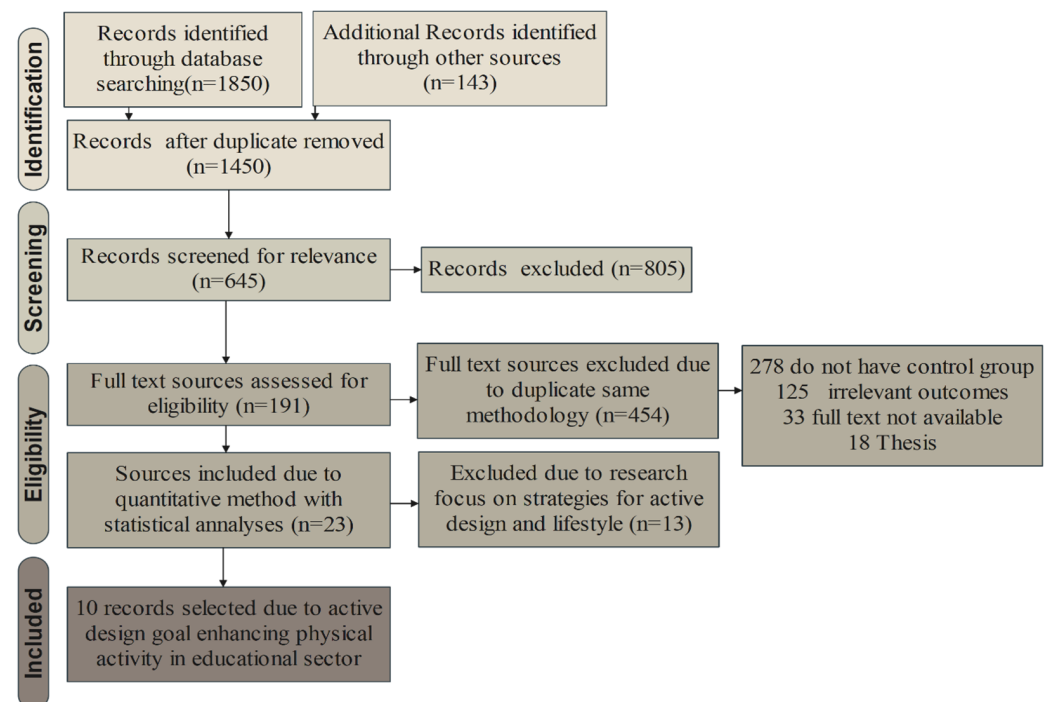


Figure 2. Flow diagram for inclusion and exclusion of studies.

3.2. Physical Activity Research Outcomes

Data extracted from the selected quantitative studies showed that five out of ten confirmed that the built environment has a favorable impact on physical activity [41,46,52–54] and five out of ten confirmed that physical activity has a positive impact on human health [42–45,55]. This shows that both the built environment and physical activity have a critical role in human health. Due to the limited number of studies adopting statistical

analyses using SPSS as crucial to extract meta-analysis data, physical activity data were generally retrieved based on three categories of human activity, namely physically active, mentally active, and socially active, benefiting from the definition of physical activity given in [21]. The authors propose a theory of healthy behavior to fill research gaps in future studies in Table 1. The study [52] showed that the positive impact of physical activity on human health can be achieved through school campuses, buildings, and play areas. Moreover, a pilot study [41] assessed pre- and post-educational buildings and found that an active school design can play a role in influencing children's sedentary behavior and physical activity. In addition, in [42], following a 6-week personalized physical activity program for students seeking mental health support, the authors found that there was a significant reduction in anxiety, depression, and psychological distress recorded before and after the program, and [56,57] studied horticulture therapy to treat mental (including anxiety) and physical disorders. In contrast, [55] aimed at demonstrating how physical exercise affects memory and attention capacity; it was discovered that the short-term effect of calories burned the day before or throughout the week was significant, but it was negatively associated with college students' memory and attention ability.

Walking has become an indispensable and sustainable means of travel and also a form of physical activity for college students in their daily lives. In this context, the study [53] views campus walkability as environmental support for physical activity. The study showed a perception of walking as a form of physical activity and considered whether certain elements of the campus layout encouraged physical activity. They concluded that the ability to walk affects the physical activity levels of university students, faculty members, and staff. In addition, [54] developed a new tool to evaluate the walkability of university campuses. They found that the rationality of the campus facility layout (shape) and the distribution of facilities have a critical role in increasing physical activity.

An important and positive effect of the campus recreation programs of 13 universities can be seen in the study by [43]. They discovered that these recreational programs and facilities were supportive of healthy lifestyles to prevent obesity, but the policies and the built environment were not. Besides the positive effect of physical activity on human health, [44] discovered that students had lower levels of physical activity than required; while most of them stated that exercise was important to them, the most common reason for this was a lack of time, energy, and motivation to exercise. Concerning mental activity, [45] examined young people's attitudes toward incorporating physical activity as part of mental health treatment, which was generally positive and appeared to be acceptable. As for social activity, [46] pointed out the importance of social spaces (outdoor spaces/landscapes) for the social interactions of students—socially active—and the association with sensory influence—mentally active—has a positive effect. Other aspects of the campus environment potentially can contribute to preventing or mitigating overweight by facilitating healthy habits and behavior regarding physical activity [58–60].

The new active design concept, which promotes physical activity in built environments, aims to create a healthy community and healthy behavior in healthy built environments. For physical activity, [21], drawing on the definition of [61], defines it as inherent aspects of physical activity that are inherently cerebral, social, situational, and political. Physical activity is defined as follows: "people move, act, and perform under specific cultural circumstances and conditions while being influenced by a variety of interests, emotions, thoughts, instructions, and connections". To be more precise, physical activity involves being active in three different ways: physically, mentally, and socially. For meta-analyses, a theory is developed at the conclusion of the statistical analysis of data for each study to solve the problem and enhance the study findings in future research. Table 1 shows that seven out of ten studies mention physical activity in general [41,43,44,52–55], while two out of ten show a link between physical exercise and mental health [42,45]. The tenth and final study [46] indicates that there is a relationship between mental health and social well-being. Accordingly, it can be said that future research may benefit from this important finding in pursuing these three distinct forms of activity.

Table 1. Overview of selected studies on physical activity and the categorization of its impact on human health.

No.	Ref.	Country	<i>n</i>	Sector	Population	Measurement	Active Design Variable			Variable	Results	Healthy Behavior Theory
							Physical Activity Mean (SD) and <i>p</i>					
							Physical	Mental	Social			
1	[52]	The U.S.	248	10 school campuses (m = 13.7 age)	7–8th grade students	Questionnaire GIS (ortho-photo) SPSS	31.13 (26.4) <i>p</i> < 0.07–0.0001 r = 0.6–0.94	-	-	Physical activity, school campuses, school buildings, and school play areas	Positive effects	Social–ecological models: factors at many levels influence health behavior [62–65].
2	[43]	The U.S.	134	13 university campuses	Students	Observation (PACES) survey questionnaire SPSS	5.4 (±1.7) <i>p</i> < 0.001	-	-	Built environment (bike rack, healthy signage, stairwell), recreation facilities, amenities, obesogenic policy	Positive effect	Diffusion of innovation: behavior changes as innovations are adopted [66–70].
3	[41]	The U.S.	53	Elementary school (8–9 years)	Students	Pre- and post-measurements (intervention), SPSS, pilot study	Old 77.4 (20.9), new 89.2 (20.1) <i>p</i> < 0.001	-	-	Sedentary behavior, LPA, MVPA	Positive effect	Theory of reasoned action and theory of planned behavior [71–75].
4	[55]	Taiwan	39	College (mean age 20.79 years old), 15 female	Students	Tests (SST and TMT), SPSS, worn trackers for 106 days	Before 36.21 (9.22) during 34.45 (9.47)	-	-	Memory capacity, attention, daily PA (calories, steps, distance, floor, elevation, sedentary time duration, LATD, FATD, VATD	Negative effects	Health belief model: personal beliefs influence health behavior [76,77].
5	[53]	The U.S.	83	10 university campuses	62 students, 21 faculty staff	Survey, SPSS	20.75 (32.05) (OR = 3.37) (95% CI = 0.78, 14.5) <i>p</i> < 0.05	-	-	Walkability, environmental scan audits	Positive effects	Social–ecological models: factors at many levels influence health behavior [62–65].
6	[54]	China	665	College campus (305 new, 310 old)	Students	Walk score method, pre- and post-measurements, questionnaire, interview	New 5.6 (1.87) Old 6.66 (0.85) Av. 6.13 (1.36)	-	-	Facility layout (public service), walkability, density, block length	Positive effects	Social cognitive theory: behavior, personal factors, and environmental factors interact with each other, and changing one changes them all [78–80].

Table 1. Cont.

No.	Ref.	Country	<i>n</i>	Sector	Population	Measurement	Active Design Variable			Variable	Results	Healthy Behavior Theory
							Physical Activity Mean (SD) and <i>p</i>					
							Physical	Mental	Social			
7	[42]	Canada	101 (68)	Post-secondary campus (m = 22.96 years)	Students	A self-reported questionnaire, semi-structured interviews (<i>n</i> = 11), pragmatism, pre-post intervention	397.21 (303.12) <i>p</i> < 0.001	2.99 (1.10) <i>p</i> < 0.001	-	Physical activity, psychological distress, depression, and anxiety	Positive effect	Social–ecological models: factors at many levels influence health behavior [62–65].
8	[44]	India	122	University (Mumbai) (15–26 years old)	Students (m = 59), (f = 63)	Questionnaire, SPSS	3.32 (1.23)	-	-	Physical health and fitness patterns (attitudes, motivation, demotivation, food consumption, perception)	Positive effect	Attribution theory: there is a cause or explanation for things that happen [81].
9	[45]	Australia	88	4 Headspace centers in Melbourne	Young (15–25)	Online survey, PA questionnaire, and intervention	Spearman ρ = 0.465 <i>p</i> < 0.001	42.33 (8.56) <i>p</i> < 0.001	-	PA (exercise), attitude, depression, and anxiety symptoms	Positive effect	Self-efficacy theory: people will only try to do what they think they can do, and people will not try what they think they cannot do [79,82–84].
10	[46]	Egypt	30	Governmental university campus	Students (different faculties)	A questionnaire, space syntax tool, SPSS	-	3.02 ± (1.13) <i>p</i> < 0.001	3.15 ± (1.28) <i>p</i> < 0.001 <i>r</i> = 0.87	Social space, outdoor space, spent time, sensory and physical features, route	Positive effect	Attribution theory: there is a cause or explanation for things that happen [81].

Note: PA: physical activity; LPA: leisure physical activity; MVPA: Moderate vigorous physical activity; PACES: Physical Activity Campus Environmental Supports; SST: spatial span test; TMT: trail-making test; DPs: day participants; LATD: lightly active time duration; FATD: fairly active time duration; VATD: very active time duration; OR: odds ratio; CI: confidence interval.

3.3. Meta-Analyses of Research Outcomes

A meta-analysis combines the quantitative results of multiple studies from separate but similar research and provides a numerical estimate of the overall effect of interest—in other words, the synthesizing of the results [85–87]. The results of the meta-analyses for continuous measures (comparison of means), displayed in Table 2, and the forest plot (Figure 3) show the standardized mean difference between groups and their effect sizes, which was extracted from the STROBE checklist and is presented in Table 1. The current research focused on physical activity in general and its impact on human health due to the limited number of studies that include statistical analyses on this aspect. The major purpose was to demonstrate how physical activity affects human health and how built environments can improve it. On the other hand, it aimed to establish a connection between active design and campus built environments through physical activity in three categories (physical, mental, and social).

The outcomes from the forest plot were distributed into three categories: the studies that are located on the left side of the forest plot are in favor of the intervention group (significant), while studies that are located on the right side are in favor of the control group (significant), and the studies whose 95% CIs cross the “the line of null effect” are not significant. Concerning outcomes located on the left of the “null effect line” in the forest plot in Figure 3, both studies [52,54] have the largest sample size, more participants, and more information about the impact of physical activity on human health through educational campuses (urban design, building design, playground, walkability as a form of physical activity), with SMD (95% CI), -0.260 (-0.437 to -0.0830), and -0.731 (-0.894 to -0.567), respectively. The study by [41] has a smaller effect size with a larger confidence interval, but [45] has an effect size larger than that of Brittin et al., with a moderate 95% CI.

Findings from [43,46,55] show smaller effect sizes with a confidence interval passing through the “null effect line”, indicating that the result is statistically not significant. Meanwhile, studies [42,44,53] are on the right of the “null effect line”, indicating that there is a significant difference in the outcomes of physical activity in general, with SDM (95% CI), 0.563 (0.0327 to 1.093), 0.442 (0.187 to 0.696), and 1.567 (0.216 to 1.918), respectively. The results are significant due to different types of physical activity contributing to supporting mental health, as well as motivating students to exercise.

The fixed-effect and random-effect model analyses show the bottom of the forest plot in a diamond shape as in the fixed-effect analysis; assuming that the true effect size is the same in all studies, and the summary effect is our estimate of this common effect size, the diamond shape is smaller in effect size and 95% CI, which indicates statistical significance ($p < 0.001$), but for the random-effects analysis, we assume that the true effect size varies from one study to the next and that the studies in our analysis represent a random sample of the effect sizes that could have been observed.

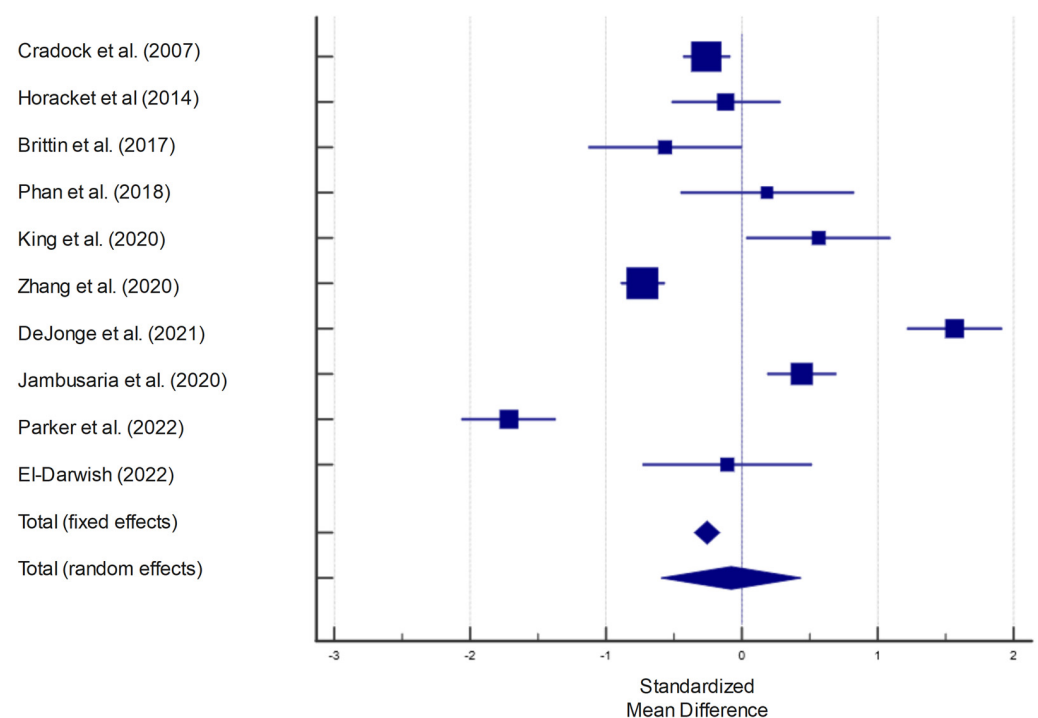
The bottom of the forest plot is depicted in a diamond shape in both the fixed-effect and random-effect model analyses. In the fixed effect analysis, we assume that the true effect size is the same across all studies, and the summary effect is our estimate of this common effect size. The diamond shape indicates a smaller effect size and a 95% confidence interval (CI), which indicates statistical significance ($p < 0.001$), but for the random-effect analysis, it is assumed that the true effect size varies from study to study and that the studies in our analysis represent a random sample of observable effect sizes. The diamond shape is wider and crosses the line of null effect, which is statistically not significant.

For heterogeneity, which represents variations in the result and impact of physical activity on human health, the I^2 (inconsistency) (96.38%) indicates considerable heterogeneity with $p < 0.0001$. The I^2 over 75% suggests considerable heterogeneity [88]. Egger’s and Begg’s tests are the most commonly used tests to detect bias in studies included in a meta-analysis [89]. Thus, the p -value for Egger’s test is 0.4459 and the p -value for Begg’s test is 0.5312, indicating no evidence of publication bias. Another common technique in evaluating the potential effect of publication bias is the funnel plot, often used in a meta-analysis [86–90].

Table 2. Pooled data show that physical activity, in general, has an impact on human health in the built environment.

Study and Country/Region	N1	N2	Total	SMD	SE	95% CI	t	p	Weight (%)	
									Fixed	Random
[52]—U.S.	248	248	496	−0.260	0.0900	−0.437 to −0.0830			26.66	10.59
[43]—U.S.	29	134	163	−0.117	0.204	−0.520 to 0.286			5.20	10.07
[41]—U.S.	32	21	53	−0.565	0.282	−1.131 to 0.00165			2.72	9.55
[55]—Taiwan	27	15	42	0.186	0.317	−0.454 to 0.825			2.16	9.29
[53]—U.S.	83	17	100	0.563	0.267	0.0327 to 1.093			3.03	9.66
[54]—China	305	310	615	−0.731	0.0832	−0.894 to −0.567			31.23	10.61
[42]—Canada	101	68	169	1.567	0.178	1.216 to 1.918			6.83	10.22
[44]—India	122	122	244	0.442	0.129	0.187 to 0.696			12.95	10.45
[45]—Australia	88	88	176	−1.716	0.176	−2.063 to −1.369			7.00	10.23
[46]—Egypt	30	15	45	−0.108	0.311	−0.735 to 0.519			2.24	9.33
Total (fixed effects)	1065	1038	2103	−0.256	0.0465	−0.347 to −0.165	−5.509	<0.001	100.00	100.00
Total (random effects)	1065	1038	2103	−0.0785	0.264	−0.596 to 0.439	−0.298	0.766	100.00	100.00

Heterogeneity: $Q = 248.9337$; $DF = 9$; significance level = $p < 0.0001$; I^2 (inconsistency) = 96.38%; 95% CI for $I^2 = 94.83$ to 97. Publication bias: Egger's test; intercept = 3.0240; 95% CI = −5.6742 to 11.7223; significance level $p = 0.4459$; Begg's test; Kendall's Tau = 0.1556; significance level $p = 0.5312$.

**Figure 3.** The meta-analysis outcomes of the forest plot show SMD, effect size, 95% CI, and total effect model analyses for both fixed-effect and random-effect model among the findings of all studies [41–46,52–55].

Overall, considering physical activity in general, it will have a significant impact on the health of the human body according to the limited studies with statistical analyses, although the results of meta-analyses show consistency in the results of the studies. Therefore, the built environment can promote physical activity and create a connection between the active design and the campus setting. It is recommended that future studies divide physical activity into three categories, mentally active, socially active, and physically active, and then analyze the results statistically. The funnel plot shows no evidence of publication bias and is symmetric. As the studies are widely dispersed near the top of the funnel, it reduces the standard error and increases the accuracy of the estimate, as shown in Figure 4.

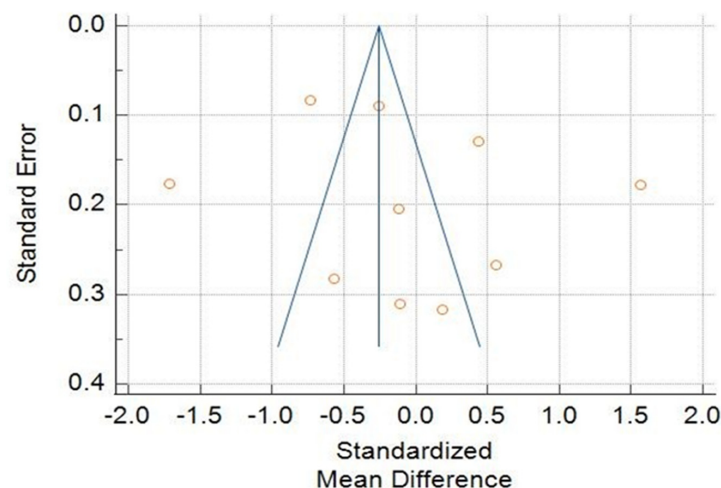


Figure 4. Funnel plot shows publication bias of meta-analysis studies. The standard error on (y-axis) represent study precision, the standardized mean difference on (x-axis) represent study result, each small circle is separate study, the vertical line in the center is overall effect from meta analyses and the line either on left and right side of vertical line represent 95% confidence intervals.

4. Discussion

The result of the meta-analysis provides an overview of the published evidence regarding the association between physical activity and campus built environments to achieve healthy behavior and active lifestyles among students through an active design approach and healthy behavior theories. Our primary goal was directed at the association of the built environment with the active design of different categories of physical activity, namely the three categories of physically active, mentally active, and socially active, and human health, but due to the limited statistical analysis evidence, physical activity was considered in general.

The built environment has a role in shaping healthy behavior outcomes [91,92]. This indicates that the built environment (urban planning, land use) and physical activity are clearly associated [93]. Therefore, there is a relationship between the campus built environment and physical activity [94]. Moreover, physical activity has a positive impact on human health through cardiovascular health and combined built environment strategies to improve public health [95]. The primary dimensions describing how the built environment affects physical activity are infrastructure, aesthetic qualities, street network design, safety, exercise facilities, density, and intensity [96,97]. We can see that there is a strong linkage between the built environment and physical activity to achieve public health; as shown in Table 1, nine out of ten studies revealed that physical activity has a positive impact on student health. Thus, we should strengthen this linkage through not only a design approach or guidelines, policy, and strategies, but the combination of models and theory.

Based on the results shown in Table 1 and the meta-analysis outputs in Table 2 and Figure 3, it can be considered that the new active design approach, by promoting different categories of physical activity (physically active, mentally active, and socially active), will produce a positive impact on human health, as well as contributing to the

reduction of chronic diseases through the design of the built environment. From the forest plots, three out of ten studies are not significant [25,28,31] and seven out of ten are significant [41–45,52–54]. There are multiple pieces of evidence showing that active design is an approach through which to enhance physical activity, create an active environment, and improve public health. Studies used active design guidelines [11], active design strategies [98], and the role of active design in improving physical health [99], as well as improving the physical activity environment [100]. Active design is an architectural intervention [101]. The new active design strategy, developed by AIA and Sport England, has Fitwell and LEED certification and aims to increase human activity through physical activity in built environments to achieve healthy behavior.

To envision physical activity and its effective intervention, healthy behavior theories are vital. Studies that have used theory have produced varying results. For instance, four main theoretical frameworks—social cognitive, humanistic, dual process, and socioecological—have been employed for years to understand and control physical activity. Each has a unique impact on how we perceive physical activity, e.g., the social cognitive tradition has significantly contributed information on key ideas relating to physical activity. The humanistic paradigm has shown some initial promise in both explaining behavior and changing it. Among the fewest and most recently researched models, the dual process model characterizes and motivates physical activity in a broader context by considering hedonic and non-conscious aspects of physical activity. However, the socioecological framework, which has attracted a lot of academic interest in the last 15 years, has been crucial in understanding how the built environment influences physical activity behavior and in formulating public health policies in the government [102]. The basic ideas of Bandura’s social cognitive theory, which explains human behavior, are related to physical activity and articulate the causal mechanisms through which efficacy beliefs, outcome expectations, socio-structural factors, and goals influence behavior [103]. Moreover, the theory of planned behavior has been advanced, adding three motivating factors to the practice of sports [9]. The social–ecological model is a scheme to support physical activity; as a result, active lifestyles are encouraged via personal characteristics that influence decision making about physical activity [104]. The ecological model of active living examines whether people engage in active lifestyles [105]. Thus, healthy behavior theories would have a crucial effect on physical activity and interventions to create a healthy and active built environment to obtain healthy behavior outcomes.

Table 1, related to the physical activity outcomes of the reviewed studies, establishes a theoretical proposal by the authors to fill the knowledge gaps in research findings in general and in future meta-analyses. This proposal is represented by designing a model to integrate active design and healthy behavior theories to achieve a healthy built environment. According to the definition in [21], a person has to be physically active, mentally active, and socially active in the built environment. From the bottom to the middle of Figure 5, healthy behavior theory is divided into intrapersonal (individual) [106] include theories as protection motivation theory [107–109], transtheoretical model [110], attribution theory [81], health belief model [76,77], theory of reasoned action and planned behaviour [71–75] and self-efficiency theory [79,82–84], interpersonal (built environment) [106] include social cognitive theory [78–80], and community (social) [62,106,111] include theories as social capital theory [112–115], social ecological model [62–65] and diffusion of innovation [66–70], which all come together to create a healthy built environment to achieve a healthy community and behavior. This model will assist researchers in conducting additional, theoretically grounded, statistically significant studies in the future to obtain an accurate estimate of a healthy built environment.

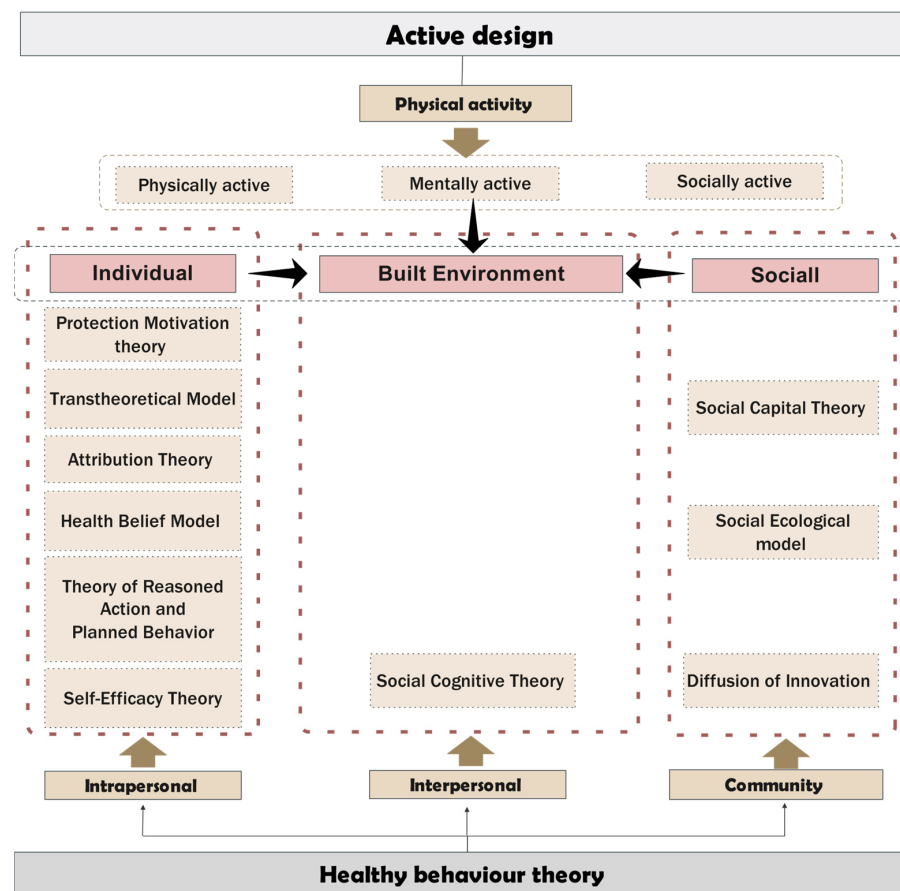


Figure 5. A model designed by the authors for the integration of an active design approach and healthy behavior theory for future research.

5. Conclusions

This study examined how physical activity affects people's health in the built environment of a university campus. It is a meta-analysis taking into account changes in human health as a result of physical exercise and the creation of a healthy built environment for society, as well as investigating the relationship between physical activity and mental health on the one hand, and the relationship between social participation and mental health on the other hand. The work showed that nine out of ten studies revealed positive effects between the built environment, physical activity, and the human body, while only one study showed a negative effect of physical activity on memory capacity and attention. The following conclusions were drawn based on the outputs of the statistical and meta-analyses:

- The important effects of physical activity in campus-built environments with aspects such as walkability, play areas, and building design on human health have been discussed in greater detail in several research studies.
- Some studies emphasize the importance of active built environments and their function in improving human health by presenting physical activity interventions on pre- and post-education campuses. The work also demonstrated the advantages of activism in caring for those with mental disorders.
- The campus layout affects walkability and enhances physical activity, thus reducing signs of stress and anxiety, which is an important element that should be taken into account in the design of built environments for university campuses. The reason behind the lack of activity of students may be that they do not have enough time to be active and this is what makes the active design approach an urgent matter.
- Additionally, the current study proved to be free of publication bias. Given this heterogeneity, and based on the data provided regarding the detection of any potential

effects related to the three categories of exercise, future studies are prompted to fill this knowledge gap with more statistical analyses.

- Due to the limited statistical analyses on the three categories of physical activity (physically active, mentally active, and socially active), this research adopted a meta-analysis of physical activity, rather than these categories. What has emerged in this study provides a solid basis for conducting future research based on these three categories with statistical analyses.

These conclusions support the following recommendations, which could lay the groundwork for future research and studies:

- It is suggested that the model be utilized alongside Figure 1 for future studies to identify keywords on the three categories of physical activity (physically active, mentally active, and socially active) to attain an active lifestyle for the community based on healthy behavior theories with statistical analyses.
- It is recommended that the relationship between the three aspects of physical activity within built environments (physically active, mentally active, and socially active) be clarified and evaluated using different methodologies and statistical analyses.
- It is recommended to evaluate the campus layouts of different educational institutions because of its role in enhancing the physical activity of students and thus improving their mental health and mood.

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