Impact of walkability with regard to physical activity in the prevention of diabetes

Carlos Mena,1 César Sepúlveda,2 Yony Ormazábal,1 Eduardo Fuentes,2,3 Iván Palomo2

1Geomatics Centre, Faculty of Forestry Sciences, University of Talca; 2Platelet Research Laboratory, Department of Clinical Biochemistry and Immunohematology, Faculty of Health Sciences, Interdisciplinary Excellence Research Program on Healthy Aging, University of Talca; 3Multidisciplinary Scientific Centre, University of Talca, Chile

Abstract

Walkability, a component of urban design intended to facilitate pedestrian traffic, depends on parameters associated with the connectivity of routes, population density and availability of destinations in the neighbourhood. The aim is to achieve levels of physical activity related to the prevention of risk factors associated with diseases, such as diabetes and the improvement of glycaemia control. It is important to consider that the effects of walkability depend on its relation with other variables present in the neighbourhood, e.g., environmental and socioeconomic factors. Considering this, improving walkability levels could be an effective strategy to reduce disease, the prevalence of diabetes in particular, in the population and thus reduce public spending. To investigate these relationships, PUBMED and ScienceDirect databases were searched using the following key words: Diabetes, Walkability and Physical activity.

Introduction

Walkability, a component of built environment associated with the degree a neighbourhood supports walking; it thus depends on variables related to connectivity, population density and ability to reach destinations (Glazier et al., 2008). Street connectivity corresponds to the number of intersections present in a neighbourhood; it facilitates pedestrian traffic, provides options for travelling between local origins and destinations and plays a role in slowing motorised traffic as a result of multiple stopping sites (Handy et al., 2003). Land use mix refers to the variety of possible destinations in a neighbourhood connected with office, retail, industrial, service, entertainment, education and public sector facilities (Duncan et al., 2010), while walkable destinations is an associated concept that refers to the number of destinations present in a neighbourhood (Carr et al., 2011). Residential (or population) density is defined as the number of residences (or people) per km² in a neighbourhood (Brownson et al., 2009; Johnson-Lawrence et al., 2015). The presence of a high number of people requires a high demand for accessible routes and stores. The composition of a walkability index usually adapts these factors at the sites where applied (Glazier et al., 2008).

There are different ways to measuring walkability. It is primarily approached by determining the perceived walkability using surveys (Nottlofth and Carstensen, 2015). Objective walkability is usually investigated using a geographic information system (GIS); it considers variables of connectivity, density and ability of reaching destinations (Mayne et al., 2013; Frank et al., 2010). Walkability indices have been employed for investigation of associations between urban design and different outcomes; They can be used to identify priority areas for transportation enhancements and it can be applied to monitor changes in urban settings over time (Frank et al., 2010). In developed countries, this kind of information has been used to develop public policies of transportation and urbanity. In Australia, under the Sydney Metropolitan Strategy, a walkability index has been important in identifying the need for urban design that encourages pedestrian and cyclist traffic (Mayne et al., 2013). Walk Score® is another tool used to evaluate walkability based on distance to various amenities, which has shown a good correlation with GIS-measured walkability indices (Duncan et al., 2011). Although based on accessible and free data, it does not consider aspects such as population density or connectivity; while latent profile analysis (LPA) is an approach aimed at the study of walkability parameters in combination with other built environment factors that allows estimation of co-occurring impacts like physical activity (Kurka et al., 2015).
Type 2 diabetes mellitus (T2DM) represents a major public health problem. It currently represents an important cause of mortality and disability, as it predisposes the development of neuropathies, cardiovascular and kidney diseases. Projections show that the prevalence of these diseases will increase in the following decades due to the aging of the population, but also due to increasingly sedentary lifestyles and the consequent rise of obesity (Wild et al., 2004; Lipscombe and Hux, 2007). Frequent physical activity (PA) has been shown to prevent the development of diabetes (Lambert and Bull, 2014), while it improves control of glycaemia and quality of life in diabetic patients (Colak et al., 2016; Rice et al., 2016). Built environment corresponds to the totality of places designed and built by humans (Sallis et al., 2012). Different studies have identified walkability as a PA promoter in a chosen neighbourhood, and the role of neighbourhood design has been given much thought with respect to health in recent years (Frank and Engelke, 2001; Sallis et al., 2012). Built environment could play an important role in the prevention of non-communicable diseases, such as diabetes, mainly by promoting physical activity. Recent studies have suggested that transiatability may be a protective factor against the development of diabetes (Muller-Riemenschneider et al., 2013; Glazier et al., 2014). Indeed, a correlation has been established between the PA such as walking/running and incidence of this disease (Yates et al., 2014). For this reason, planning of built environment encouraging PA would contribute to a better control of glycaemia.

In this article, we review the protective role of walkability with respect to diabetes and its relation with prevalence and incidence of this disease, examining factors that favour the development of regular physical activities.

Materials and Methods
To investigate which associated factors primarily influence the development of diabetes, PUBMED and ScienceDirect databases were searched using the following key words: Diabetes, Walkability and Physical activity. These search terms delivered a total of 38 articles using both databases, Walkability appeared independently 7 times in the title and 5 times in the abstract; the combination Walkability and Diabetes appeared 4 times in the title and 9 times in the abstract; Walkability and Physical activity appeared once in the title and 5 times in the abstract; while the three words together appeared twice in the title and 14 times in the abstract. Thirty-three publications were original articles with other types of articles in minority: one systematic review, one systematic review with meta-analysis, two reviews and one editorial letter.

Results and Discussion
Prevalence of diabetes and walkability
Recent cross-sectional studies show a correlation between walkability and prevalence of diabetes (Muller-Riemenschneider et al., 2013; Glazier et al., 2014). This is related to effects of walkability on diabetes risk factors. For example, the high body mass index (BMI) prevalence decreases with walkability (Sallis et al., 2009; Duncan et al., 2014), while moving to a highly walkable neighbourhood reduces BMI (Wasfi et al., 2016). Age is another risk factor where walkability counteracts the development of diabetes as it is associated with increased PA (King et al., 2011; Van Holle et al., 2016). The effects of walkability tend to be more effective in men. This correlation is generally significant when evaluated in the immediate radius but loses significance when the range of analysis is extended (Muller-Riemenschneider et al., 2013). It is likely that the effects of walkability on diabetes prevalence is linked not only to the fact that people walk more, but also to factors such as increased bicycle use and public transport instead of owned-car use (Glazier et al., 2014). The main disadvantage of these studies is that they are cross-sectional, so a correlation between diabetes and walkability is only suggested and the results cannot be used as evidence of a causal relation (Sedgwick, 2014).

Effects of walkability on diabetes incidence
The perception of how friendly a neighbourhood is for the development of PA is also important. Based on a 5-year survey, Auchinloss et al. (2009) showed the importance of the suitability of the neighbourhood for PA in the development of diabetes, i.e. the stronger the perception of the walkability of a neighbourhood, the lower the incidence of diabetes. This has been partly corroborated by Canadian study, carried out in Ontario, Canada between the years 2001-2012 (Creatore et al., 2016). However, the initial prevalence of T2DM in this study was decreases only in the highest quintile of the degree of walkability, while the diabetes incidence did not vary significantly in the lower quintiles. Sundquist and colleagues (2015) initially found that the incidence of diabetes decreased with walkability, but that this correlation lost significance when adjusted by socio-demographic features. They used prescription of drug treatment for diabetes as proxy, so cases of diabetes not treated pharmaceutically were excluded (Sundquist et al., 2015). In contrast, a study investigating cardio-metabolic risk factors based on laboratory parameters using HbA1c and fasting glucose for the diagnosis pre-diabetes or diabetes showed that the risk of developing these disorders was lower in areas with greater walkability qualities (Paquet et al., 2014). In accordance, Booth and co-workers (Booth et al., 2013) found that the diabetes incidence increases in environments less favourable for walking, a situation particularly pronounced in immigrants, a group prone to developing diabetes due to acculturation, i.e. change in lifestyle when adapting to another culture (Misra and Ganda, 2007).

Effects of walkability in diabetic patients
PA has favourable effects in T2DM patients (Yates et al., 2014). There are different factors that determine the performance of PA in this connection. Among these are environmental, socio-demographic, psychosocial factors, etc. (Van Holle et al., 2015; Marques et al., 2016; Grazioso et al., 2016). Walkability may be an important environmental factor in the promotion of PA among people with T2DM (De Greef et al., 2011). Diabetics living in highly walkable areas do more daily steps than others, which may have clinical significance when adjusted for variables such as age, BMI and gender, but loses clinical importance when adjusting for car access (Colley et al., 2011). On the other hand, it has been noted that overall walkability is related to expert recommendations that diabetics should aim at walking for ≥150 minutes per week (Hosler et al., 2014). In fact, a study by Hajna and colleagues (2016) has shown that T2DM patients living in areas with a high-walkability index do more steps per day compared to diabetics in area characterised by a low-walkability index.
Prevention of diabetes: Walkability and physical activity

There is a negative correlation between objectively measured walkability and sedentary behaviour, e.g., watching TV (Sugiyama et al., 2007; Kozo et al., 2012) or driving a car (Kozo et al., 2012; Koohsari et al., 2014). Walkability promotes the development of PA and is thus related to increases in moderate to vigorous physical activity (MVPA) and walking. The latter is a PA that can be divided into utilitarian walking and leisure-time walking; together they make up the total walking time (Hajna et al., 2015). As seen in Table 1, walkability is associated with increased utilitarian walking, while the correlation with leisure-time walking is weak.

Table 1 summarises the findings of different studies linking PA with walkability indices. In most of the above-mentioned studies, GIS-based surveys contribute significantly. These systems comprise collection, management and interpretation of complex geospatial information, where geo-referencing allows all study subjects to be positioned in the territory under examination, a situation which generates radii along which walkability information for each subject can be obtained and calculated. For example, in the study by Todd et al. (2016), the ArcGIS 10.0 software (ESRI, Redlands, CA, USA) was used to determine the walkability parameters of the study area, such as net residential density, intersection density, land use mix (diversity and accessibility of nearby destinations) and retail floor area ratio (which indicates the likely retail development) for a 1-km radius for each of the participants in the study. Participants can be classified into different groups according to the level of walkability: quartiles, quintiles, deciles, etc. In this way, it is possible to relate walkability to the level of PA developed in each group and to measure the contribution of walkability in the achievement of PA goals that lead to overall health benefits in the general population, in particular in groups of individuals or in people with particular ailments. For example, the influence of walkability achieving ≥150 minutes per week of walking in diabetics may be determined; or 75 min per week of intense PA in older adults. In this way, the GIS approach contributes to defining the characteristics of the routes and distances to be realised to obtain health benefits for different interest groups.

Studies comparing physical activity according to walkability use two different strategies to measure it: Surveys are an economical way to collect information from a large number of individuals but have the disadvantage of being subjective, while accelerometers and pedometers allow the registration of objective PA information. However, they are relatively expensive limiting the number of participants than can be studied. Differences between these strategies exist with respect to the value of PA reported, something which is frequently underestimated by surveys (Dyrstad et al., 2014; Lipert and Jegier, 2016; Liu et al., 2016b). However, usually there is a good correlation in trends of PA and health when comparing these methods (Merwether et al., 2006; De Cock et al., 2009; Schuna et al., 2013). Table 1 provides an overview of how general walkability is related to other forms of PA, measured subjectively or objectively.

As can be seen from Table 1, walkability can determine significant differences in PA performance, and these differences can promote concrete improvements in parameters associated with diabetes. People making ≥30 min per day of MVPA had lower BMI and lower levels of glycosylated haemoglobin (HbA1c), a laboratory parameter for control of diabetes. (Hamer et al., 2012). Interventions aimed at PA increase showed that a change from 13 min per day to 18 min of moderate PA is associated with a HbA1C decrease from 8.9% to 7.7% and a BMI decrease from 37.11 to 36.58 kg/m² (Allen et al., 2008). Another study (Swartz et al., 2007) compared differences in steps per day between older volunteers with recommended levels of HbA1C and those without. Voluntaries with controlled HbA1c levels (mean of 5.8%) were stronger walkers than a group with uncontrolled HbA1c (mean of 8.7%), the former group making 1,343 more steps per day on average than the latter.

Metabolic Equivalent of Task (MET) is a unit of energetic expenditure that corresponds to the amount of energy spent in an activity relative to the energy spent at rest (Bushman, 2012). The MET values for diverse activities of different intensity have been defined by Ainsworth et al. (2011). Expressing this expenditure as MET hours per week may be useful for setting goals for the physical activity performed for a given purpose (Matthews et al., 2007; Gielen et al., 2015). It can be useful to express the benefit of various degrees of PA as MET values, e.g., diabetics increasing their energy expenditure with at least 11 MET hours per week show significant reductions in several parameters, such as HbA1c, blood pressure, total cholesterol and triglycerides (Di Loreto et al., 2005). Another study describes that HbA1C decreases with 0.1% for every 30 MET hour increase per week (Barakat et al., 2013). MET expenditure has also an effect on mortality due to diabetes: diabetics classified into four groups according their daily MET expenditure (≥7.5; 7.5-12.6; 12.6-25.2 and ≥25.2 MET hours per week) and followed for 9 years lowered the mortality with 39.4%, 63.8% and 90.6%, respectively, in the three highest MET daily expenditure groups compared to lowest (Williams, 2013). Whenever possible, we calculated the difference in MET hours per week between the neighbourhoods with the greatest transitability and those with the lowest (Table 1). In others words, the simple fact of living in a high-walkability neighbourhood means an advantage with regard to health and protection against the development of diabetes.

Influence of other factors on walkability in the prevention of diabetes

We have reviewed the role of walkability, a component of the built environment, as a protective element in the development of diabetes. However, in practice, its benefits depend also on the interaction with other factors present in the neighbourhood (Figure 1). The effect of how the environment is perceived has been studied from various perspectives and how this influences walking: aesthetics (Sugiyama et al., 2014), rout quality (Hallal et al., 2010; Sugiyama and Thompson, 2008) and the degree of access to green areas and recreational spaces (Sugiyama and Thompson, 2008; Hallal et al., 2010; Stathi et al., 2012; Sugiyama et al., 2014). Access to parks has been linked to increased physical activity (Roemmich et al., 2006) and decreased BMI (Mena et al., 2015). In addition, neighbourhood access to healthy foods (presence of supermarkets and fruit-vegetable stores) as well as the presence of recreational facilities (dance, bowling, water activities, team sports, etc.) are independently associated with a lower incidence of diabetes (Christine et al., 2015).

Social support from family and friends (Rech et al., 2014), in addition to having activity partners (Stathi et al., 2012), encourage PA. Conversely, but not surprising, the perceived criminal insecurity of the neighbourhood (Evenson et al., 2012; Sugiyama et al., 2014) as well as high homicide rates (Lovasi et al., 2013; Gomes et al., 2016) are related to a decreased PA. The socioeconomic status largely determines these variables; high-income neighbourhoods have more favourable patterns with respect to aesthetics,
Table 1. Physical activity related to walkability.

<table>
<thead>
<tr>
<th>Type of physical activity</th>
<th>No of subjects studied</th>
<th>Population sector</th>
<th>Area, region, country</th>
<th>Measure of walkability</th>
<th>Tool or approach used</th>
<th>Parameter measured</th>
<th>Results in the low-walkability group</th>
<th>Results in the high-walkability group</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall walking</td>
<td>10</td>
<td>20 to 64</td>
<td>Olomouc, Czech Republic</td>
<td>GIS walkability index</td>
<td>Pedometer</td>
<td>Steps per day</td>
<td>9.21 steps/day</td>
<td>11.18 steps/day</td>
<td>Dygrén et al. (2010)</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>20 to 65</td>
<td>Sint-Niklaas, Belgium</td>
<td>GIS walkability index</td>
<td>Pedometer</td>
<td>Steps per day</td>
<td>8.09 steps/day</td>
<td>9.08 steps/day</td>
<td>Van Dyck et al. (2008)</td>
</tr>
<tr>
<td></td>
<td>16,944</td>
<td>18 to 64</td>
<td>Queensland, Australia</td>
<td>Walk score™</td>
<td>Survey reported</td>
<td>% walk per day</td>
<td>6.2%</td>
<td>25.8%</td>
<td>Cole et al.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mean trip duration</td>
<td>2.5 min</td>
<td>7.3 min</td>
<td></td>
</tr>
<tr>
<td>Utilitarian walking</td>
<td>151,318</td>
<td>&gt; 12</td>
<td>Canada</td>
<td>Walk score™</td>
<td>CHS survey</td>
<td>MET/day for transport</td>
<td>0.86 h/day</td>
<td>1.3 h/day</td>
<td>Thielman et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>1,287</td>
<td>20 to 65</td>
<td>Seattle, WA &amp; Washington DC, USA</td>
<td>LPA</td>
<td>IPAQ survey</td>
<td>Time used for transport</td>
<td>13.7 min/week</td>
<td>15.9 min/week</td>
<td>6.2 Adams et al. (2015)</td>
</tr>
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<td></td>
<td>75</td>
<td>18 to 65</td>
<td>Alberta, Canada</td>
<td>Cluster-analysis</td>
<td>IPAQ survey</td>
<td>Time used for transport</td>
<td>11.4 min/week</td>
<td>17.0 min/week</td>
<td>2.7 Jack and McCormack (2014)</td>
</tr>
<tr>
<td></td>
<td>4,034</td>
<td>18 to 65</td>
<td>Calgary, Canada</td>
<td>Cluster-analysis</td>
<td>IPAQ survey</td>
<td>Time used for transport</td>
<td>105 min/week</td>
<td>209 min/week</td>
<td>4.3 McCracken et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>277</td>
<td>&lt;50</td>
<td>Paris, France</td>
<td>Walk score™</td>
<td>GPS and accelerometer</td>
<td>% walk per day</td>
<td>21.7%</td>
<td>16.6%</td>
<td>Duncan et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>879</td>
<td>18 to 65</td>
<td>Curitiba, Brazil</td>
<td>GIS walkability index</td>
<td>IPAQ survey</td>
<td>Time used for transport</td>
<td>43.3 min/week</td>
<td>61.0 min/week</td>
<td>1.8 Van Hollebeke et al. (2014)</td>
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<tr>
<td></td>
<td>438</td>
<td>≥25</td>
<td>Gent, Belgium</td>
<td>GIS walkability index</td>
<td>IPAQ survey</td>
<td>Time used for transport</td>
<td>100 min/week</td>
<td>150 min/week</td>
<td>2.1 Sundquist et al. (2011)</td>
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<tr>
<td></td>
<td>2,269</td>
<td>20 to 66</td>
<td>Stockholm, Sweden</td>
<td>GIS walkability index</td>
<td>IPAQ survey</td>
<td>Time used for transport</td>
<td>15.6 min/week</td>
<td>32.0 min/week</td>
<td>0.8 Sallis et al. (2010)</td>
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<td></td>
<td>667</td>
<td>≥20</td>
<td>Washington DC, USA</td>
<td>GIS walkability index</td>
<td>IPAQ survey</td>
<td>Time used for transport</td>
<td>6.7 min/week</td>
<td>32.1 min/week</td>
<td>1.3 King et al. (2013)</td>
</tr>
<tr>
<td></td>
<td>106,371</td>
<td>&lt;20</td>
<td>Ontario, Canada</td>
<td>Walk score™</td>
<td>CHS survey</td>
<td>% walk per day</td>
<td>44.9%</td>
<td>31.1%</td>
<td>Chiu et al. (2015)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Mean trip duration</td>
<td>10.3 min</td>
<td>4.9 min</td>
<td></td>
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<tr>
<td>Time walking for leisure</td>
<td>1,065</td>
<td>18</td>
<td>Alberta, Canada</td>
<td>Cluster-analysis</td>
<td>IPAQ survey</td>
<td>Time used for recreation</td>
<td>58.9 min/week</td>
<td>128 min/week</td>
<td>0.4 Jack and McCormack (2014)</td>
</tr>
<tr>
<td></td>
<td>4,014</td>
<td>18</td>
<td>Calgary, Canada</td>
<td>Cluster-analysis</td>
<td>IPAQ survey</td>
<td>Time used for recreation</td>
<td>182 min/week</td>
<td>138 min/week</td>
<td>0.7 McCracken et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>97</td>
<td>18 to 65</td>
<td>Curitiba, Brazil</td>
<td>GIS walkability index</td>
<td>IPAQ survey</td>
<td>% walk per day</td>
<td>10.5%</td>
<td>13.4%</td>
<td>Siqueira Reis et al. (2013)</td>
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<tr>
<td></td>
<td>438</td>
<td>≥25</td>
<td>Gent, Belgium</td>
<td>GIS walkability index</td>
<td>IPAQ survey</td>
<td>Time used for recreation</td>
<td>71.7 min/week</td>
<td>85.7 min/week</td>
<td>0.5 Van Hollebeke et al. (2014)</td>
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<tr>
<td></td>
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<td>20 to 66</td>
<td>Stockholm, Sweden</td>
<td>GIS walkability index</td>
<td>IPAQ survey</td>
<td>Time used for recreation</td>
<td>60 min/week</td>
<td>68 min/week</td>
<td>0.3 Sundquist et al. (2011)</td>
</tr>
<tr>
<td></td>
<td>2,199</td>
<td>20 to 65</td>
<td>Washington DC, USA</td>
<td>GIS walkability index</td>
<td>IPAQ survey</td>
<td>Time used for recreation</td>
<td>13.3 min/week</td>
<td>16.4 min/week</td>
<td>0.1 Sallis et al. (2008)</td>
</tr>
<tr>
<td>Time used for MVPA</td>
<td>714</td>
<td>66 to 77</td>
<td>Washington DC, USA</td>
<td>LPA</td>
<td>Acceleo-meters</td>
<td>Time used for MVPA</td>
<td>6.3 min/day</td>
<td>11.6 min/day</td>
<td>1.6 Todd et al. (2016)</td>
</tr>
<tr>
<td></td>
<td>1,267</td>
<td>66 to 77</td>
<td>Washington DC, USA</td>
<td>LPA</td>
<td>Acceleo-meters</td>
<td>Time used for MVPA</td>
<td>3.2 min/day</td>
<td>4.2 min/day</td>
<td>1.0 Adams et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>439</td>
<td>≥25</td>
<td>Gent, Belgium</td>
<td>GIS walkability index</td>
<td>Acceleo-meters</td>
<td>Time used for MVPA</td>
<td>90.4 min/day</td>
<td>128.8 min/day</td>
<td>2.0 Van Hollebeke et al. (2014)</td>
</tr>
<tr>
<td></td>
<td>2,269</td>
<td>20 to 66</td>
<td>Stockholm, Sweden</td>
<td>GIS walkability index</td>
<td>Acceleo-meters</td>
<td>% doing ≥30 min MVPA</td>
<td>39 min/day</td>
<td>47 min/day</td>
<td>2.8 Sallis et al. (2011)</td>
</tr>
<tr>
<td></td>
<td>367</td>
<td>20 to 70</td>
<td>Atlanta, GA, USA</td>
<td>GIS walkability index</td>
<td>Acceleo-meters</td>
<td>% doing ≥30 min MVPA</td>
<td>0.1%</td>
<td>0.7%</td>
<td>3.1% Frank et al. (2005)</td>
</tr>
<tr>
<td></td>
<td>1,798</td>
<td>≥18</td>
<td>Calgary, Canada</td>
<td>Cluster-analysis</td>
<td>Telephone-interviews</td>
<td>% doing ≥30 min MVPA</td>
<td>1.8%</td>
<td>3.7%</td>
<td>3.7% Frank et al. (2005)</td>
</tr>
<tr>
<td></td>
<td>2,199</td>
<td>20 to 65</td>
<td>Washington DC, USA</td>
<td>GIS walkability index</td>
<td>Acceleo-meters</td>
<td>Time used for MVPA</td>
<td>26.8 min/day</td>
<td>34.4 min/day</td>
<td>2.1 Sallis et al. (2008)</td>
</tr>
<tr>
<td></td>
<td>677</td>
<td>≥40</td>
<td>Washington DC, USA</td>
<td>GIS walkability index</td>
<td>Acceleo-meters</td>
<td>Time used for MVPA</td>
<td>52.1 min/day</td>
<td>83.4 min/day</td>
<td>0.9 King et al. (2011)</td>
</tr>
</tbody>
</table>

MET, Metabolic Equivalent of Task; GIS, Geographic Information System; CHS, Canadian Community Health Survey; LPA, LumenProfile Analysis; IPAQ, International Physical Activity Questionnaire; NPAQ, Neighborhood Physical Activity Questionnaire; GIS, Global Positioning System; MVPA, Moderate Vigorous Physical Activity. \*The MET/h week value is calculated multiplying reported physical activity value by the Metabolic Equivalent of Task (MET) defined in (Ainsworth et al., 2011). 1 MET = 3.5 ML/day for utilitarian and leisure time walking (that is, to say, this activities means 2.5 times of energy spent at rest), while was assigned 3 METS for MVPA. \*The GIS-walkability index is calculated by measuring the chosen variables in each geographical unit studied and summarizing them by a score. Because both geographical units and variables for the walkability calculation vary between studies, there is no homogeneous index. For example, Frank et al. (2008) choose census blocks as a geographic unit, in corresponding total area of study for a county, being the variables for the calculation intersection density, residential density, floor area ratio and land use mix. After estimating the z-score, for each block the walkability index was defined as: Walkability = \[(z \times \text{score for intersection density} + z \times \text{score for land use mix})/2\] + (z-score for residential density + z-score for land use min). Walk Score™ works with a private algorithm based on the distance to the closest amenity in different available categories. It measures walkability of any address assigning a number between 0 and 100.
walking infrastructure, access to recreation facilities and safety from crime (Sallis et al., 2011; Sugiyama et al., 2015). These factors explain differences between perceived and objectively measured walkability regarding the development of PA (Hanibuchi et al., 2015). However, Koohsari and colleagues (2015) suggest that people living in less walkable areas could still perceive them as walkable, and living in more walkable areas could be thought of as less walkable. Thus, safer and more pleasant neighbourhoods can improve the perception of walkability in neighbourhood with a low walkability index.

Some of the factors presented and discussed here are especially important for older adults (Sugiyama and Thompson, 2008; Stathi et al., 2012). Given the impact of PA on the prevention and management of diabetes in older people, interventions that focus on improving walkability and related factors may have a particularly good impact on this group considering that walking is the main physical activity performed at this time in life (Crespo et al., 1996; Szanton et al., 2015). On the other hand, environmental factors can influence the effects of walkability. Air pollution can reverse the positive health effects generated by walkability (Hankey et al., 2012). Urban design should focus on generating neighbourhoods with high walkability and low air pollution rates (Marshall et al., 2009; Cowie et al., 2016). Walkability in turn can influence environmental factors and thus play an additional protective role against diabetes (Figure 1). Air pollution is related to vehicular use (Patil et al., 2015), e.g., neighbourhoods that encourage walking end up with less car traffic (Frank et al., 2006, 2007). If the walkability index is related to fewer vehicle miles travelled, it could indeed contribute to the reduction of air pollution (Frank et al., 2006). Interestingly, recent articles have highlighted the fact that air pollutants are significantly associated with increased risk of T2DM (Meo et al., 2015; Liu et al., 2016a). The social capital is defined as the degree of social collaboration between different groups of a human collective, thereby indicating community engagement (Bjørnskov, 2006). A positive relation exists between walkability and social capital (Rogers et al., 2011; Rogers et al., 2013) and walkability can foster social capital by favouring social connectedness and people involvement within the local community. Social capital is protective both with regard to obesity and diabetes (Holglye and Crosby, 2006). In diabetics, social capital is related to upholding a good control of diabetes treatment as assessed by HbA1c levels (Farazadegan et al., 2013; Smalls et al., 2015).

Conclusions

The cost of diabetes, considering diagnosis, treatment and loss of productivity, amounts to billions of USD annually. In addition, this expenditure increases incessantly over time. Recent studies suggest that walkability is a protective element for the development of diabetes based on the nexus between walkability and physical activity. It is clear that walkability facilitates reaching recommended levels of PA for the prevention and treatment of diabetes. In this sense, walkability is a parameter that should be considered in urban planning to promote PA and health. Designing neighbourhoods with high levels of transiitability through physical activities could contribute to reducing the incidence of diabetes, improving the effectiveness of interventions and also lower spending on health. Additionally, since changes in zoning, urban planning and design, variables of walkability are modifiable (Glazier et al., 2014), the benefits of walkability could be applicable even in established neighbourhoods. For this strategy to become effective, it is necessary to consider the relationship between walkability and other factors involved in urban design, as well as socioeconomic and environmental variables, with regard to the PA promotion. However, more studies are needed to fully evaluate the association between walkability and diabetes.

References


Figure 1. Schematic representation of the relationship between walkability and other factors present in the neighbourhood as determinants of physical activity and diabetes.

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