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The Influence of Built Environment on Walkability Using Geographic Information System

by
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The main goal of this study was to analyze the residential environment (built environment), by exploring the relationship between neighborhood walkability characteristics using Geographic Information System (GIS) and level of physical activity (PA). A randomly selected sample of 135 adults from Olomouc, Czech Republic was divided into low and high walkability neighborhoods based on the walkability index (calculated using GIS). The average daily number of steps (using Yamax SW-700 pedometer) between the groups also was measured. Result showed that participants living in the high walkable areas took more steps a day than participant in the low walkable areas. Furthermore, the mean body mass index (BMI) level was inversely correlated with the number of steps on weekdays and during the whole week. On weekend days it was still inversed throughout with the number of steps; taken but the but the relationship was not statistically significant.
Key words: *neighborhood buffer; land-use mix; walkability index; pedometer; BMI*

Introduction

Strong evidence demonstrates that, compared to less active persons, more active men and women have less health problems, exhibit a higher level of cardiorespiratory and muscular fitness, have a healthier body mass, and are able to live longer productive life (USDHHS, 2000). Despite the clear evidence of the health benefits of even moderate intensity of physical activity, many adults in Europe, as well as in other parts of the world are not active. It has been estimated that 30% to 60% of the population does not engage in sufficient level of physical activity (Haskell et al., 2007; European Commission, 2003).

Sallis et al., (2002) in his article suggested that multilevel approaches of psychological, sociocultural, and built environmental factors are needed to change this unwanted behavior. The built environment and human behavior has been studied in urban planning for long time; however, the emphases were on the physical health of the community (improvements in system efficiency, or reductions in environmental impacts) not on the personal health of its residents. The built environment, which has a positive effect on PA, is frequently represented by high population density, high street connectivity, land-use mix and a high value of the area used for retails - floor area ratio (FAR). The direct assessments of the links between the built environment and PA are still rare in urban planning; however, the cooperation between urban planning specialist and built environment specialist that will consider the PA as an important element have become important (Frank et al., 2005; Rodríguez et al., 2006).

The health community, on the other hand, recognized the association between the built environment and PA as an important element of public health (Frumklin et al., 2004). It has become apparent that environment is a determinant which influences PA and that adequately planned new residential areas provide more opportunities for active transportation

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and meeting health recommendations for PA than traditional neighborhoods (Abu-Omar et al., 2008; Badland et al., 2008; Giles-Corti et al., 2002; Saelens, et al., 2003; McCormack et al., 2008; Humpel et al., 2002; Sallis et al., 1998). The international grant project that is let by the research center in California "IPEN: International Study of Built Environment, Physical Activity, and Obesity", and the formation of the Center for the Built Environment and Health in Western Australia are also evidence of this trend.

Humpel et al., (2002) found that the built environment is correlated with recreational physical activity. Supporting this, Frank et al., (2003) found that obesity levels of residence are higher in the areas where the built environments make it difficult to walk to a destination. In the Czech Republic, walking is the most widespread moderate physical activity and to a large extent, influenced by the type and structure of the built environment (Frömel et al., 2004). Most of the studies on built environment and walking have been performed in United States and Australia. The Czech Republic build environment is very different compared to the United State and Australia. In addition, most of the previous studies have used self-reported measures of PA that had limited validity. The general consensus is that the absolute time of self-reported PA is overestimated (Sallis et al., 2000). To be objective, this study used the GIS to describe the built environment (low and high walkable neighborhoods) and pedometers to measure the PA. More research is needed to improve evidence of how built environments with low and high walkable neighborhoods influence the level of PA.

The main aim of the study was to analyze whether the adults in Olomouc living in the high walkable neighborhoods are more physically active than adults in Olomouc living in low walkable neighborhoods on weekdays, weekend days, and during the whole week. In addition, the study determined whether the adults BMI correlated with the number of steps on weekdays, weekend days, and during the whole week.

Methods

Recruitment

The sample consisted of 135 randomly selected adult participants from Olomouc, Czech Republic. The participant's ages ranged from 20 to 64 years old. Every participant signed a written informed consent form. From the sample of 135, only 70 par-

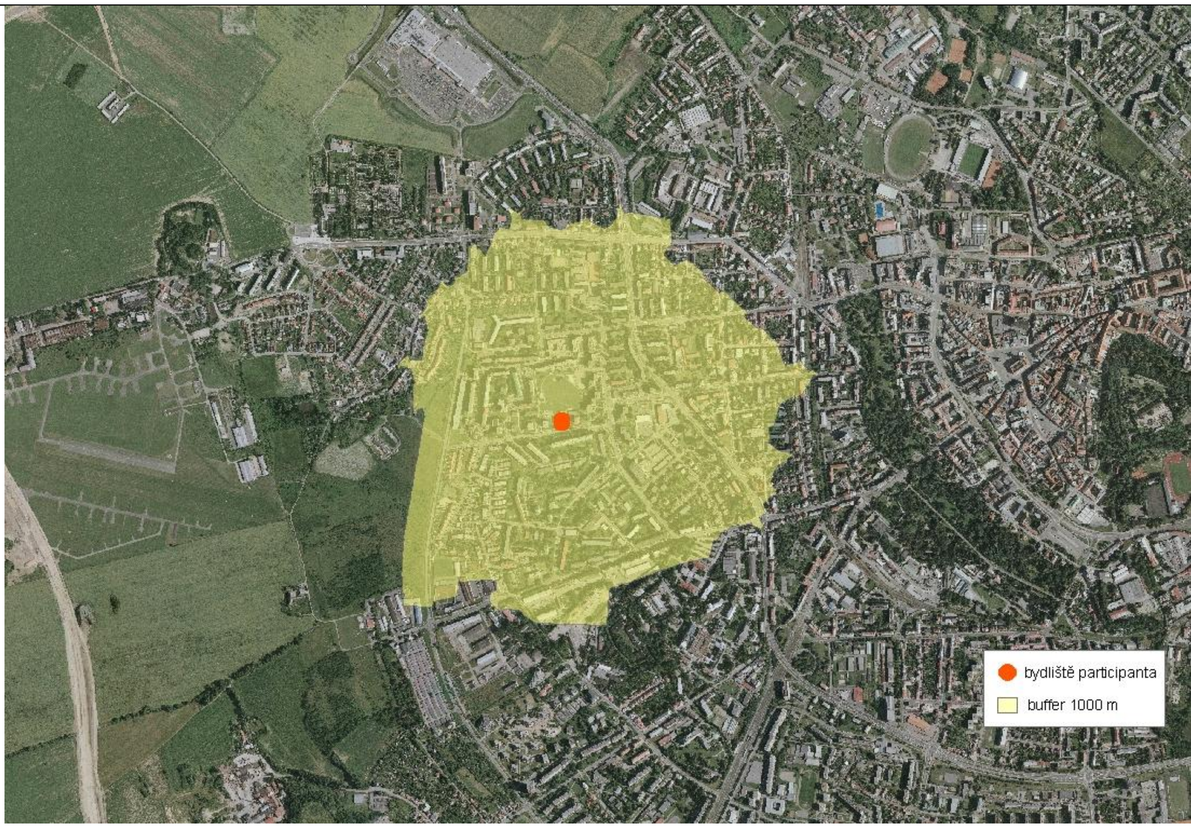

Figure 1

Neighborhood buffer - area within walking distance of 1000 m from home

Table 1

Number of steps in buffers with different walkability

Steps	Buffer 1	Buffer 2	p	t	SD 1	SD 2	d
	Mdn[b]	Mdn[b]			Mdn[b]	Mdn[b]	
weekdays	9916	12035	0.025	-2.29	2950	4602	0.55
weekend days	7516	9523	0.034	-2.17	2835	4685	0.52
week	9230	11318	0.013	-2.56	2554	4091	0.61

Glossary:
1 – low walkability, 2 – high walkability, Mdn[b] – median values, SD – standard deviation, p – level of statistical significance, d – coefficient "effect size".

ticipants completed the data and signed the consent form; therefore only data from 70 participants (41 men and 29 women, BMI 23.87 ± 3.96 kg·m^{-2}) were included in the analyses. Data collection took place in Spring, 2009. The city Olomouc has 103,293 residents and the mean temperature during Spring is 8.2^{o}C. Participants were selected randomly from the whole city and the built environment was defined for every participant in the study by creating a buffer neighborhood in GIS environment (Figure 1) to specify an area within 1000 m from one´s home.

The PA was measured using Yamax SW-700 pedometers. All pedometers were tested for accuracy before and after the data collection. Participants were ask to wear the pedometers on the right hip for seven consecutive days, reset the pedometers to 0 at the beginning of each day and remove the pedometer only when showering. They also used an activity log at the end of the day to record the numbers from the pedometers.

Frank et al., (2005) methodology was used calculate the walkability index. The data that had to be collected to calculate the walkability index were:

Residential density - the information on the number of inhabitants in houses and apartments in Olomouc city was obtained from the Permanent Residence Registration Office.

Connectivity index - the indicator is based on the number of intersections (of three or more roads) in a buffer and shows the level of connectivity in a given area. The data were obtained from the street graph of Olomouc city.

Land-use mix - the data on land-use mix were obtained from the land-use plan. The original plan was classified into 7 basic types (residential, commercial, service, institutional, industrial, recreational and others). Land-use mix (index of entropy) indicates the level of diversity of land use. The values are normalized on a scale from 0 to 1, where 0 refers to only one type of land use (e.g., residential) and 1 indicates balanced representation of all types of land use.

FAR index - the last factor necessary to determine the walkability index was the FAR (area used for retail). Such data did not exist in Olomouc, therefore results were obtained in a terrain survey. The index indicates the ratio of retail area to the entire commercial area.

Walkability index

The formula for calculating the walkability index:

Walkability index = [(2 x z–connectivity index) + (z–residential density) + (z–FAR index) + (z– land-use mix)].

The walkability index was calculated for every participant and the results were arranged in 10 groups from 1 to 10. Every group had 7 participants and represented areas with low walkability 1-5 groups and areas with high walkability from 6-10 groups (Frank et al., 2004, 2005; Cerin et al., 2007).

Pedometer

To measure the PA volume, represented by the average daily number of steps, we used the Yamax SW-700 pedometer along with the activity log. The use of a pedometer to monitor PA for the period of one week is sufficient (Tudor-Locke et al., 2005).

Statistics

To process the data, we used the two sample t-tests in the Statistica 8.0 (StatSoft CR, 2007) program. Statistical significance was set at the level of $p < 0.05$ upon the final calculation. The effect size was estimated using the d coefficient. According to Cohen (1988) d = 0.2 small effect, d = 0.5 medium effect, d = 0.8 high effect.

Results

From the total random sample of 135 participants, only 70 participants participated in the study (51.85%). The reason for not participating was not signing the consent form or not completing the data from the pedometers.

The results confirm that there is a relationship between the type of built environment and the level of PA measured with pedometers in adult participants (Table 1). The pedometers were worn for 7 consecutive days, which is in compliance with the Tudor-Locke et al. 2004, recommendation that to wear pedometers for 3 consecutive days for the adult population is sufficient. Low population density, low street connectivity, along with low land-use mix and low value of FAR index were associated with decline in PA measured with the pedometers. Significant differences in average number of daily steps were identified in participants from buffers with low walkability and high walkability areas. The differences between the average number of steps between high walkability areas and low walkability areas were on weekdays (M2 – M1 = 2119, p* = 0.025), weekends (M2 – M1 = 2007, p* = 0.034), and the whole week (M2 – M1 = 2088, p* = 0.013) were significant.

Invert relationship was found between the body mass index (BMI) and the mean number of steps on weekdays (M2 – M1 = 3383, p* = 0.001) and whole week (M2 – M1 = 2538, p* = 0.008). The relationships between the BMI and weekend days was still inverted; however, it was not significant (M2 – M1 = 424, p = 0.69).

Discussion

The purpose designed to determine the influence of a built environment on neighborhood walkability using a sample of 135 randomly selected adult participants from Olomouc, Czech Republic. The walkability characteristic index was calculated using Geographic Information System (GIS) data and the methodology employed by Frank at al., (2005), and physical activity (PA) levels of the sample participants were determined using pedometers.

The overall sample averaged 9752 steps per day and 53% participants met the minimum recommended value of 10,000 steps per day or 30 minutes of moderate PA per day (USDHHS, 2000). The data show, however, distinct differences between participants living in neighborhoods with a low walkability index and those in neighborhoods with a high walkability index. Those in the low index area averaged 9,230 steps per day while those in a high index area took 2,088 more steps or an average of 10,274 steps per day.

A similar Belgian study using a sample of 120 adult participants from a city of 70,000 residents, used field observations to define the low and high walkability indices, and pedometers to measure the number of steps taken by participants (Van Dyck at al., 2009) found that participants living in high walkability neighborhoods took significantly more steps per day, 9318, than those living in low walkability neighborhoods, 8096 steps per day. Steps taken for the entire sample averaged 8707 per day and 36.7% of the participants reached the 10000 steps/day recommendation level (USDHHS, 2000).

Relative to this research, the Belgian participants averaged 1045 less steps per day (9752 versus 8707) and 16.3% (53% versus 36.7%) less satisfied the minimum recommendation walking level. One possible explanation for the difference in the results of the two studies is the season of year in which the data were collected. The Belgian study was conducted during winter months as opposed to the spring season in this study. As suggested by Matthews et al, (2001), physical activity levels are con-

Table 2

Number of steps in adults with different BMI

Steps	BMI[a] ≥ 25 Mdn[b]	BMI[a] ≤ 25 Mdn[b]	p	t	SD ≥ 25 Mdn[b]	SD ≤ 25 Mdn[b]	d
weekdays	8463	11846	0.001	-3.32	3059	3918	0.1
weekend days	8204	8628	0.69	-0.39	5184	3519	0.0
week	8389	10927	0.008	-2.74	3350	3402	0.0

Glossary:

[a]BMI – body mass index (kg•m^{-2}), Mdn[b] – median values, SD – standard deviation, p – level of statistical significance, d – coefficient "effect size".

sistently lower in winter months than those of the spring, summer or fall.

Studies done on build environment in the United States and Australia such as (Saelens et al., 2003; Frank et al., 2005; Sallis et al., 2006b; Sallis et al., 2009; Owen et al., 2004; Gebel et al., 2007) also found a positive relationship between the level of PA and build environment. For example, Frank et al., (2005) using accelerometers to measure PA levels for a sample of 357 adults in Atlanta, Georgia and the GIS walkability index found a statistically significant relationship between community design and moderate levels of physical activity (p=0.002). Thirty-seven percent of the participants in the highest walkability quartile met the minimum recommended PA compared to only 18% of participants in the lowest walkability quartile.

This study also examined the question of whether BMI correlates with the number of steps walked. Previous studies have found that obesity is more common in areas where walking is difficult or income levels are below average (Saelens et al., 2003; Frumklin et al., 2004; Ewing et al., 2003; Frank et al., 2004; Frank et al., 2003).. For example, Giles-Corti et al., (2002) found an inverse relationship between obesity levels and the recreational resources available to sample participants. Sallis et al., (2009) found that participants living in low income neighborhoods had higher average BMI's than those in higher-income neighborhoods and participants living in low-walkability neighborhoods were associated with about a 50% increase in the risk of being overweight even though they were in the higher income group. Sugiyama et al., (2009) also reported that high walkability neighborhoods are associated with walking behaviors. His data were consistent with the finding from this study of an inverse relationship between the body mass index (BMI) and the mean number of steps.

While generalizations from the data of this study are restricted because of small sample size and establishing walking as the sole measure of physical activity, its strength lies in the use of objective measurements. GIS is thought to be the best metric available for assessing environmental influences (Frank at al., 2004) and the pedometer is considered an excellent tool for measuring the average daily number of steps walked (Tudor-Locke et al., 2005). Both would be valuable components in the methodology of further research on the relationship between built environment and physical activity and the influence of demographic, biological, psychological and behavioral variables on physical activity and overall health.

Conclusions

Available research identifies a wide range of variables such as demographic, biological, psychological, behavioral, and environmental that influence physical activity levels of children and adults. While this study only examined the influence of one variable, built environment and the walkability index, the following conclusions can be drawn:

1. The research design and data produced by this and similar studies are important for evaluating comparisons between populations of different countries and for the decision making process of public health officials.
2. Insufficient physical activity and obesity are significant global health problems (World Health Organization, 2004) and this study provides additional evidence that built environment, a variable controlled by public policy, is related to both issues.
3. A built environment is an important determinant of at least one moderate physical activity, walking.
4. A built environment encourages more walking which has a positive influence on BMI.

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