A Scoping Review of the Definition of Walkability and its Relationship with Depression and Anxiety Symptoms

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ABSTRACT

Walkability is a composite factor of the built environment which has been investigated in regards to its relationship with mental illness within a community. This scoping review aims to summarize the definition of walkability, and to investigate its relationship with depression and anxiety in previous literature. Walkability was defined theoretically, and by the subcomponents used in its composite measurement. Inconsistency in the definition of walkability limits the possibility of determining whether it is related to depression or anxiety. Future research should investigate the subcomponents of walkability in order to understand the impact of specific community-level factors on mental health outcomes.

Keywords: built environment, walkability, mental health, depression, anxiety

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RÉSUMÉ

L'accessibilité piétonnière, l'un des éléments de l'environnement bâti, a été étudiée au niveau de sa relation avec la maladie mentale au sein d'une communauté. Cet examen de la portée vise à résumer la définition de l'accessibilité piétonnière et à examiner sa relation avec la dépression et l'anxiété dans de précédentes publications. L'accessibilité piétonnière a été définie théoriquement, et par les sous-composants utilisés dans sa dimension composite. Les variantes dans la définition de l'accessibilité piétonnière limitent la possibilité de déterminer si elle est liée à la dépression ou à l'anxiété. Les recherches futures devraient étudier les sous-composants de l'accessibilité piétonnière afin de comprendre l'incidence de facteurs communautaires particuliers sur les résultats en matière de santé mentale.

Mots clés : environnement bâti, accessibilité piétonnière. santé mentale, dépression, anxiété

Depressive and anxiety disorders are among the most prevalent forms of mental illnesses and represent a leading disease burden around the globe (GBD, 2017; Disease and Injury Incidence and Prevalence Collaborators, 2018). Depressive and anxiety disorders can affect individuals at any age and are highly comorbid with each other and with a range of other mental and physical health conditions (Public Health Agency of Canada, 2016). These disorders may result in negative impacts over the course of an individual's life, including educational attainment, employment status, and overall quality of life (GBD, 2018; Mental Health Commission of Canada [MHCC], 2013, 2017).

Decades of research have focused primarily on the individual and family-level factors that are associated with depression and anxiety, including genetic predisposition, a family history of these disorders, poverty, unemployment, lower education, food insecurity, and the experience of trauma and abuse (MHCC, 2017; Glahn et al., 2018; Nurius et al., 2013). While these factors influence disease development on an individual level, addressing them requires a multifaceted approach, through public education, systemic changes, and policy implementation and intervention to reduce their impact on individual mental health (Rose et al., 2008).

Community-level factors affect the health of a population of individuals sharing a geographic location. Recent interest in these factors have led to research on the impact of urbanicity and population density, income inequality, ethnocultural and racial diversity, the availability of green and blue spaces, pollution, and availability of community resources with respect to population mental health (James et al., 2017; Julien et al., 2012; Kim, 2008). Research in this area may have significant public health implications as exposure to these community-level factors can be modified by effective health policies and/or city planning (Rohe, 1985). While improving these factors may not fully counterbalance the impact of individual-level factors on mental health, by affecting a large proportion of the population, they have the potential to shift the population curve to a more mentally healthy state. One community characteristic that has received a high level of attention about physical health is walkability; however, the relationship between walkability and mental health has not yet been comprehensively described.

Walkability is a term used to describe the ease in which individuals can navigate their community, often taking into account residential density, intersection density, and locations of interest (Forsyth, 2015). Walkability is a community-level factor that has been investigated on a smaller scale in comparison to other

built-environment exposures regarding its impact on mental health. Most of the research on walkability is related to physiological outcomes such as obesity, and type-2 diabetes, and health behaviours such as walking time, with varying results (Hajna, Ross, Joseph et al., 2015; Van Cauwenberg et al., 2015; Tarlov, et al., 2019; Paulo dos Anjos Souza Barbosa, et al., 2019). Physical activity is one mechanism that is thought to mediate the relationship between walkability and health outcomes, such as the development of risk factors for disease, and disease itself. At the same time, physical activity has been associated with a reduced risk of incident depression and anxiety (Rosenbaum et al., 2014). Thus, walkability may also confer some benefit to population mental health. Walkability may also support residents' mental health through other mechanisms, such as improved quality of life, ease of accessibility of services, and creating a sense of community (Bogumil, 2015). Walkability has been defined and measured in a number of ways, and there is no single, gold-standard tool that is widely used to measure walkability (Forsyth, 2015). Nevertheless, walkability holds promise as a neighbourhood characteristic that may be important for mental health, which can be shaped through urban planning to support both the physical and mental health of the population.

The objectives of this scoping review are to describe the variation of the definition of walkability and the measurement tools used in this context, and to investigate the relationship between walkability and the presence of depressive and anxiety disorders.

METHODS

Search Strategy

This scoping review was conducted by following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for scoping reviews (Tricco, 2018). The search was executed using OVID search databases MEDLINE, APA PSYCHINFO, and EMBASE and included the use of titles, abstracts, subheadings, key terms, and MeSH terms before July 10, 2020. This search strategy was formed with the assistance of a librarian from the Royal Ottawa Mental Health Centre in Ottawa, Ontario, Canada. The basis of the search string used for walkability is based on the work of Hajna, Ross, Brazeau, and colleagues (2015) in their systematic review of the relationship between walkability and daily steps in adults (Hajna, Ross, Brazeau et al., 2015). Depending on the database, variations of the following search string were used: [Built Environment OR (built adj2 environment) OR built environment OR (residential environment or residential neighborhood or healthy neighbourhood) OR (walkable or walkability) OR (street connectivity or road connectivity) OR "land use mix" OR Residence Characteristics OR (residential density or population density) OR (urban environment or urban design) OR (neighbourhood adj3 (environment or factor or attribute or characteristic)) OR neighbourhood environment OR Environment Design OR City Planning or urban planning] AND [Depression OR depressive disorder OR depressive disorder, major OR (depression or depressive) OR Anxiety OR Anxiety Disorders OR Mental Health]. A full outline of the search strategies is available upon request.

Article Review and Data Extraction

All articles found by this search strategy were collected, de-duplicated, and screened using Covidence (Covidence, Melbourne, VIC, Australia). Two independent reviewers (EW and DN) were responsible for the

screening of title and abstracts, full-text review, and information extraction. Full-text screening was done by EW and DN independently to assess eligibility, with any disagreement regarding inclusion settled by deliberation between the screeners. The following criteria was used in the screening of the articles:

1. The study population was not a part of a community which had recently experienced collective trauma (such as war or a natural disaster).
2. The study investigated the relationship between neighbourhood walkability and the presence of depression or anxiety, in which the term "Walkability" had been explicitly used in the article to describe the exposure variable.
3. Validated instruments for depression and anxiety were used.
4. Effect estimates were reported.
5. The full article was published in English.

Following full-text screening, two reviewers independently extracted data from eligible articles and entered information into an extraction form developed a priori. Data extraction forms were compared, and any discrepancies were resolved by consensus decision from all three authors. The following information was extracted and recorded:

1. data related to publication details (author, title, year of publication, journal, etc.)
2. country of population
3. study population description
4. definition of the term "walkability", including proxy/sub-concepts used in its definition
5. measurement tools utilized for the measurement of "walkability"
6. measurement tools utilized for the measurement of the presence of depressive/anxiety disorders
7. measures of association and effect measures between walkability and the presence of depression/anxiety disorders
8. other covariates measured

If multiple eligible studies examining the same cohort of individuals were included after full-text screening, only one study was included unless the same cohorts reported different exposure-outcome associations. Study authors were contacted for further information if relevant information was missing. Relevant information includes missing measures of association or crude numbers and key study details when selection procedure was unclear. Authors were contacted via email or phone call, and if queries go unanswered, missing data is considered unavailable.

To assess for risk of bias at the study level, EW and DN assessed the methodological quality of each included study using the Appraisal Tool for Cross-Sectional Studies (AXIS) (Downes et al., 2016). AXIS is a tool used to appraise the quality of observational cross-sectional studies (Downes et al., 2016). AXIS is composed for 20 yes/no questions for the user to answer regarding whether the study appropriately discussed several key factors, which included the study's aims, study design, sample size, sample selection, variables and measurement tools, statistical methods, description and presentation of the results, conclusions and limitations, funding, conflicts of interest, and ethical approval. AXIS was not designed with the intention to

be graded and scored; however, for the purpose of summarizing the overall quality of the studies extracted in this article, we will describe the results of the quality assessment in terms of a score out of 20 points, as well as describe any potential common themes amongst the papers.

RESULTS

Screening and Selection

Upon the completion of the search for studies using the above-described methods, 7,308 studies were found and imported into Covidence, at which point 1,602 studies were removed as duplicates. From this point, 5,706 were screened at the Title and Abstract level and 5,610 of these studies were deemed irrelevant. Ninety-five studies were then screened at the full-text level, resulting in 82 studies being excluded (results are available upon request). Ultimately 13 studies were included in the final analysis of the present study.

Included Study Information

Table 1 describes the descriptive information of the studies included in this review. Of the 13 included studies, seven studies focused on people over the age of 60 years, three studies included individuals aged 40

Figure 1

Flow Diagram for Scoping Review of the Relationship between Neighbourhood Walkability and Depression and Anxiety Symptoms

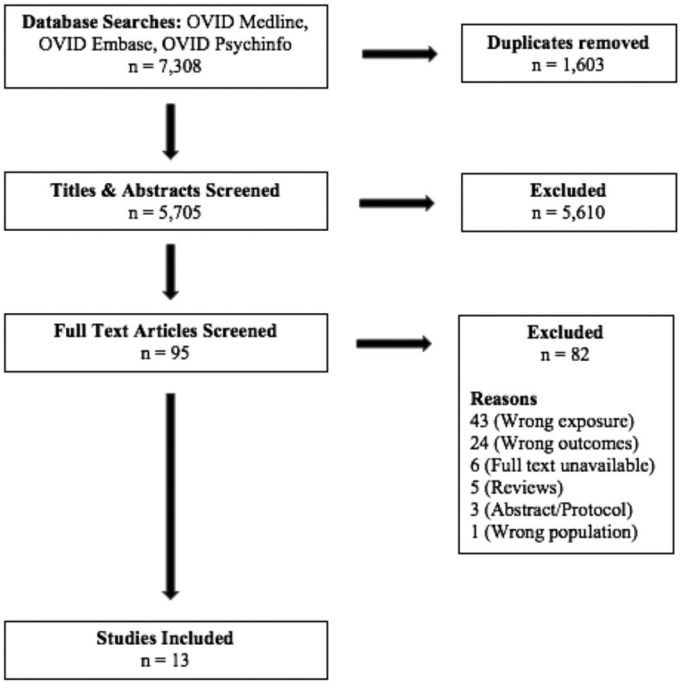

Table 1

Descriptive Information on Included Studies

Study	Sample Size	Cohort	Exposure	Assessment Tool	Outcome	Assessment Tool	Covariates	Measures of Association
Berke et al. (2007)	740	King County, Washington / 65+yrs	Neighborhood walkability	The walkable and bikeable communities project (WBC) (scored 0-100)	Depressive symptoms	Center for epidemiologic studies depression scale (CES-D), 20-item	Indicators of overall health, social isolation, wealth, and level of physical activity, self-reported walking, living alone age, smoking status, level of education, self-reported, ethnicity, and self-reported income.	Found a significant association between CES-D score and walkability score in men after adjusting for covariates. OR: 0.31-0.33 (0.12-0.82)
Chen et al. (2016)	400	Low-income public rental housing in Hong Kong / 60+yrs	Perceived neighborhood walkability	The Leyden walkability Instrument	Depressive symptoms	The Hong Kong Chinese version of the 15-item Geriatric Depression Scale (GDS-15)	Neighborhood support network, age, gender, income, ADL, recent fall history, marital status, education level, and monthly income.	Found a significant association having a medical facility within walking distance and lower depression scores. Non-significant with recreational, necessities, dining, or other places of interest. (B: 2.31, SE: 0.87, Beta: 0.30; p<0.01)
Domenech-Abella et al. (2020)	869	Detection, , Support, and Care for Older People: Belgium / 60+yrs	Neighborhood Walkability	4 items of the Neighborhood Environment Walkability Scale. (Likert 1-5)	Mental health (including depression, anxiety)	Psychological subscale of the comprehensive frailty assessment instrument	Age, sex, education, marital status, and physical functioning social/emotional loneliness, social environment, social cohesion,	Neighbourhood mobility [9.2 (8.6, 9.8) / 7.9 (7.7, 8.2) / 6.7 (6.5, 7.0) <0.001] and safety [8.1 (7.5, 8.7) / 7.6 (7.3, 7.9) / 7.0 (6.8, 7.3) <0.001] were significantly associated with mental health on all levels, but access to services and traffic density were not.

Table 1, continued

Descriptive Information on Included Studies

Study	Sample Size	Cohort	Exposure	Assessment Tool	Outcome	Assessment Tool	Covariates	Measures of Association
Gibney et al. (2019)	2094	HaPAI Age-friendly cities and countries (AFCC) survey; Dublin, Cork, Limerick, and Galway / 55+yrs	Walkability	Age-friendly urban index score (AFUI) composite index	Depressive symptoms	The Centre for Epidemiological Studies Depression Scale (CES-D-10), 10-item	Age, gender, marital status, household composition, education, material deprivation, employment status, inactivity, frequency of meeting with friends, frequency of participation in any groups	Age-Friendly Urban Environment Scores were significantly associated with 'affective wellbeing' (B 0.271, S.E. 0.076, $p<0.01$)
Guo et al. (2019)	29,099	Elderly individuals who received health check-ups at 18 elderly health centres across Hong Kong/ 65+yrs	Neighborhood walkability	Walk Score (Scored 0-100)	Depressive symptoms and depression	The 15-item Geriatric Depression Scale (GDS) Short Form	Age group, gender, marital status, educational level, comprehensive social security assistance (CSSA) receiver, housing types, smoking status, physical activity per week, number of chronic illnesses, activities of daily living (ADL), neighborhood social attributes (neighborhood poverty, ethnic minority, residential stability and elderly concentration	Neighbourhood walkability was associated with fewer depression symptoms, independent of the physical activity levels of the respondent. (OR:0.994; CI:0.989 to 1.000)

Table 1, continued

Descriptive Information on Included Studies

Study	Sample Size	Cohort	Exposure	Assessment Tool	Outcome	Assessment Tool	Covariates	Measures of Association
Hernandez et al. (2014)	570	Caminemos! Intervention Study; Greater Los Angeles Region/ 60+yrs	Neighborhood environment walkability	Neighborhood Environment Walkability Scale (NEWS) (Shortened Version)	Depressive symptoms	Geriatric Depression Scale (GDS-5), 5-item	Age, sex, education, income, marital status, and linguistic acculturation, medical comorbidities, series of health education lectures and 1-hr exercise class	Both unadjusted and adjusted, neighbourhood perception of crime was the only factor significantly associated with depression scores. (OR: 0.90, CI: 0.82-0.996, p-value: 0.04)
James et al. (2017)	73, 225	The Southern Community Cohort Study of adults/ 40–79yrs	Neighborhood walkability	Author Derived walkability index (z-scores)	Depressive symptoms	Center for Epidemiologic Studies' Depression Scale (CES-D), 10-item	Age, sex, race, household income, marital status, smoking, and employment status, education, housing, occupation, poverty, race, and residential stability variables, self-reported walking MET hours per day, antidepressant use, living in a metropolitan/micropolitan/small town or rural area	The index was not significantly associated with moderate/severe depression. The relationship between population density (a component of the walkability index) and depression symptoms was statistically significant. [OR: 1.10 / 95% CI.1.03, 1.17]

Table 1, continued

Descriptive Information on Included Studies

Study	Sample Size	Cohort	Exposure	Assessment Tool	Outcome	Assessment Tool	Covariates	Measures of Association
Mayne et al. (2018)	91, 142	Arthritic Individuals who have visited a participating practice associated with the North Carolina Family Medicine Research Network / 18+yrs	Postal area walkability	Sydney Walkability Index	Psychological distress	Kessler psychological distress scale (K-10)	Sex, five-year age group at baseline interview, language spoken at home, educational level, relationship status, employment status, health insurance type, smoking status, World Health Organisation body mass category, moderate and vigorous-intensity physical activity in the previous seven years, number of chronic conditions ever diagnosed and treated in the previous 4 weeks, limitation on physical functioning, socioeconomic disadvantage.	No significant relationship between walkability quintile and levels of psychosocial distress. Low– Ref. Low-medium –OR: 1.00 (0.94–1.07) Medium-high –OR: 1.07 (0.99–1.16) High – OR: 1.03 (0.94–1.13)

Table 1, continued

Descriptive Information on Included Studies

Study	Sample Size	Cohort	Exposure	Assessment Tool	Outcome	Assessment Tool	Covariates	Measures of Association
Martin et al. (2010)	1541	The Sax Institute's 45 and Up Study in New South Wales, Australia/ 45+yrs	Neighborhood characteristics (including walking/ exercise environment)	Self-Reported Neighborhood Characteristics (Echeverria et al 2004) (5-point Likert)	Depression symptoms	The Center for Epidemiologic Studies Depression Scale (CES-D), 20-item	Demographics (age, race, sex), health status and characteristics, chronic health conditions, health attitudes and beliefs, health behaviors, daily living, and perceptions of neighborhood environment, arthritis status: osteoarthritis, fibromyalgia, carpal tunnel syndrome, gout, or another arthritis condition, social cohesion and trust. Individual SES measures (education, household income, occupation, and home ownership). Neighborhood SES (block group poverty rate)	Once controlled using a multivariate analysis, only safety remained significantly associated with depressive symptoms and walkability was not (OR: 1.59 CI(1.19–2.12))

Table 1, continued

Descriptive Information on Included Studies

Study	Sample Size	Cohort	Exposure	Assessment Tool	Outcome	Assessment Tool	Covariates	Measures of Association
Saarloos et al. (2009)	5218	Health in Men Study of men living in Perth, Western Australia/ 65–79yrs	Neighborhood walkability	Author Derived Score	Prevalence of depression	Geriatric Depression Scale, 15-item	Socioeconomic disadvantage, low income, low educational attainment, unemployment, unskilled jobs, and variables that reflect disadvantage (e.g. indigenous and divorced), age, place of birth, education level, living arrangement, type of housing, several psychosocial factors, satisfaction with their network of relationships, individual health factors and smoking behaviour	Overall walkability index scores were not significantly related with depression scores. When broken down, land-use mix was significantly associated with depression, and living in areas of high land-use mix increased odds of having depression. T1 (low) :Ref T2 : 1.54 (1.10–2.16) T3 (high): 1.52 (1.08–2.14)
Sallis et al. (2009)	2199	Neighbourhood QOL Study (King Country Seattle and Balitmore Washington DC)/ 20–65yrs	Neighborhood walkability	Author Derived walkability index based on the census block group	Depression symptoms	The Center for Epidemiologic Studies' 20-item depression scale (CES-D)	Physical quality of life, social cohesion, neighbourhood satisfaction, gender, age, education, ethnicity, number of motor vehicles in household, marital status, number of people in household, years at current address	Individuals living in high-walkability / low income areas had higher depression scores than individual living in other areas after controlling for 'reasons for moving' (p = 0.015)

Table 1, continued

Descriptive Information on Included Studies

Study	Sample Size	Cohort	Exposure	Assessment Tool	Outcome	Assessment Tool	Covariates	Measures of Association
Vancampfort et al. (2019)	99	Out-patients with DSM-5 diagnosis in Kampala, Uganda/ 18–65yrs	Neighborhood walkability	Neighborhood Environment Walkability Scale for Africa (News-Africa) instrument	Depression	The Brief Symptoms Inventory-18 (BSI-18)	Age, gender, marital status, educational level, family income, smoking behavior, body mass index BMI, physical activity, sedentary time	Non-significant findings between depression and anxiety scores, and any of the NEWs variables (values not presented in paper)
Wang et al. (2019)	1231	Respondents to Renmin University of China mental health survey in Haidian District in Beijing /	Urban Walkability	Street View Data from Images (visible skyline)	Depression and anxiety	Geriatric Depression Scale, 15-item and Geriatric Anxiety Inventory, 20-item	Education attainment, individual social ties, individual physical conditions, gender, age, race, marital status, party membership, Hukou status	Areas of lower walkability had significantly lower depression and anxiety scores GDS scores [Q2: Coeff.= 0.981, SE= 0.367; Q3: Coeff.= 1.023, SE= 0.391; Q4: Coeff.= 1.596, SE= 0.389 GAI scores [Q2:Coeff.= 0.349, SE= 0.173; Q3: Coeff.= 0.394, SE= 0.178; Q4: Coeff. =0.551, SE= 0.177].

Table 2

Measurement Type and Variables Included in the Measurement of Walkability by Study

Study	Measurement Type	Variables included in Walkability Variable
Berke et al. (2007)	Self-report & geographically measured	Self-report: Survey themes included questions on physical activity, walking, biking, transit use, perception of a subject's neighbourhood, feelings about the environment and transportation Geographically measured: Regional data considers parks, foot trails, bicycle trails, land slope, and public transit use, destinations likely to be associated with walking
Chen et al. (2016)	Self-report	Perception of traveling to various locations on foot from their home (recreational, medical, necessities, dining, and others)
Domenech-Abella et al. (2020)	Self-report	Sufficient basic services Amount of traffic Ease of movement around neighborhood on bike or by foot Safety of neighbourhood
Gibney et al. (2019)	Self-report	Traffic Pedestrian Infrastructure
Guo et al. (2019)	Geographically measured	Distance to nearby amenities (education, retail, food, recreational, and entertainment facilities)
Hernandez et al. (2014)	Self-report	Sidewalk availability and quality Neighbourhood aesthetics Traffic safety Crime safety
James et al. (2017)	Geographically measured	The number of 3-way intersections within a 1200m buffer (street connectivity) Points of interest (grocery stores, restaurants, banks, and hospitals) Population density (number of individuals per square mile)
Mayne et al. (2018)	Geographically measured	Residential dwelling density Intersection density Land-use mix
Martin et al. (2010)	Self-report	Aesthetic environment Walking/exercise environment (walkability) Safety Social cohesion
Saarloos et al. (2009)	Geographically measured	Street connectivity Number of intersections Residential density Land-use mix

Table 2, continued

Measurement Type and Variables Included in the Measurement of Walkability by Study

Study	Measurement Type	Variables included in Walkability Variable
Sallis et al. (2009)	Geographically measured	Residential density Land-use mix Street connectivity Building setbacks from the street or sidewalk Retail floor area Active transport Sidewalks Traffic calming Intersection characteristics
Vancampfort et al. (2019)	Self-report	Sidewalk availability and quality Neighbourhood aesthetics Traffic safety Crime safety
Wang et al. (2019)	Geographically measured	The amount of available sky from eye-view

years and older, two studies included individuals aged 18/20–65 years, and a single study only required the participants to be over the age of 18. All studies included the analysis of both men and women. In terms of geography, five of the 13 studies were conducted in the United States, two in Hong Kong, two in Australia, one in mainland China, one in Uganda, one in Belgium, and one in Ireland.

Quality Evaluation

Due to the cross-sectional nature of the studies reviewed, the Appraisal Tool for Cross-Sectional Studies (AXIS) tool was used to evaluate the qality of the studies included in this review (Downes et al., 2016). AXIS includes 20 questions for which the reviewer evaluates the available studies. While AXIS was not designed to provide a composite score to represent the overall quality of the study, a scoring system was used to evaluate the inter-rater reliability between the two reviewers (EW and DN). Overall, an average of 15/20 points were awarded to the included studies, with an agreement of 92.5% between the two reviewers.

Common themes, which reduced the quality of the included studies, are authors failing to discuss the power and adequacy of the sample size in their studies (0/13), and a lack of disclosure surrounding the data on non-responders and missing data (8/13). Most of the included studies (8/13) utilized data of previously recruited participants, which may be a partial explanation as to why these two limitations were commonly seen amongst the studies. A full breakdown of individual study scores, and individual criteria scores, can be found in Table 2.

Definition of Walkability

Through data extraction, it has been found that the definition of walkability can be expressed in two different means. The first means of defining walkability amongst the included papers is the conceptual definition given by the authors. Of the 13 papers, six studies proposed a conceptual definition of walkability. Three studies (Berke et al., 2007; Mayne et al., 2018; Wang et al., 2019) defined walkability to be a part of the built environment of the neighbourhood. Chen et al. (2016), Mayne et al. (2018), and Wang et al. (2019) referred to walkability as being a factor which promotes walking behaviour in one's neighbourhood for a number of reasons (transit, socialization, recreation). Berke et al. (2007) and Chen et al. (2016) both noted walkability to be influential on social capital, referring to the potential effects that walkability may have on individuals' ability to socialize within their neighbourhoods. Finally, Hernandez et al. (2014) and Sallis et al. (2009) defined walkability through specific reference to physical neighbourhood attributes, such as scenery, places of interest, and street-connectedness. Full quote of definitions of walkability is available upon request.

The second means of defining walkability in the selected studies is through the examination of the individual variables used in each study to either geographically measure or self-report walkability, as walkability is a composite measure of the built environment. Of the 13 studies included in this review, seven measured walkability using geographically measured methods, such as geographic information systems and street-view visualizers. Seven studies measured walkability via a self-report survey of the participants regarding their perception of a variety of community-level factors. Table 2 describes the status of variable measurement and which variables were measured amongst each study.

Of the geographically measured studies, residential/population density, intersection density, and land-use mix were included in four of the seven available studies. Other variables measured included proximity to places of interest such as grocery stores, community centres, and medical buildings were present in three of the seven studies. Sallis and colleagues (2009) included all the above-mentioned variables, as well as traffic calming, availability of active transport, and other intersection characteristics. Uniquely, Wang et al. (2019) measured walkability by evaluating the amount of skyline present at street-view.

Amongst the self-report measured studies, three studies utilized the Neighbourhood Environment Walkability Scale to measure neighbourhood walkability, and individual measurement tools were used amongst the remaining four studies. Neighbourhood infrastructure, such as the availability and quality of sidewalks, presence of streetlights, and "ease of movement" in the neighbourhood, was present in four of the seven self-report measured studies. Vehicle traffic and neighbourhood crime were included as walkability-variables in four of the seven studies. Three of the seven studies asked the participants about neighbourhood aesthetics and pleasantness and two studies measured the participants' perception of having places of interest/amenities within walking distance of their homes.

Relationship Between Walkability and Depression and Anxiety

Table 1 describes the main findings of all the included studies in this review. Due to the frequently composite nature of how walkability has been measured across the included studies, it is important to note that there were three potential relationship outcomes in evaluating the relationship between walkability and depression and anxiety.

The first outcome is that the composite/overall walkability score was found to be significantly associated with depression and anxiety outcomes, in five of the 13 included studies. Berke et al. (2007) found a significant relationship between walkability scores and CES-D depression scores in men only, indicating that living in a neighbourhood with high levels of walkability significantly associated with less depressive symptoms, regardless of buffer distance from the respondent's home (OR: 0.31-0.33 CI 0.12-0.82). Gibney et al. (2019) also found a similar result, that living in an area which was more age-friendly (which constituted walkability), was negatively associated with depression (b 0.271, S.E. 0.076, $p<0.01$). Once more, this negative association with depression symptoms was reinforced by Guo and colleagues (2019), who found that neighbourhood walkability was associated with fewer depression symptoms, independent of the respondents' activity levels (OR:0.994; CI:0.989- 1.000). Interestingly, Sallis et al. (2009) found that, when controlling for the fact that some individuals intentionally move to areas of high walkability (i.e., reason for moving), that individuals in areas of high walkability had higher levels of depression. Finally, Wang et al. (2019) found that the three lowest quintiles of walkability had significantly higher levels of anxiety and depression in comparison to the area of highest walkability.

The second outcome is that the composite walkability score was not significant, but one of the independent components of walkability were found to be significant, in terms of their associations with depression or anxiety. Five studies in this review found partially significant results. Chen et al. (2016), who defined walkability as proximity to places of interest, found that elders who could walk to medical facilities with ease scored 2.31 points lower on depression scores than elders who could not. This significant association to proximity to

medical centres was not seen for recreational, dining, necessities, or "other" locations. Domenech-Abella et al. (2020) measured walkability using the Neighbourhood Environment Walkability Scale (NEWS) and did not provide a composite walkability score but evaluated the sub-components of the scale: (i) access to basic services, (ii) traffic density, (iii) neighbourhood mobility, and (iv) neighbourhood safety. They only found a significant relationship between mobility and safety with depression scores, indicating that lower levels of mobility and safety were associated with lower levels of mental health. Hernandez et al. (2014) found that total walkability scores were not significantly associated with depression in the fully adjusted models (OR = 0.89; 95% CI = [0.76, 1.04). The only individual component of the walkability measure found to be significantly related to depression in the fully adjusted model was perception of community crime/safety (OR =0.90 [CI=0.82, 0.996]), indicating that individuals living in an area with what they perceive as lower crime levels were less likely to have elevated depression symptoms. James et al. (2017) found that while the overall walkability index was not statistically associated with a moderate/greater risk of depression, they demonstrated that participants in areas with the highest quintile of population density were at 10% increased odds of displaying moderate or greater symptoms of depression (95% CI=1.03, 1.17). Finally, Saarloos et al. (2011 found that overall walkability was not significantly associated with depression scores, but that odds of depression in older men were higher in the two highest tertials of land-use mix, in comparison to the tertial with the lowest land-use mix (T2: OR=1.54 (CI=1.10–2.16), T3: OR=1.52 (CI=1.08–2.14), in the fully adjusted model.

Three of our 13 papers concluded that the final relationship showed completely insignificant results regarding the relationship between walkability and depression or anxiety. Martin et al. (2010) determined that there was no relationship between neighbourhood walkability and depression symptoms (OR=1.03 (CI=0.71–1.49)). Mayne et al. (2018) found no relationship between the level of walkability, in reference to the lowest quantile of walkability, and levels of psychosocial stress (K10) [Q2 OR=1.00 (CI=0.94–1.07), Q3 OR=1.07 (CI=0.99–1.16), Q4 OR=1.03 (CI=0.94–1.13). Finally, Vancampfort et al. (2019) found a nonsignificant relationship between depression and anxiety scores amongst any of the subcategories of the Neighbourhood Environment Walkability Scale.

DISCUSSION

Overall, this scoping review aimed to investigate how the academic community currently defines "walkability," and whether there is a relationship between walkability and depression/anxiety. For the majority of included studies, walkability is used to define a collection of variables that, conceptually, are factors that either promote walking behaviour or increase the ease of walking behaviour within a community for travel, leisure, or recreational purposes.

In defining the variables which compose walkability, one challenge is providing an effective summary of what walkability exactly means. While the conceptual idea of walkability is generally focused on factors that aid and promote the use of walking within one's community, a clear consensus about what these factors are and how they are measured, has not been agreed upon. The lack of consistency in the definition and measurement of walkability is not a novel discovery, and this lack of consistency poses a significant challenge when investigating the effects of walkability on health as a whole. Therefore, it is necessary to evaluate the relationships between the components of composite walkability and symptoms of depression and anxiety.

Walkability was found to be measured using both geographically measured and self-reported measures in the studies included in this review. Many geographically measured studies utilized the same factors, e.g., population density, intersection density, and land-use mix, and utilized a different range of distance buffers for the walkability score. The use of geographically measured walkability indexes has the potential to be useful when studying large sample sizes and population-level data, for example collected from government resources and surveys, and linked to common geographic buffers such as postal code. The self-report measured studies utilized various measurement tools, the most common being the Neighbourhood Environment Walkability Scale. However, this scale is often used to measure "physical neighbourhood attributes" or "built environment" amongst several excluded studies, of which walkability is certainly a component but was not specified as the specific outcome. This highlights the grey area surrounding what exactly walkability is in the context of the built environment. Overall, few studies have utilized both self-reported and geographically measured tools of walkability in its overall measurement, while both factors are important to consider.

Based on the selected studies, the relationship between walkability and depression/anxiety is not conclusive due to how walkability is defined and measured. Therefore, it is important to evaluate the independent relationships between walkability's subcomponents and anxiety and depression. When the sub-components of walkability were investigated independently, the only factor that was found to be significant in multiple studies was crime levels/safety. Domenech-Abella et al. (2020) found that a lack of safety was significantly associated with lower levels of mental health. Hernandez et al. (2014) found that lower perceived crime decreased the odds of having elevated depression symptoms. These findings are not surprising, as the relationship between neighbourhood level factors (crime, safety, vandalism litter, etc.) and depression has been well documented (Ross, 2000; Latkin & Curry, 2003). Beyond the chronic stress created by living in an unsafe community, it is possible that crime may be a part of the causal pathway to depression and reduce one's likelihood of walking for leisure or necessity. This may decrease the likelihood that one might exercise in their neighbourhood or make it more difficult to complete daily activities such as buying groceries (Sallis et al., 2011). Exercise is proven to be a protective factor and treatment for depression. Therefore, living in an unsafe community may reduce the odds of one exercising near their home and limit the protective prospects of physical activity (Sallis et al., 2011; Cooney et al., 2013). Further research should include an evaluation of the relationships between the subcomponents of walkability with mental health outcomes, and not just composite measures.

Future research should also consider the socioeconomic and demographic factors of the communities being studied with regard to walkability to understand the effect of walkability on individuals of varying ages and socioeconomic factors. Some studies reported higher composite levels of walkability are associated with less depression (Berke et al., 2007; Gibney et al., 2019; Guo et al., 2015). Whereas Sallis and colleagues (2009) found that individuals living in high walkability/low-income areas had higher depressive scores if they had not chosen that area specifically because of its walkability-related factors. Individuals with higher income may have more choices about where they buy their homes and consider factors such as physical walkability, nearby amenities, and safety. Individuals with lower incomes may not necessarily have this choice and reside in areas of high physical walkability, such as urban centres, which historically may also have higher rates of violent crime which may in turn affect mental health (Joshi et al., 2017). In 12 of the 13 studies included in this review, income was controlled for in a variety of forms, such as controlling for

personal or household income, neighbourhood income, or proxies for income such as "material deprivation" or "socioeconomic disadvantage." Chen et al. (2016) and James et al. (2017) specifically recruited in low-income populations. While socioeconomic status may have been controlled for in most of the analysis, its influence in the relationship between depression and walkability was rarely stratified and largely undiscussed. Considering the influence of both individual and neighbourhood income, walkability may act differently in high-income and low-income populations, and therefore, socioeconomic status should be more consistently and clearly controlled for in future studies to further elucidate its role in the relationship between mental health and walkability.

This scoping review found that only three of the 13 studies examined individuals under the age of 40, and a vast majority focused on more elderly populations. Elderly populations are particularly important to highlight in the discussion surrounding walkability as they may have limited physical capabilities to walk long distances or in areas difficult to navigate, higher needs for health services, as well as potentially no longer have access to personal transportation (Distefano et al., 2020). This may partly explain the significant association between walkability and depression in studies with samples of elderly population. Overall mobility is seen to act as a protective factor for healthy ageing and well-being in elderly populations, and neighbourhood walking infrastructure has the potential to influence mobility, transport choices, and walking behaviours within their communities (Distefano et al., 2020). This limitation on mobility may influence one's opportunity for socialization outside of the home and increase loneliness (Van den Berg et al., 2014). Perceived neighbourhood walkability has also been found to influence food insecurity amongst older populations as communities with poor walkability may limit one's ability to obtain food, which is also known to negatively impact mental health (Chung et al., 2011). However, in theory, increased walkability in communities would be beneficial for all age ranges, as it actively promotes physical activity, may influence social capital, and can also potentially influence air quality and pollution levels as the need for vehicles to obtain necessities would be reduced. More studies that include people with a wide age range are needed.

There are several limitations to this review. Firstly, due to the widely heterogeneous nature of the included studies, it was not possible to complete a meta-analysis with the available data, which could have provided a more comprehensive vision of the collective results of the data. Furthermore, all of the studies included in this review are cross-sectional in nature and therefore cannot be interpreted in a causal manner. Due to both limitations, future systematic reviews and meta-analyses are needed once more primary studies on this topic become available.

Reflecting on the definition and use of the term "walkability" throughout the included studies, several recommendations can be made. While the definition of walkability was found to consistently describe community-level variables which promote walking behaviour, or make transportation via walking easier, which variables exactly compose this composite measure are unclear. To accurately describe how walkability influences health at any level, a clear consensus about which variables constitute walkability must be reached, as well as its relationship to other concepts in the built-environment sphere. From this clear definition, validated measurement tools can be developed for research purposes. As seen in this review, few studies utilized both self-report and geographically based measurement tools, both of which are equally important. While geographic characteristics of walkability, such as presence of sidewalks are important, it is equally as necessary to measure perception of walkability, as walking is a health behaviour whose motivation can vary from

person to person. The ideal tool to measure walkability would include both forms of questions to adequately capture the multi-faceted nature of this variable. Finally, the scoring of walkability should be presented as a whole, as well as by its composite measures. As seen in the research, the composite nature of walkability may influence its association based on the population being measured. While physical accessibility may be more influential amongst older populations, other factors such as safety may influence others. Therefore, the scoring of overall walkability should be complemented by the individual breakdown of its sub-variables.

In conclusion, the present study highlights the current issues present in the literature surrounding walkability and mental health. Going forward, it would be beneficial for knowledge synthesis purposes if a concrete conceptual definition of walkability and its associated variables is established. Future studies should consider the importance of both geographically measured and self-reported tools used in the measurement of walkability and evaluate the relationships between depression and anxiety symptoms with the individual subcomponents of walkability composite measures. In doing so, this will elucidate which specific factors within the context of walkability impact the mental health of those in the community. The potential implications of improved, more cohesive research on the association between mental health and community-level factors such as walkability are a more robust basis of research to inform policymakers and city planners in the development and improvement of communities which support the mental health of the population.

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