

How the neighborhood influences our physical activity and mental health:

A scoping review

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Abstract

Background The built neighborhood an individual lives in can have an influence on the physical activity and mental health of this individual. The neighborhood has different characteristics and can be measured objectively or subjectively. Also, physical activity can have an effect on the mental health of individuals. The aim of this review was to find out which neighborhood characteristics most influence the physical activity and mental health of the residents. Additionally, it was investigated whether there is a difference between the objectively and subjectively measured neighborhood. Lastly, it was investigated whether there was a mediation effect of physical activity on the relationship between the neighborhood and mental health. **Methods** A scoping literature review was conducted. PsychInfo and Scopus were used as databases. The inclusion criteria were that the studies needed to be open access, in a non-occupational context and had a measure of mental health, neighborhood and physical activity. The studies that were found were screened using Endnote X9. Further Microsoft Word was used to organize the results in tabular form and to give a profound overview and exploration of the found data. **Results** This review found that the pedestrian infrastructure of the neighborhood and a feeling of safety in traffic as well as generally in the neighborhood are among the most important characteristics that determine physical activity and mental health of the residents. Further, it was found that the perceived walkability increases physical activity and mental health. Objective greenspace could not predict an increase in physical activity but in mental health. However, it was found that physical activity can have a mediating effect on the relationship between objective greenspace and mental health. **Discussion** An increase in the walkability and greenspace of neighborhoods can increase physical activity and better mental health of its residents. In order to accelerate those benefits of greenspace it is suggested to pair an increase of greenspace with the onset of e.g., walking programs.

How the neighborhood influences our physical activity and mental health A scoping review

The neighborhood we live in can have an impact on our everyday life. It can influence our physical activity levels and our mental health (Maas et al., 2006). There are different factors in the neighborhood that can affect our physical activity and mental health. Physical activity and mental health are crucial components of living a healthy and fulfilling life (McAuley & Morris, 2007). So, it is of interest to investigate which specific elements of the neighborhood environment have an effect on the physical activity and mental health of the residents.

Built neighborhood environment

The effects the neighborhood has on its residents is dependent from various factors. Among others those factors can be of socioeconomic nature, societal nature and of environmental nature. The socioeconomic and societal factors are determined by the people living there, e.g., whether they have a good paid job or whether they have supporting family and friends in the neighborhood (Cramm, Van Dyck & Nieboer, 2013; Van Dyck et al., 2010). The environmental factor is more about the actual built neighborhood. This is the factor that can be influenced drastically and directly by designing the neighborhood in a resident friendly way (Zuniga-Teran et al., 2019). When designing a neighborhood, the walkability and the greenspace are common fields. To identify the most resident friendly way of designing the neighborhood it is important to identify the specific characteristics of the walkability and greenspace of the neighborhood that have the most influence on the physical activity and mental health of its residents.

The built neighborhood walkability and greenspace can be measured in different ways.

It is important to differentiate between the objectively measured and the perceived neighborhood since citizens of the same neighborhood may have a dissimilar perception of it (Peters et al., 2020). Also, results coming from perceived and objective ratings can differ (Thompson et al., 2014). First, the built neighborhood can be objectively measured (Hoehner et al., 2005). It can be measured how walkable a neighborhood is (Van Dyck et al., 2010). An objective neighborhood measurement can include the quality of the pathways or the distance between the residential area and parks. It can also be measured how green a neighborhood is (Besser & Mitsova, 2021). There the greenspace of a neighborhood gets estimated by using different devices to see for example how much percentage of the neighborhood is green or to assess the tree density in a neighborhood. Secondly, the built neighborhood can be measured by its citizens (Hoehner et al., 2005). The, by the citizens, perceived neighborhood environment can be measured with questionnaires where the citizens indicate for example their feeling of how far the nearest park is or how they like the greenness of the neighborhood. Both, the objectively measured and the perceived neighborhood environment can have effects on the physical activity and mental health of its citizens.

Physical activity

It has shown that individuals living in objectively measured more walkable neighborhoods also have higher physical activity levels than those who do not (Rundle et al., 2019; Van Dyck et al., 2010; Besser & Mitsova, 2021). This can be because individuals in more walkable neighborhoods may engage in more walking for transportation or cycling (Van Dyck et al., 2010). They also engage in more recreational walking and general physical activity (Sundquist et al., 2011). It is stated that the physical activity of the citizens may be context-related in the neighborhood. Here, context-related describes the frame of the physical activity, for example leisure time walking or walking for transportation (Sundquist et al., 2011). In addition to the objective walkability of a neighborhood also the objectively

measured greenspace can influence the physical activity level of the citizens (Richardson, Pearce, Mitchell & Kingham, 2013; Besser & Mitsova, 2021). Greenspaces may give the opportunity and motivate the citizens to be more physically active (Richardson et al., 2013). The perceived greenspace of the neighborhood can have a positive impact on physical activity (De Jong et al., 2012). De Jong et al. (2012) state that the perception of the greenspace of the neighborhood may have a stronger effect on physical activity than the objectively measured greenspace. In addition, high objectively measured greenspace can also lead to higher perceived greenspace (De Jong et al., 2012; Stronegger, Titze & Oja, 2010). So, the built neighborhood, either objectively or subjectively measured, can have effects on different areas of physical activity.

Mental health

It was shown that the built neighborhood environment can have an impact on the physical activity levels of the residents. In addition to that the built neighborhood environment can influence the resident's mental health. However, there is few existing research displaying the influence of the built neighborhood on mental health since most studies focus on the bodily health of the residents. Generally, studies have shown that time spend in green areas can have positive effects on mental health issues like depression, anxiety and generally can improve mood (Hansen & Tocchini, 2017). Nature therapy shows that simply being in nature or watching a landscape can alleviate stress and improve the affective state of individuals (Rajoo et al., 2021). Additionally, it has shown that traditional therapy approaches like Cognitive Behavioural Therapy (CBT) show greater effectiveness when carried out in a forest than indoors (Furuyashiki et al., 2019). Also, the wellbeing of individuals improves when being in greenspace because the connectedness to nature sensitizes the individual in being part of a greater whole, therefore encouraging a greater sense of meaning (Berger, 2009). Moreover, it was found that the objectively measured

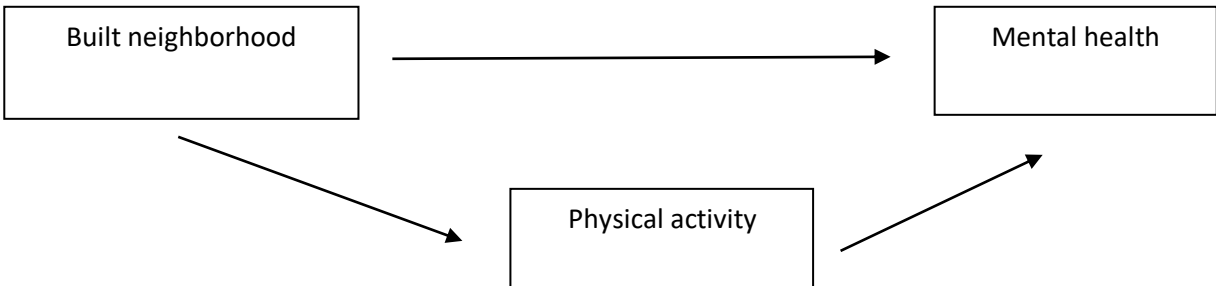
greenspace in a neighborhood can improve the mental health of its citizens (Maas et al., 2006). Also, it has shown that the perceived walkability of a neighborhood has a positive effect on mental health, because the residents felt safe to move in their neighborhood which led to higher satisfaction (Leslie & Cerin, 2008). So, an increase of greenspace and walkability could decrease mental health issues.

There also is a well-established connection between physical activity and mental health. It has shown that physical activity can alleviate the symptoms of e.g., depression or anxiety (Paluska & Schwenk, 2000). Physically active individuals display better mood and general mental health than their physically inactive counterparts (Biddle, 2016). So, it is expectable that physical activity has an indirect effect on the relationship between the built neighborhood and mental health.

As shown above literature implies that there is a relationship between the built neighborhood and physical activity and between physical activity and mental health. Also, it was shown that there is a literature gap in the relationship between the built neighborhood and mental health. Consequently, this scoping review will explore which elements of the built neighborhood influence mental health. Also, it was explored whether physical activity has a mediating effect on the relationship between built neighborhood and mental health. Lastly, it was explored what difference there is when the neighborhood is subjectively or objectively measured.

Figure 1

Theoretical framework



Methods

A scoping review as described by Arksey and O'Malley (2005) will be done. In retrospect two sub questions were formulated, because there was not enough evidence to sufficiently answer the research question. The introduction was adapted accordingly.

Identifying the research question

The first stage of the model by Arksey and O'Malley (2005) is "Identifying the research question". As can be drawn from the theoretical framework above, the research question is "what effects do the characteristics of the built neighborhood have on the physical activity and the mental health of the residents?". The later added sub question are "what effects do the objectively measured and perceived built neighborhood have on the physical activity and mental health of the residents?" and "is there a mediating effect of physical activity on the association between neighborhood and mental health?".

Identifying relevant studies

The second stage is "Identifying relevant studies". The database PsychInfo was chosen because it features a lot of different journals regarding mental health which makes it useful for this review. Scopus was chosen because it is offering many articles and journals from different disciplines. It is important that both databases feature different research disciplines because this review includes different disciplines.

The topics of this review are the neighborhood environment, physical activity and mental health. In order to find corresponding articles a search string was constructed. The search string includes different synonyms for the before mentioned topics. Also, themes of the topics like "depression" for mental health were used to get an comprehensive overview of all related articles. Further the search string contains different spellings of the same words e.g. "behaviour" and "behavior", to make sure that all relevant articles are included.

(anxiety OR depression OR "mental health" OR "mental illness" OR "stress" OR “wellbeing” OR “well being” OR “well-being”) AND (neighborhood OR neighbourhood OR “green areas” OR "neighborhood changes" OR “neighbourhood changes” OR “neighbourhood environment” OR “urban environment” OR "environmental changes" OR “neighborhood environment”) AND “physical activity” AND (adult OR adults OR “older adults”) NOT (children OR adolescents)

For Scopus (anxiety OR depression OR "mental health" OR "mental illness" OR "stress" OR “wellbeing” OR “well being” OR “well-being”) AND (neighborhood OR neighbourhood OR “green areas” OR "neighborhood changes" OR “neighbourhood changes” OR “neighbourhood environment” OR “urban environment” OR "environmental changes" OR “neighborhood environment”) AND “physical activity” AND (adult OR adults OR “older adults”) AND NOT (children OR adolescents)

In order to organize the references in a systematic way the program Endnote X9 was used.

Study selection

The third stage is “Study selection”. To ensure that the studies are eligible for this scoping review inclusion criteria were formulated. The first inclusion was that the study needs to be open access. Secondly the study had to be in a non-occupational context. And thirdly the study got included when there was a measure of mental health, neighborhood and physical activity. This means that for example for mental health the study needed to have a wellbeing or mental pathology measure. Also, fourthly the study needed to have results to be included.

Charting the data

The fourth stage is “Charting the data”. The data that is extracted by the studies is written down in tabular form. To create the tables the program Microsoft Word was used. The section includes the study characteristics (authors, year, study design, country, number of participants and age range) and the content and findings of the studies (aims, instruments and findings) (Table 1; Table 2).

Collating, summarizing, and reporting the results

The fifth stage is “Collating, summarizing and reporting the results”. Then the results were reported by describing four topics. The first topic describes the specific built neighborhood characteristics that influence mental health and physical activity the most. The third and fourth topic then describe the results regarding the objective and perceived walkability of the neighborhood and the objective and perceived greenspace of the neighborhood.

Results

First, the results of the screening process will be shown. Next the general characteristics of the chosen studies will be described. Then the research questions will be investigated. A summary of the findings can be found in Table 2.

After putting the search strings in the corresponding data bases a total of 507 articles were accumulated. After the title screening 319 were excluded. In the abstract screening 158 articles were excluded because 12 of them were not about the non-occupational context, 4 articles were proposals without results and 142 were excluded because there was either a mental health measure, a neighborhood measure or a physical activity measure missing. In the full text screening 16 articles were excluded because 5 articles were not open access, and 11 articles did not have a measure of mental health, neighborhood, or physical activity. So, there

were 14 articles included in this review (Figure 2). Almost all of the studies were cross-sectional survey studies. There was one experimental design study (Thompson et al., 2014). Also, eight studies have samples that are middle aged or older. For more study characteristics see Table 1.

Figure 2

Diagram for article selection

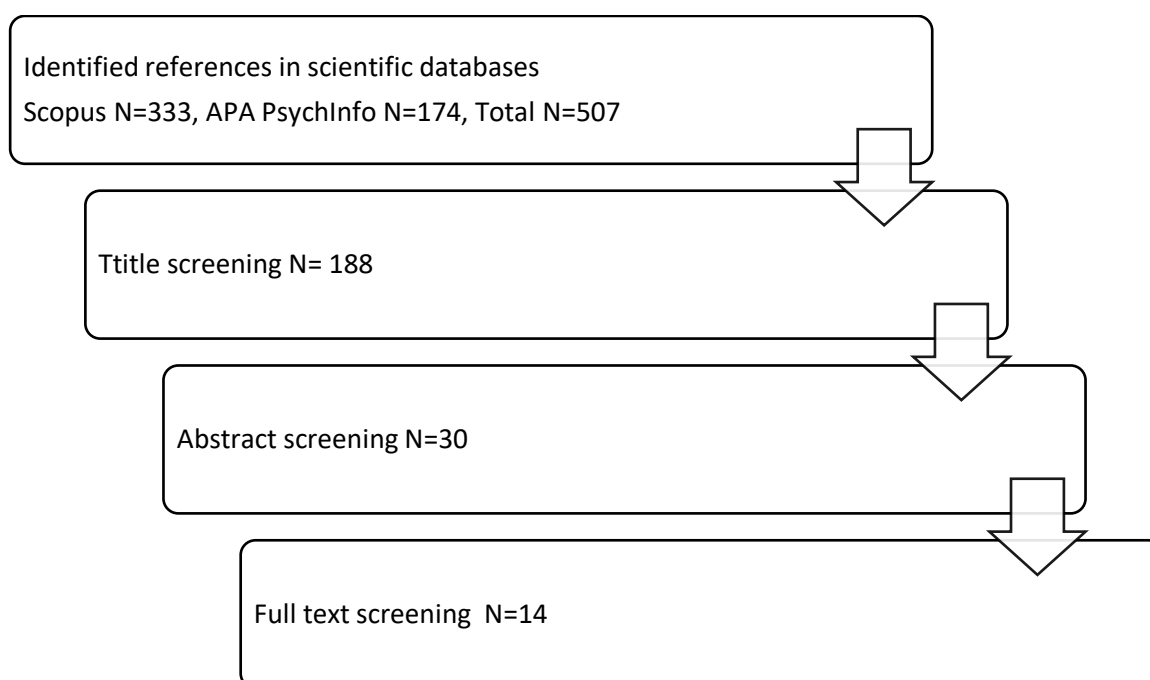


Table 1

Study characteristics

Authors	Year	Study Design	Country	Number of Participants	Age range
Astell-Burt et al.	2013	Cross-sectional study	Australia	260,061	45 to 106

De Vries et al.	2013	Cross-sectional study	Netherlands	1,641	μ 51
Dzhambov et al.	2018	Cross-sectional study	Bulgaria	720	18-35
Fan et al.	2011	Cross-sectional study	USA	1,699	18-75
Liu et al.	2022	Cross-sectional study	China, Ghana, India, South-Africa, Russia, Mexico	5,870	50+
Orstad et al.	2018	Cross-sectional study	USA	60,133	61-88
Orstad et al.	2020	Cross-sectional study	USA (New York)	3,811	18-65+
Petrunoff et al.	2021	Cross-sectional study	Singapore	3,435	21-75
Theodoropoulou et al.	2017	Cross-sectional study	Greece	684	18-65
Thompson et al.	2014	Experimental Pre-post design, postquestionnaire 2 years later	England, Wales, Scotland	Pre: Intervention group: 56 Comparison group: 40 Post: Intervention	65+

				group: 29	
				Comparison	
				group: 32	
Van Dyck et al.	2015	Cross-sectional study	Australia	3,965	55-65
Wang et al.	2019	Cross sectional study	China	1,029	20-76
Yu et al.	2017	Cross-sectional study	China	181	60+
Zhang et al.	2019	Cross-sectional study	China	909	65+

Neighborhood characteristics

Six of the 14 studies examined specific neighborhood characteristics that influence physical activity and mental health (Orstad et al., 2018; Theodoropoulou et al., 2017; Thompson et al., 2014; Van Dyck et al., 2015; Yu et al., 2017 & Zhang et al., 2019).

The walkability of a neighborhood has a positive effect on the physical activity and wellbeing of its residents. The number of public open spaces and population density as well as the walking infrastructure, safety in traffic and access to non dwelling areas are the most important characteristics in that regard (Orstad et al., 2018; Yu et al., 2017 & Zhang et al., 2019). Residents of a neighborhood with high connectivity experience higher physical activity rates ($p= 0.017$). Physical activity also acts as a mediator for the positive relationship between connectivity and depression ($p= 0.001$). The same results were found with pedestrian infrastructure (PA: $p= 0.009$; mediation effect: $p= 0.006$) (Zhang et al., 2019).

There were also positive associations found between a physical activity friendly

environment and different forms of physical activity, namely transportation walking (95% CI = 0.15, 0.34) and cycling (95% CI = 0.04, 0.15), leisure time walking (95% CI = 0.15, 0.34) and moderate-to-vigorous physical activity (MVPA) (95% CI = 0.19, 0.37), and quality of life (95% CI = 1.82, 4.11) (Van Dyck et al., 2015). There also was a mediating effect of those physical activities and the positive relationship between the physical activity friendly environment and quality of life (transportation walking: $\beta = 0.45$, 95% CI = 0.08, 0.83; transportation cycling: $\beta = 0.95$, 95% CI = 0.30, 1.59; leisure time walking: $\beta = 0.85$, 95% CI = 0.48, 1.22; leisure time MVPA: $\beta = 0.93$, 95% CI = 0.56, 1.30). Similar to that they also found that individuals that perceive their neighborhood as safe also had higher physical activity in transportation cycling (95% CI = 0.02, 0.10) and leisure MVPA (95% CI = 0.01, 0.14), and higher quality of life scores (95% CI = 1.54, 3.22). There were also corresponding meditation effects found (transportation cycling: $\beta = 0.96$, 95% CI = 0.01, 0.11; leisure MVPA: $\beta = 1.07$, 95% CI = 0.01, 0.14). For the perceived aesthetics of a neighborhood there were no associations found to physical activity or quality of life (QoL: 95% CI = -0.96, 1.55) (Van Dyck et al., 2015).

Adding to that it was found that residents who experience their neighborhood as generally physical activity friendly also have higher physical activity levels ($\beta = 0.11$, $p < 0.05$) and higher mental health levels ($\beta = 0.11$, $p < 0.05$) (Theorodopoulou et al., 2017).

Moreover, it was found that improving the pathways for walking and cycling and creating an attractive route network to public open places were important factors for the improvement of wellbeing ($\beta = 0.280$, $p < 0.001$) and physical activity ($\beta = 0.293$, $p < 0.05$). It has shown that the accessibility of those places also improves wellbeing ($\beta = 0.231$, $p < 0.05$) and time spent outdoors ($\beta = 0.236$, $p < 0.05$). Also, the possibility to park the car outside led to more time that was spend outdoors (Thompson et al., 2014).

To conclude there are numerous neighborhood characteristics that improve the

physical activity and mental health of the residents. The number of public open spaces and population density has an impact on the physical activity of the residents (Orstad et al., 2018). The walking infrastructure, safety in traffic and access to areas that are not dwelling areas can improve wellbeing (Yu et al., 2017). A physical activity friendly environment and general safety feeling in the neighborhood can increase physical activity and mental health levels (Van Dyck et al., 2015 & Theodoropoulou et al., 2017). Lastly, connectivity, pedestrian infrastructure, pathways for walking and cycling, an attractive route network to public open places and parking slots can improve physical activity and mental health (Thompson et al., 2014 & Zhang et al., 2019).

Neighborhood measures: objective and perceived walkability

From the 14 examined articles there were two articles measuring the walkability of the neighborhood (Orstad et al., 2018 & Yu et al., 2017). One of the studies measured the walkability of the neighborhood objectively and additionally measured the perceived walkability (Orstad et al., 2018). The other study only measured the perceived walkability (Yu et al., 2017).

It was found that higher perceived walkability improved physical activity by 1.99 times (95% BC CI = 1.92, 2.06). Also, the perceived walkability improved by 1.59 times when there were higher ratings of objective walkability. So, higher objective walkability led to higher perceived walkability which in turn led to higher physical activity. However, the effect on physical activity decreased, but was not diminished, when there were depressive symptoms (Orstad et al., 2018).

Additionally, there was no effect found of perceived walkability on physical activity, but a positive effect on walking time ($p = 0.001$). Individuals with better perception of the neighborhood ratings also experienced better wellbeing than their counterparts ($p = 0.002$) (Yu et al., 2017).

To conclude, Orstadt et al., (2018) found that the perceived walkability of a neighborhood increases physical activity. Lastly, Yu et al., (2017) found that perceived walkability increases wellbeing and walking time but not general physical activity.

Neighborhood measures: objective and perceived greenspace

Out of 14 examined articles eight articles measured the greenspace of a neighborhood. Seven of those studies examined the effects of objectively measured greenspace (Astell-Burt et al, 2013; De Vries et al., 2013; Fan et al, 2011; Liu et al, 2022 & Wang et al, 2019). Two other studies investigated both the objective and perceived greenspace (Dzhambov et al., 2018 & Petrunoff et al., 2021). One study examined only the effects of perceived greenspace (Orstad et al.,2020).

It was found that individuals living in greener neighborhoods have higher physical activity levels. However, greenspace alone did not provide that effect. Also, individuals living in more greenspace had decreased psychological distress (OR 0.83, 95% CI: 0.76, 0.92). There was a positive effect between greenspace and mental health mediated by physical activity (OR 0.82, 95% CI: 0.67, 0.99), with the condition that the individuals are moderately active. Individuals with lower activity rates did not benefit from a greener neighborhood (OR 0.99, 95% CI: 0.85, 1.15) (Astall-Burt et al., 2013). Adding to that, Liu et al. (2022) also did not find a relationship between objective greenspace and physical activity ($\beta = -0.136$, $p > 0.05$). However, the individuals living in greener neighborhoods had higher life satisfaction ($\beta = .200$, $p < 0.05$) There was no mediation effect found of physical activity on objective greenspace and life satisfaction ($\beta = -0.004$, $p > 0.05$).

Contrary to that, Wang et al. (2019) found a positive effect of greenspace on physical activity and on mental health separately. Both measures had a positive relationship to regarding physical activity (streetscape greenery: $\beta = 24.397$, $p < 0.01$; NDVI: $\beta = 10.028$, $p < 0.05$) and mental health (streetscape greenery: $\beta = 3.768$, $p < 0.05$; NDVI: $\beta = 9.960$, $p < 0.05$).

They also found that physical activity has a mediating effect on the positive relationship between objective greenspace and mental health (Sobel test: streetscape greenery: $Z = 2.412$, $p = 0.016$; NDVI $Z = 2.077$, $p = 0.038$). The only difference of the measures was that higher streetscape greenery decreases stress whereas the NDVI measure had no effect (streetscape greenery: $\beta = -3.082$, $p < 0.05$; NDVI: $\beta = 1.623$, $p > 0.01$) (Wang et al., 2019).

Another study did not only assess the objective quantity of greenspace but also the quality of greenspace. Objective quantity and quality have a positive effect on mental health (quantity: $\beta = 1.220$, $p < 0.01$; quality: $\beta = 3.231$, $p < 0.05$) and stress (quantity: $\beta = -0.154$, $p < 0.05$; quality: $\beta = -0.381$, $p < 0.01$). There was no effect on physical activity (quantity: $\beta = 0.074$, $p > 0.05$; quality $\beta = 0.112$, $p > 0.05$). However, only the observed quality has a positive effect on green activity ($\beta = 0.305$, $p < 0.01$). Green activity also has a mediating effect on the positive association between objective quantity and quality of greenspace and mental health (quantity: $\beta = 1.151$, $p < 0.01$; quality: $\beta = 2.936$, $p < 0.001$) (De Vries et al., 2013). Further Fan et al., 2011 did not only measure overall greenspace but also the overall number of parks and park distance. There was no measure of a mediation effect for physical activity. It was found that the overall greenspace does not influence physical activity ($\beta = -0.001$, $p > 0.1$), but it improves stress ($\beta = -0.044$, $p < 0.1$). Moreover, the distance to which an individual lives from a park does not predict stress or physical activity levels. However, a higher number of parks in a neighborhood predicts higher physical activity ($\beta = 0.024$, $p < 0.1$), but not stress levels ($\beta = 0.017$, $p > 0.1$) (Fan et al., 2011).

Besides the objective number of parks in a neighborhood also the perceived access to parks was measured by two studies (Orstad et al., 2020 & Petrunoff et al., 2021). It was found that there was higher park related physical activity and mental health levels when the individuals perceived that they could access the park quickly (PA: $\beta = 0.16$, 95% CI = 0.10, 0.18; MH: $\beta = -0.35$, 95% CI = -0.61, -0.10)). There also was a mediation effect of park

related physical activity on the positive association of perceived park access and mental health ($\beta = 0.16$, 95% CI = 0.10, 0.18). However, for those associations the individuals need to be low in worry about crimes in the park (Orstad et al., 2020). Partially in line with that Petrunoff et al. (2021) found that the perception of easy and quick park access predicts higher wellbeing scores ($p = 0.05$). Although, it also predicts higher park usage ($p < 0.001$) it did not predict physical activity. Higher park use also predicts better wellbeing ($p < 0.001$). Additionally, objective park access could not predict park usage, physical activity or wellbeing (wellbeing: $p = 0.215$). Also, the perception of the park access of the individuals was different from the actual identified access (Petrunoff et al., 2021).

Another study found that individuals living in objectively green areas score better in mental health ($p = 0.049$), but their physical activity levels are not influenced. There was a mediating effect of physical activity on the relationship between objective greenspace, perceived green space and mental health ($p = 0.002$) (Dzhambov et al, 2018).

Seven out of 14 studies examined the objective greenspace (Astell-Burt et al, 2013; De Vries et al., 2013; Fan et al, 2011; Liu et al, 2022; Wang et al, 2019; Dzhambov et al., 2018 & Petrunoff et al., 2021). Two of those found a positive effect on physical activity (Astell-Burt et al, 2013 & Wang et al, 2019). The remaining five did not find an effect on physical activity (De Vries et al., 2013; Dzhambov et al., 2018; Fan et al, 2011; Liu et al, 2022 & Petrunoff et al., 2021). Four studies found a positive effect on mental health (De Vries et al., 2013; Dzhambov et al., 2018; Liu et al, 2022 & Wang et al, 2019). Two studies did not find an effect on mental health (Astell-Burt et al, 2013 & Petrunoff et al., 2021). Also, three studies have found a positive effect on stress. (De Vries et al., 2013; Fan et al, 2011 & Wang et al, 2019). Three studies found that physical activity acted as a mediator on the positive relationship between objective greenspace and mental health (Astell-Burt et al, 2013; De Vries et al., 2013 & Wang et al, 2019). One study did not find an effect (Liu et al, 2022). Four

studies did not measure the mediation effect (Dzhambov et al., 2018; Fan et al, 2011 & Petrunoff et al., 2021).

Three of the 14 studies examined the perceived greenspace (Dzhambov et al., 2018; Orstad et al., 2020 & Petrunoff et al., 2021). Two studies found a positive effect on physical activity (Dzhambov et al., 2018 & Orstad et al., 2020). Correspondingly, one study did not find an effect (Petrunoff et al., 2021). All three studies (Dzhambov et al., 2018; Orstad et al., 2020 & Petrunoff et al., 2021) found a positive effect on mental health. Two studies found that physical activity mediated the positive relationship between perceived greenspace and mental health (Dzhambov et al., 2018 & Orstad et al., 2020). One study did not measure the mediation effect (Petrunoff et al., 2021).

Table 2*Aims, Findings and Instruments of the studies*

Study	Aims	Instruments	Findings
Astell-Burt et al.	This study wants to assess the relationship between objectively measured green space and psychological distress, and whether green space improves the positive effect of physical activity in decreasing psychological distress	K10 Meshblocks, GIS (for amount of parkland) AAS	Objective greenspace leads to more physical active, no effect on mental health Objective greenspace leads to better physically active leads to way better distress, when little activity green space does not matter for distress
De Vries et al.	This study assesses whether (objectively measured) more or better streetscape greenery leads to less stress and higher physical activity, and whether stress decreases health and physical activity	SF-36, MHI-5, PSS-SF Observed quantity and quality streetscape greenery SQUASH, green physical	Observed quantity & quality of greenspace leads to better mental health, better stress, no effect on physical activity Observed quantity of greenspace leads to only better stress

	increases health, and that stress and physical activity influences the relationship between streetscape greenery and health	activity	Observed quality of greenspace leads to better green physical activity Observed quantity & quality of greenspace leads to better green physical activity leads to better mental health
Dzhambov et al.	The study assesses the relationship between greenness/blueness and mental health, further it assesses whether the objective and subjectively measured greenness/blueness has an influence on that relationship and whether physical activity plays a role	GHQ-12 NDVI, Tree Cover Density 2012 map, Urban atlas 2012 (percentage of green areas), Euclidean distance Perceived Neighborhood greenness/blueness (own questionnaire developed) SQUASH (only commuting/leisure walking/bicycling)	Objective greenspace leads to better mental health, no effect on physical activity Objective greenspace leads to better perceived greenspace leads to better mental health (stronger), better physical activity Objective greenspace leads to better perceived greenspace leads to better physical activity leads to mental health

Fan et al.	The study assesses whether greenness influences physical activity and stress and whether stress and physical activity influence each other opposite wise	PSS NDVI, total number of parks, distance to nearest park Self-reported physical activity	Objective overall greenspace leads to better stress, no effect on physical activity Objective distance nearest park leads to no effect on physical activity, no effect on stress Objective Park acreage leads to no effect on stress, better physical activity No measure of a mediation effect by physical activity
Liu et al.	The study assesses whether greenery has an influence on physical activity and then an influence on the subjective wellbeing, also it is assessed whether greenery has a direct effect on subjective wellbeing	Subjective wellbeing (cognitive [life satisfaction] and emotional [positive and negative affect] component) NDVI Total amount of time in travel- and recreation related physical activity	Objective greenspace leads to better life satisfaction, no effect on physical activity Physical activity did not mediate the relationship between greenspace and life satisfaction

Orstad et al. (2018)	The study assesses what influence the objectively measured neighborhood walkability has on physical activity and what indirect effect via subjectively perceived neighborhood walkability it has on physical activity. Also, it is assessed whether depressive symptoms influence any of these relationships.	GDS-15 GIS, intersection count, facility count, population density PANES Neighborhood walking, physical activity recommendations	Objective walkability leads to better perceived walkability Perceived walkability leads to better physical activity Objective walkability leads to better perceived walkability leads to better physical activity, but when adding depressive symptoms those weaken effect (still effect there) Objective facility count and population density most important
Orstad et al. (2020)	This study assesses whether the relationship between park proximity and mental distress is influenced by the individual using the park that is nearest at home for physical activity. Also, it is assessed whether a negative relationship between park proximity and mental	Measures of general psychological distress, quality of life Park proximity exposure (self-reported) GPAQ	Perceived Park proximity leads to better park use for physical activity, better mental health Perceived Park proximity leads to better park use for physical activity leads to better mental health Only when the individuals were not concerned about perceived park crime

	distress is stronger in physical active populations.		
Petrunoff et al.	This study assesses the relationships between true and perceived park access, park usage and park physical activity. It is also assessed how those associations relate to the overall wellbeing of the citizens.	WELL True Park access, perceived park access Park physical activity	Observed Park access leads to no effect on park physical activity, no effect on park use, no effect on wellbeing Perceived Park access leads to no effect on park physical activity, better park use, better wellbeing Park use leads to better wellbeing Poor consensus between objective and perceived park access
Theodoropoulou et al.	This study assesses the associations between the perceived neighborhood environment, physical activity, and quality of life.	SWLS, SF-36 (MCS factor) NES (perceived) IPAQ	Perceived neighborhood environment for physical activity leads to better (but low) physical activity, better mental health, better quality of life No measure of mediation effect by physical activity
Thompson et al.	This study assesses the influence of the built neighborhood on the physical	CASP-19, EQ-5D NOS (perceived)	Objective neighborhood leads to better wellbeing, better physical activity

	activity, wellbeing and quality of life. It also assesses the differences of wellbeing and quality of life after changes in the built environment were undertaken. Further it assesses the self-reported and true physical activity of the participants. (Intervention DIY streets)	Accelerometer, self-reported physical activity	Perceived neighborhood leads to better wellbeing, better physical activity Good walking/cycling paths, no perceived barriers, good routes to open spaces important factors
Van Dyck et al.	The study assesses whether there is a mediation effect of physical activity on the relationship between the perceived neighborhood environment and mental health of the citizens.	SF-36 Perceived neighborhood environment IPAQ-L	Perceived neighborhood safety leads to better cycling for transport, better leisure time MVPA, better quality of life Perceived physical activity neighborhood environment: better walking for transport, better cycling for transport, better leisure time walking better leisure time MVPA, better quality of life Perceived neighborhood aesthetics leads to no effect on physical activity, no effect on quality of life

			There is also a mediation factor of the corresponding physical activity on all above shown associations
Wang et al.	This study assesses the relationship between the two neighborhood measures and mental health. Also, it assesses whether this relationship is mediated by physical activity. Additionally, it assesses whether there are mediation differences with the two neighborhood measures.	WHO-5, self-reported stress Semantic image segmentation techniques (streetscape greenery objects), NDVI Self-reported physical activity	Objective on ground greenspace leads to better physical activity, better mental health, better stress Objective NDVI (birds view) greenspace leads to better physical activity, better mental health, no effect on stress Objective on ground greenspace leads to better physical activity leads to better mental health Objective NDVI greenspace leads to better physical activity leads to better mental health
Yu et al.	The study assesses the relationship between the walkability of the neighborhood and wellbeing and physical activity. It also assesses which walkability elements have the strongest	Subjective Wellbeing NEWS-CS (perceived) PASE, self-reported physical activity	Perceived walkability leads to better wellbeing, better walking time, no effect on physical activity Traffic safety, land use mix-access and walking infrastructure most important

	effects on wellbeing.		
Zhang et al.	The study assesses whether neighborhood characteristics combined with depressive symptoms develop because the neighborhood characteristics are related to low physical activity (because that would increase the chance of depressive symptoms). The study also assesses whether high destination accessibility is associated with higher physical activity and therefore lower depressive symptoms.	GDS-4 EAST-HK IPAQ-SC, NWQ-CS	Objective neighborhood connectivity leads to better physical activity, better depressive symptoms Objective pedestrian infrastructure leads to better physical activity, better depressive symptoms Objective neighborhood connectivity leads to better physical activity leads to better depressive symptoms Objective pedestrian infrastructure leads to better physical activity leads to better depressive symptoms

Note. K10: Kessler Psychological Distress Scale; Meshblocks; GIS: Geographic Information System; AAS: Active Australia Survey; SF-36:

Short-Form 36; MCS factor: factor consisting of social functioning, emotional role and mental health subscales in SF-36; MHI-5: Mental Health

Inventory; PSS-SF: Perceived Stress Scale Short Form; SQUASH: Sort Questionnaire to Assess Health-enhancing physical activity; NDVI:

Normalized Difference Vegetation Index; GHQ-12: General Health Questionnaire 12 item form; NES: Neighborhood Environment Scale; PANES: Physical Activity Neighborhood Environment Survey; GPAQ: Global Physical Activity Questionnaire; GDS-15: Geriatric Depression Scale 15 items; GDS-4: Geriatric Depression Scale 4 items; SWLS: Satisfaction With Life Scale; WELL: WELL for Life Scale; NOS: Neighborhood Open Scale; EQ-5D: general health measure; CASP-19: measure of quality of life; IPAQ-L: International Physical Activity Questionnaire Long Form; IPAQ-SC: International Physical Activity Questionnaire Short Chinese version; WHO-5: World Health Organization Well-Being Index; NEWS-CS & Chinese NEWS-A: Neighborhood Environment Walkability Scale for Chinese Seniors & Chinese Neighborhood Environment Walkability Scale Abbreviated ; PASE: Physical Activity Scale for the Elderly; EAST-HK: Environment in Asia Scan Tool-Hong Kong; NWQ-CS: Neighborhood Walking Questionnaire for Chinese Seniors; MVPA: Moderate to Vigorous Physical Activiy

Discussion

The aim of this study was to find out which neighborhood characteristics do influence the physical activity and mental health levels of its residents. Additionally, it was examined what effects the objective and perceived measures of neighborhood walkability and greenspace have on physical activity and mental health. Lastly, it was examined whether physical activity has a mediating effect on the relationship between neighborhood and mental health. This review found that a general feeling of safety in the neighborhood and the pedestrian infrastructure of the built neighborhood, pathways for walking and cycling, an attractive route network to public open spaces, accessibility of non-residential areas and traffic safety are among the most important factors in improving physical activity and the mental health and wellbeing of the residents. It was found that the perceived walkability of a neighborhood increases physical activity, walking time and wellbeing. Also, objectively measured greenspace did not have an effect on physical activity but a positive effect on mental health and stress. Lastly, there was a mediating effect of physical activity on the positive relationship between objective greenspace and mental health.

Characteristics and walkability of the neighborhood

This review suggests that the perceived walkability of a neighborhood can have positive effects on physical activity and mental health. One of the most important identified factors is the perceived safety in the neighborhood. Here either crime rates (personal safety) and pedestrian traffic safety were extracted. This is in line with various studies showing that individuals who are living in a safe environment have higher wellbeing and less pathology (Baranyi et al., 2021). Also, the pedestrian traffic safety fits other criteria that were identified to be important in this review namely neighborhood connectivity and infrastructure. Those characteristics may give the individuals a sense of self-efficacy and independence since the

individuals have the possibility to use the public transportation system on their own. For example, they engage in more walking for transport because the bus stops are easily accessible. Because the individuals can easily access the bus, they have more mobility and are not dependent on e.g., having a car. This may be of special value in low socioeconomic neighborhoods. The individuals living there often do not have a car and the crime rates are high. Those factors may play a role in why physical activity and mental health is rather low among those neighborhoods (Meyer et al., 2014). So, it can be concluded that in order to improve physical activity and wellbeing the general safety feeling in neighborhood needs to be tackled. This could be done either by improving the general crime rates but also by improving the pedestrian safety in traffic.

Greenspace in the neighborhood

Greenspace in the neighborhood has shown to be a predictor of mental health and stress. In line with that the literature indicates that individuals who are exposed to nature and frequently experience nature have higher wellbeing scores (Sandifer et al., 2015). Being in nature can also consistently decrease stress levels (Alvarsson et al., 2010). Since stress can also be a predictor of mental health, being in greenery could improve mental health by decreasing stress levels. However, the measure for greenspace should be inspected since in this review the streetscape measure could predict stress levels and other objective measures like the NDVI could not. In line with that are the findings by Helbich et al. (2019). They found that a greenspace streetscape measure could predict the wellbeing of the residents while the NDVI measure could not (Helbich et al., 2019).

Contrary, to what was found in the literature in this review objectively measured greenspace did not predict physical activity levels. This could be because several studies found that for the onset of physical activity not only environmental factors, but other factors have shown to be more important (Rhodes & Quinlan, 2015 & Seefeldt, Malina & Clark,

2002). The perceived self-efficacy or social cohesion have shown to be of higher meaning in predicting physical activity (McAuley & Blissmer, 2000 & Yip et al., 2016). Jennings & Bamkole (2019) propose that social cohesion and greenspace together may predict physical activity because the residents e.g., may feel safer and more confident to walk in the neighborhood or because the residents may exchange their knowledge about the parks with each other. However, except for one study, all greenspace studies that measured the mediation effect of physical activity found a positive mediating effect on the positive relationship between greenspace and mental health. Physical activity seemed to double the effect of greenspace on mental health. Also, Han (2017) found that physical activity in a green environment has even better outcomes on mental health than the green environment alone. The experiment compared physical exercise in a green environment (40 percent visible greenery rates) and physical exercise in a more urban environment. It found that being in nature alone already has a positive effect on wellbeing. But the benefits on wellbeing increased when the individuals were combining the nature with physical activity (Han et al., 2017). This present review suggests that physical activity in a green environment has better effects on mental health than just being in a green environment alone. Since physical activity in greenspace is an established treatment of e.g., depression or anxiety, this effect was expected. The positive evidence of forest bathing or nature therapy supports these findings (Kotera et al., 2022).

Future recommendations for practice

Since this review found that opposed to the objectively measured greenspace the perceived greenspace had a positive effect on physical activity, it may be advisable to increase the awareness of the residents for the greenery of the neighborhood. This could be done by administering walking programs. Those walking programs would combine the benefits of greenspace and physical activity (Marselle et al., 2013). Long term those programs can help

to raise awareness to the greenery that is surrounding the individuals in their neighborhood.

Also, the perceived safety and pedestrian infrastructure of the neighborhoods should be improved to increase physical activity and mental health. This could be done by having sidewalks on every street or by increasing the streetlamps so there is light when it gets dark at night. Since improving the pedestrian infrastructure can improve independence and therefore self-efficacy, there should be adequate measures taken like increasing the count of bus stops or having sidewalks connect important public spaces with each other.

Future recommendations for research

Since reducing stress can help with improving wellbeing and protect from pathology it is important to further investigate the relationship between neighborhood greenery and stress and mental health. This could be done by comparing the residents stress levels and mental health in neighborhoods with a lot of greenery and neighborhoods with less greenery. Then it could be looked into whether there is a mediating effect of stress on the relationship between neighborhood greenery and mental health. This review has only made the beginning in examining this relationship.

Strengths and limitations

The strength of this review is that it gives a profound overview of the state of research in this field. In this review it has been possible to not only cover broad neighborhood concepts but also to pinpoint specific neighborhood characteristics and their effects on physical activity and mental health. Moreover, the strength of this review is that it is topic overarching. It does not only cover psychological concepts but also ecological and architectural constructs.

Still this review also has its limitations. First there was only one researcher so there is no interrater reliability. It could be that the screening of this review is biased, and another researcher maybe would have added more articles to this review. Also, there were only two

databases used. With more databases there may also have been more literature available for the screening. Also, the one of the databases had a bias towards psychology. If other databases than PsychInfo would have been searched, perhaps there would have been more literature regarding the objective walkability rating of a neighborhood since this is a rather architectural topic.

Conclusion

To conclude this review showed promising implications of greenspace and infrastructural/safety concerns in neighborhoods for the improvement of physical activity and mental health. It has shown that greenspace already has a positive effect on mental health that can be accelerated by physical activity. Also, it was shown that perceived safety and infrastructure of a neighborhood can help with physical activity and mental health.

References

- Alvarsson, J. J., Wiens, S., & Nilsson, M. E. (2010). Stress recovery during exposure to nature sound and environmental noise. *International journal of environmental research and public health*, 7(3), 1036-1046.
- Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International journal of social research methodology*, 8(1), 19-32.
- Astell-Burt, T., et al. (2013). "Mental health benefits of neighbourhood green space are stronger among physically active adults in middle-to-older age: Evidence from 260,061 Australians." *Preventive Medicine: An International Journal Devoted to Practice and Theory* 57(5): 601-606.
- Baranyi, G., Di Marco, M. H., Russ, T. C., Dibben, C., & Pearce, J. (2021). The impact of neighbourhood crime on mental health: a systematic review and meta-analysis. *Social Science & Medicine*, 282, 114106.
- Berger, R. (2009). Being in nature: An innovative framework for incorporating nature in therapy with older adults. *Journal of Holistic Nursing*, 27(1), 45-50.
- Besser, L. M., & Mitsova, D. P. (2021). Neighborhood Green Land Cover and Neighborhood Based Walking in US Older Adults. *American Journal of Preventive Medicine*, 61(1), e13-e20.
- Biddle, S. (2016). Physical activity and mental health: evidence is growing. *World Psychiatry*, 15(2), 176.
- Cramm, J. M., Van Dijk, H. M., & Nieboer, A. P. (2013). The importance of neighborhood social cohesion and social capital for the wellbeing of older adults in the community. *The Gerontologist*, 53(1), 142-152.

- De Jong, K., Albin, M., Skärbäck, E., Grahn, P., & Björk, J. (2012). Perceived green qualities were associated with neighborhood satisfaction, physical activity, and general health: Results from a cross-sectional study in suburban and rural Scania, southern Sweden. *Health & place, 18*(6), 1374-1380.
- De Vries, S., et al. (2013). "Streetscape greenery and health: Stress, social cohesion and physical activity as mediators." *Social Science and Medicine* 94: 26-33.
- Dubowitz, T., et al. (2019). "Results from a natural experiment: Initial neighbourhood investments do not change objectively-assessed physical activity, psychological distress or perceptions of the neighbourhood." *International Journal of Behavioral Nutrition and Physical Activity* 16(1).
- Dzhambov, A. M., et al. (2018). "Multiple pathways link urban green- and bluespace to mental health in young adults." *Environmental Research* 166: 223-233.
- Fan, Y., et al. (2011). "Neighborhood green, social support, physical activity, and stress: Assessing the cumulative impact." *Health and Place* 17(6): 1202-1211.
- Furuyashiki, A., Tabuchi, K., Norikoshi, K., Kobayashi, T., & Oriyama, S. (2019). A comparative study of the physiological and psychological effects of forest bathing (Shinrin-yoku) on working age people with and without depressive tendencies. *Environmental health and preventive medicine, 24*(1), 1-11.
- Han, K. T. (2017). The effect of nature and physical activity on emotions and attention while engaging in green exercise. *Urban Forestry & Urban Greening, 24*, 5-13.
- Hansen, M. M., Jones, R., & Tocchini, K. (2017). Shinrin-yoku (forest bathing) and nature therapy: A state-of-the-art review. *International journal of environmental research and public health, 14*(8), 851.

- Helbich, M., Yao, Y., Liu, Y., Zhang, J., Liu, P., & Wang, R. (2019). Using deep learning to examine street view green and blue spaces and their associations with geriatric depression in Beijing, China. *Environment international*, *126*, 107-117.
- Hoehner, C. M., Ramirez, L. K. B., Elliott, M. B., Handy, S. L., & Brownson, R. C. (2005). Perceived and objective environmental measures and physical activity among urban adults. *American journal of preventive medicine*, *28*(2), 105-116.
- Jennings, V., & Bamkole, O. (2019). The relationship between social cohesion and urban green space: An avenue for health promotion. *International journal of environmental research and public health*, *16*(3), 452.
- Kotera, Y., Richardson, M., & Sheffield, D. (2022). Effects of shinrin-yoku (forest bathing) and nature therapy on mental health: A systematic review and meta-analysis. *International Journal of Mental Health and Addiction*, *20*(1), 337-361.
- Leslie, E., & Cerin, E. (2008). Are perceptions of the local environment related to neighbourhood satisfaction and mental health in adults?. *Preventive medicine*, *47*(3), 273-278.
- Liu, Y., et al. (2022). "Can multiple pathways link urban residential greenspace to subjective well-being among middle-aged and older Chinese adults?" *Landscape and Urban Planning* *223*.
- Maas, J., Verheij, R. A., Groenewegen, P. P., De Vries, S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: how strong is the relation?. *Journal of epidemiology & community health*, *60*(7), 587-592.
- Marselle, M. R., Irvine, K. N., & Warber, S. L. (2013). Walking for well-being: are group walks in certain types of natural environments better for well-being than group walks

- in urban environments?. *International journal of environmental research and public health*, 10(11), 5603- 5628.
- McAuley, E., & Blissmer, B. (2000). Self-efficacy determinants and consequences of physical activity. *Exerc Sport Sci Rev*, 28(2), 85-88.
- McAuley, E., & Morris, K. S. (2007). State of the art review: advances in physical activity and mental health: quality of life. *American Journal of Lifestyle Medicine*, 1(5), 389-396.
- Meyer, O. L., Castro-Schilo, L., & Aguilar-Gaxiola, S. (2014). Determinants of mental health and self-rated health: a model of socioeconomic status, neighborhood safety, and physical activity. *American journal of public health*, 104(9), 1734-1741.
- Orstad, S. L., et al. (2018). "Neighborhood walkability and physical activity among older women: Tests of mediation by environmental perceptions and moderation by depressive symptoms." *Preventive Medicine* 116: 60-67.
- Orstad, S. L., et al. (2020). "Park proximity and use for physical activity among urban residents: Associations with mental health." *International Journal of Environmental Research and Public Health* 17(13): 1-13.
- Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health. *Sports medicine*, 29(3), 167-180.
- Peters, M., Muellmann, S., Christianson, L., Stalling, I., Bammann, K., Drell, C., & Forberger, S. (2020). Measuring the association of objective and perceived neighborhood environment with physical activity in older adults: challenges and implications from a systematic review. *International journal of health geographics*, 19(1), 1-20.

- Petrunoff, N. A., et al. (2021). "Associations of park access, park use and physical activity in parks with wellbeing in an Asian urban environment: A cross-sectional study." *The International Journal of Behavioral Nutrition and Physical Activity* 18.
- Rajoo, K. S., Karam, D. S., Abdu, A., Rosli, Z., & Gurusu, G. J. (2021). Addressing psychosocial issues caused by the COVID-19 lockdown: Can urban greeneries help?. *Urban Forestry & Urban Greening*, 65, 127340.
- Rhodes, R. E., & Quinlan, A. (2015). Predictors of physical activity change among adults using observational designs. *Sports Medicine*, 45(3), 423-441
- Richardson, E. A., Pearce, J., Mitchell, R., & Kingham, S. (2013). Role of physical activity in the relationship between urban green space and health. *Public health*, 127(4), 318-324.
- Rundle, A. G., Chen, Y., Quinn, J. W., Rahai, N., Bartley, K., Mooney, S. J., ... & Neckerman, K. M. (2019). Development of a neighborhood walkability index for studying neighborhood physical activity contexts in communities across the US over the past three decades. *Journal of urban health*, 96(4), 583-590.
- Sandifer, P. A., Sutton-Grier, A. E., & Ward, B. P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem services*, 12, 1-15.
- Seefeldt, V., Malina, R. M., & Clark, M. A. (2002). Factors affecting levels of physical activity in adults. *Sports medicine*, 32(3), 143-168.
- Stronegger, W. J., Titze, S., & Oja, P. (2010). Perceived characteristics of the neighborhood and its association with physical activity behavior and self-rated health. *Health & place*, 16(4), 736-743

Sundquist, K., Eriksson, U., Kawakami, N., Skog, L., Ohlsson, H., & Arvidsson, D. (2011).

Neighborhood walkability, physical activity, and walking behavior: the Swedish Neighborhood and Physical Activity (SNAP) study. *Social science & medicine*, 72(8), 1266-1273.

Theodoropoulou, E., et al. (2017). "Neighborhood environment, physical activity, and quality of life in adults: Intermediary effects of personal and psychosocial factors." *Journal of Sport and Health Science* 6(1): 96-102.

Thompson, C. W., et al. (2014). "Do changes to the local street environment alter behaviour and quality of life of older adults? the 'DIY Streets' intervention." *British Journal of Sports Medicine* 48(13): 1059-1065.

Van Dyck, D., Cardon, G., Deforche, B., Sallis, J. F., Owen, N., & De Bourdeaudhuij, I. (2010). Neighborhood SES and walkability are related to physical activity behavior in Belgian adults. *Preventive medicine*, 50, S74-S79.

Van Dyck, D., et al. (2015). "Relationship of the perceived social and physical environment with mental health- related quality of life in middle-aged and older adults: Mediating effects of physical activity." *PLoS ONE* 10(3).

Wang, R., et al. (2019). "Urban greenery and mental wellbeing in adults: Cross-sectional mediation analyses on multiple pathways across different greenery measures." *Environmental Research* 176.

Yip, C., Sarma, S., & Wilk, P. (2016). The association between social cohesion and physical activity in Canada: A multilevel analysis. *SSM-population health*, 2, 718-723.

- Yu, R., et al. (2017). "Associations between perceived neighborhood walkability and walking time, wellbeing, and loneliness in community-dwelling older Chinese people in Hong Kong." *International Journal of Environmental Research and Public Health* 14(10).
- Zhang, C. J. P., et al. (2019). "To what extent does physical activity explain the associations between neighborhood environment and depressive symptoms in older adults living in an Asian metropolis?" *Mental Health and Physical Activity* 16: 96-104.
- Zuniga-Teran, A. A., Stoker, P., Gimblett, R. H., Orr, B. J., Marsh, S. E., Guertin, D. P., & Chalfoun, N. V. (2019). Exploring the influence of neighborhood walkability on the frequency of use of greenspace. *Landscape and urban planning*, 190, 103609.