The impact of neighbourhood walkability on the effectiveness of a structured education programme to increase objectively measured walking

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Abstract

Background

Incorporating physical activity into daily activities is key for the effectiveness of lifestyle education interventions aimed at improving health outcomes; however, consideration of the environmental context in which individuals live is not always made. Walkability is a characteristic of the physical environment, and may be a potential facilitator to changing physical activity levels.

Methods

Using data collected during the Walking Away from Diabetes randomised controlled trial, we examined the association between the walkability of the home neighbourhood and physical activity of participants. We also determined whether home neighbourhood walkability of participants was associated with the intervention effect of the education programme.

Results

Data from 706 participants were available for analysis. Neighbourhood walkability was not significantly associated with any of the physical activity measures at baseline, or at 12, 24 or 36 months following the intervention ($p>0.05$ for all). There was no association between walkability and change in purposeful steps/ day from baseline to 36months in the usual care or intervention arm; 25.77 (-99.04, 150.58) and 42.97 (-327.63, 413.45) respectively.

Conclusion

Neighbourhood walkability appeared to have no association with objectively-measured physical activity in this population. Furthermore, the walkability of participant's neighbourhood did not influence the effectiveness of a lifestyle programme.

Background

The current estimated prevalence of type 2 diabetes mellitus (T2DM) for adults aged between 20 and 70 years is 415 million globally [1]. Approximately 4 million people live with the condition in the UK alone, and this figure is predicted to reach 5.5 million by 2025 [1]. Importantly, evidence reviews demonstrate that lifestyle education programmes, based on improving diet quality and increasing physical activity can significantly delay or prevent the onset of T2DM, and lead to a reduction in body weight and blood glucose levels [2,3]. Incorporating physical activity into daily activities is key for the effectiveness of these interventions, and evidence consistently demonstrates an inverse association between physical activity and T2DM [4].

The Prediabetes Risk Education and Physical Activity Recommendation and Encouragement (PREPARE) study demonstrated that group-based structured education can increase step count and improve blood glucose in individuals with impaired glucose tolerance [5]. The intervention used in the PREPARE trial was subsequently developed into the Walking Away from Type 2 Diabetes (Walking Away) programme [6]. This was tested in a cluster randomised trial that aimed to determine whether results from the PREPARE trial could be replicated within primary care practices in those identified at high risk of T2DM, and if results are maintained at 12, 24 and 36 months[7]. Results showed that Walking Away, a pragmatic low-resource group-based education programme, resulted in a modest increase in ambulatory activity compared with usual care at 12 months. These effects were not however maintained at 36 months. This demonstrates the difficulty of translating research into practice, and understanding what influences physical activity behaviours is essential for the improvement of these public health interventions [8]. Consideration of the social context in which a person lives may be important when it comes to implementing lifestyle changes at the individual level. Further, a range of factors within the social-environmental context have been shown to influence physical activity [9]. Indeed, growing evidence suggests that environmental factors influence behaviour both directly and indirectly [10]. The home neighbourhood in which an individual resides may be an important consideration when an individual attempts to increase their physical activity following lifestyle advice, because it may pose barriers, or act as a facilitator to achieve physical activity recommendations [11].

Walkability is a characteristic of the physical environment, which may be defined as the suitability of a neighbourhood to walk in, and includes characteristics such as continuity of pathways, lighting, safety, design of crossings, and access to local amenities. There is growing evidence that neighbourhood walkability correlates to levels of physical activity, and may be a potential preventable factor for T2DM [12]. We believe that evidence from social-ecological models of health behaviours has particular relevance to individual-level interventions, as it may be the context in which intervention participants live that acts as a determinant of intervention efficacy. For example, given the evidence that walking behaviours are associated with area walkability, it is reasonable to suggest that a walking intervention might work better for participants living in a more walkable area even if the intervention makes no change to walkability itself. We therefore believe the context of interventions should routinely be examined as part of outcome evaluations, yet this is rarely done.

Using data collected during the Walking Away from Diabetes randomised controlled trial, we examined the association between the walkability of the home neighbourhood and objectively-measured physical activity both at the cross-sectional and longitudinal level. We also aimed to determine whether the home neighbourhood walkability of participants influenced the intervention effect of the education programme.

Methods

Participants

The present analyses used data from a completed cluster randomised controlled trial of 808 participants conducted in Leicestershire, UK (Walking Away from Diabetes; NCT00941954) [6]. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by the Nottingham Research Ethics Committees. Written informed consent was obtained from all participants. The study and intervention have been described in detail elsewhere [6]. Briefly, individuals aged between 18 to 74 years inclusive, were identified from GP practices as being at high risk of having T2DM using the Leicester Practice Risk Score [13]. Those identified as being diabetes-free but at high risk of developing T2DM were then randomised at the level of the primary care practice (GP practice) to receive usual care or to attend a group-based education programme encouraging increased physical activity, specifically focusing on increasing step count. Ten GP practices were included; nine from Leicester City (three urban, five suburban, one semi-rural) and one from Leicestershire county (rural). Participants were excluded if they had a previous diagnosis of T2DM. All participants in the Walking Away from Diabetes study were potentially eligible for these analyses. Participants were excluded if they did not have valid postcode data available at baseline, as this was used to derive the walkability measures.

Variables

All of the physical activity outcome variables were objectively-measured at baseline, 12, 24, and 36 months using an accelerometer (GT3X, Actigraph, FL, USA). Participants were asked to wear the accelerometer on their right anterior axillary line for seven consecutive days during waking hours. Data were captured in 15 second epochs but were re-integrated to 60 seconds for this analysis. The primary outcome was ambulatory activity (walking), defined as the average number of steps per day. This was also the primary outcome in the original study [6]. The secondary outcomes were purposeful ambulatory activity (average number of purposeful steps per day), time spent in moderate-to-vigorous physical activity (MVPA), and time spent sedentary. Purposeful ambulatory activity is defined as the average number of accumulated steps per day undertaken above an intensity threshold (≥500 counts/minute) distinguishing steps accumulated in incidental activity from those involving more purposeful walking [14]. Sedentary time (<100 counts-per-minute) and MVPA (≥1952 counts-per-minute) were defined using validated counts-per-minute cut-points [15]. Participants were excluded if they did not have four valid days of accelerometer wear at baseline, as this was required to calculate the primary outcome. Valid days were defined as ≥10 hours of waking wear.

The main explanatory variable was neighbourhood walkability. Data for six indicators of neighbourhood walkability were computed (effective walkable area, road density, footpath density, number of junctions, number of cul-de-sacs, connected node ratio (Supplementary Table S1) [16]. ArcGIS 10.1 (ESRI, California, USA), a geographic information system, was used to calculate these measures [17]. To delineate neighbourhood boundaries, the home postcode of each participant at baseline was geo-located using the UK Ordnance Survey Code-Point® database [RW.ERROR - Unable to find reference:10378], which provides a set of coordinates depicting the average latitude and longitude of all mail delivery locations within each postcode, which contains 15 addresses on average. Neighbourhoods were delineated based on an 800m road network buffer around these coordinates. This buffer was chosen as it represents an approximate 10 minute walk from the participant's home [18]. The measures were combined into a single composite index, where a higher value indicates a more walkable neighbourhood. This index was created by reverse coding those scores that were inversely associated with walkability (so that a higher score always inferred higher walkability), calculating z-scores for each indicator, and then summing these to give an overall index.

Other explanatory variables were measured at baseline and treated as confounders: ethnicity (self-reported using Census categories and grouped as White European and non-White due to the small number of participants in some ethnic groups); age (calculated from the participant's self-reported date of birth and date of baseline visit; continuous); sex (self-reported; men/women); social deprivation score (Index of Multiple Deprivation [IMD] score; continuous); body mass index (BMI; kg/m^2; continuous); and current smoker (self-reported; yes/no). IMD scores are publically available and are calculated using a variety of measures, including income, employment, health, education, and housing [19]. Trained staff measured weight and height, which were used to calculate BMI, to the nearest 0.1kg and 0.5cm, respectively.

Statistical analysis

Participant characteristics at baseline were summarised as mean (standard deviation [SD]) for Normally-distributed continuous variables, median (interquartile range) for non-Normal continuous variables, and number (percentage) for categorical variables. To investigate the cross-sectional association at baseline between the neighbourhood walkability index (explanatory variable; continuous) and the physical activity variables (outcome variables; continuous), the following linear regression models were fitted. Unadjusted Model: unadjusted for confounders, but accounted for the average accelerometer wear time in minutes (continuous); Adjusted Model 1: ethnicity, age, sex, and social deprivation score; Adjusted Model 2: As in Model 1 plus BMI and current smoker. All models were fitted with standard errors that accounted for the practice-level clustering.

Additional linear regression models were fitted to determine whether changes in the physical activity variables from intervention baseline to each follow-up point (outcome) were associated with the neighbourhood walkability index (explanatory variable) with adjustment for change in wear time, treatment allocation, and all of the confounders listed above (i.e. Adjusted Model 2), and with standard errors that accounted for the practice-level clustering. A treatment-walkability interaction was also fitted to determine whether neighbourhood walkability was associated with the effectiveness of the allocated treatment; subset analyses were conducted by treatment arm where the interaction term was significant at the 10% level. The main analyses used a road network buffer of 800m to define the home neighbourhood; sensitivity analyses were performed using buffers of 400m and 1600m. Additional sensitivity analyses repeated the main analyses using the individual walkability indicators as explanatory variables, instead of the composite neighbourhood walkability index.

Analyses were performed in Stata v14.0. P-values <0.05 for main effects and <0.10 for interactions were treated as statistically significant. Missing data were not imputed.

Results

Baseline characteristics

The Walking Away from Diabetes study included 808 individuals at high risk of T2DM. Of these, one participant had an invalid postcode and 101 did not have four days of valid accelerometer wear at baseline and were thus excluded; therefore, data from 706 participants were analysed. Age of participants included in this analysis ranged from 30 to 74 years. Mean age and BMI of the population were 63.8 years (SD 7.7 years) and 32.2 kg/m^2 (SD 5.3 kg/m^2), respectively (Table I). The majority of participants were of White European background (89%), with 11% from other ethnic groups. Males comprised 65% of the study population. The 102 excluded participants were, on average, younger (mean age 58.9 years; p for difference < 0.001) and heavier (mean BMI 34.3kg/m^2; p for difference < 0.001) than those included in the analyses, but included a similar percentage of White Europeans (84%; p for difference = 0.13) and males (56%; p for difference = 0.08).

Cross-sectional associations between walkability and physical activity

Table II shows the association between neighbourhood walkability and objectively-measured physical activity at baseline. In unadjusted and adjusted analyses, neighbourhood walkability was not significantly associated with any of the physical activity measures ($p>0.05$ for all). The exception to this was that a more walkable neighbourhood was associated with more sedentary time in unadjusted analyses (coefficient [95% confidence interval]: 1.52 [0.02, 3.02], $p = 0.048$), but this association was attenuated and non-significant after adjustment for confounders.

Longitudinal associations between walkability and physical activity

Table III shows the adjusted association between baseline walkability and change in the physical activity measures from baseline to follow-up at 12, 24, and 36 months. There was no significant association between neighbourhood walkability and change in physical activity ($p > 0.05$ for all).

Association between walkability and intervention effect

When a treatment-walkability interaction term was included in each of the models in Table III, the only significant interactions were between treatment allocation and neighbourhood for total steps ($p = 0.01$) and purposeful steps ($p = 0.04$) at 36 months. These analyses were then stratified by treatment allocation, which did not demonstrate any significant associations within each treatment arm (Table IV).

Sensitivity analyses

The analyses were repeated using 400m and 1600m buffers (data not in Table), instead of 800m. When a 400m buffer was used, the pattern of results was the same as with the 800m buffer, except that the interaction between walkability and treatment allocation for purposeful steps was not significant ($p = 0.113$). When a 1600m buffer was used, all of the results demonstrated the same pattern as with the 800m buffer.

The analyses were also repeated using the individual walkability indicators as explanatory variables, rather than the combined walkability index used in the main analyses. These sensitivity analyses (Supplementary Tables SII and SIII) demonstrated the same pattern as the main results, i.e. no significant associations, with two exceptions (fewer junctions was significantly associated with fewer average steps/day at baseline; higher road density was significantly associated with a greater change in average steps/day from baseline to 12 months).

Discussion

Main Finding

This study used baseline and longitudinal data from the Walking Away from Diabetes randomised controlled trial to explore associations between the walkability of the home neighbourhood and physical activity, where both were objectively-measured. Our data suggested that neighbourhood walkability was not associated with physical activity levels or with the effectiveness of the lifestyle programme used in the trial.

What is already known on this topic

Our finding that neighbourhood walkability was not associated with physical activity is in contrast to some earlier studies; however, we used objectively-measured physical activity whereas previous work has found associations between neighbourhood walkability and self-reported weekly walking [20]. Our results support a systematic review which examined associations between the environment and physical activity in older adults, and adds to the limited data available in this older population [10]. Findings may indicate that other aspects of the environment should be considered when exploring the effect of the neighbourhood environment and health outcomes [12]; for example, we have previously demonstrated strong associations between the number of fast food outlets and risk of developing diabetes in this population [21]. It has also been suggested that there is significant heterogeneity between studies examining obesity and the built environment [22]; thus, results should be interpreted with caution, as different walkability measures examine different aspects of the environment. This is an emerging field of research and contrasting data may suggest that we are still at the early stages of understanding the impact of the local environment on individual behaviours, and the most appropriate methods by which to measure this.

What this study adds

We explored whether the treatment effect of the lifestyle education programme differed according to neighbourhood walkability. Generally, this was not the case. Stratified analyses suggested stronger associations between walkability and total (inverse association) and purposeful (positive association) steps/day in the intervention than the usual care arm. None of the stratified associations were however statistically significant, further suggesting that the impact of walkability on treatment effect was weak. This may indicate that lifestyle education programmes do not necessarily need to be tailored to the environment; although, we believe this is the first study to examine the social-environmental context on the effect of lifestyle education, and further research should be encouraged.

This study included participants from Leicester City and Leicestershire, comprising a broad range of environments, from inner city to suburban to rural, providing a large variation in exposure. However, the measures of walkability included may not capture all of the differences between the environments equally as well. For example, road network measures may be less informative in rural settings, where off-road footpaths are available. An important consideration is that only one of the GP practices included is classed as Leicestershire, not Leicester which may limit the generalisability of findings. However, the percentage of included participants ranged from 5% to 16% across GP practices; demonstrating a relatively even number of participants per cluster. The overall neighbourhood walkability included in our analysis represents an area of good street connectivity, with mean connected node ratio and footpath density of 0.7 and 0.74 respectively [16].

A consideration in interpreting these data should be perceived (i.e. participant reported) walkability; we did not measure this in our study and so were unable to take this measure into account in our analyses. A number of studies have demonstrated differences between objectively-measured walkability and perceived walkability [RW.ERROR - Unable to find reference:10371]. Hajna *et al* 2016 calculated walkability using both GIS derived walkability measures and self-reported perceived walkability measures [23]. When using the objectively-measured walkability, there was a difference of 606 steps per day when comparing the highest to lowest walkability areas. Yet when measuring perceived walkability, there was a difference of 1345 more steps between those who perceived the area to be the most walkable compared with those who perceived the area to be the least walkable [23]. A study in Australia also showed clear differences between objectively-measured walkability and perceived walkability, and highlights the importance of promoting a positive view of a neighbourhood to support walking [RW.ERROR - Unable to find reference:10371]. People's perception of the environment may be more important than objective walkability measures in determining whether they undertake activity or not, and research into this should be considered.

Limitations of this study

A limitation which should be considered is that the Walking Away Programme was not originally designed to investigate walkability, thus the sampling frame may not have provided a great enough exposure to maximise potential differences between different neighbourhood walkability variables. Furthermore, the walking environment was not a focus discussed within the intervention curriculum. Nonetheless, there is evidence our results are robust as the findings did not substantially alter when two alternative buffer sizes were used, nor when alternative measures of walkability were used. The population included in this analysis are an "at risk" population and therefore results may not be generalizable to the wider population. Furthermore we should consider the possibility of selection bias, those excluded were younger and had a higher BMI than those included in the analysis. Adjustment for age and BMI did not significantly affect overall results; however, we cannot exclude the possibility that residual confounding factors may have attenuated results. We believe our study also has a number of additional strengths. We used objective measures of step count, sedentary behaviour and activity; a criticism of previous work is that studies have relied on self-report. We also examined both cross-sectional and longitudinal data to interpret the association between neighbourhood walkability and physical activity.

Conclusion

Objectively-measured neighbourhood walkability was not associated with physical activity in this population. Walkability also appeared to have little influence on the effectiveness of the lifestyle programme aimed at increasing walking. This particular intervention did not include any discussion on walkability or the neighbourhood environment of participants; however to our knowledge this is the first study to examine the social-environmental context of the effect of lifestyle education and future work should be encouraged which considers the context in which interventions take place, and how this may influence both activity and health outcomes.

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Conflict of interest: Professor Melanie J Davies has acted as consultant, advisory board member and speaker for Novo Nordisk, Sanofi-Aventis, Lilly, Merck Sharp & Dohme, Boehringer Ingelheim, AstraZeneca and Janssen and as a speaker for Mitsubishi Tanabe Pharma Corporation. She has received grants in support of investigator and investigator initiated trials from Novo Nordisk, Sanofi-Aventis, Boehringer Ingelheim, Janssen and Lilly. Professor Kamlesh Khunti reports he has acted as consultant, advisory board member and speaker for Novo Nordisk, Sanofi-Aventis, Lilly, Merck Sharp & Dohme, Boehringer Ingelheim, AstraZeneca and Janssen. He has received grants in support of investigator and investigator initiated trials from AstraZeneca, Novartis, Novo Nordisk, Sanofi-Aventis, Lilly, Janssen, Boehringer-Ingelheim and Merck Sharp & Dohme and Roche. KK (Chair), MJD and TY are members of the NICE Public Health Guidance (PH38) Preventing type 2 diabetes: risk identification and interventions for individuals at high risk. All other authors have nothing to declare.

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Table I. Baseline descriptive characteristics of 706 participants from the Walking Away from Diabetes study included in these analyses.

Variable	Mean (SD) or Median [IQR]
Demographic characteristics	
Age, years	63.77 (7.71)
Social deprivation score	18.91 (15.15)
BMI, kg/m^2	32.15 (5.31)
Weight, kg	91.59 (16.61)
Walkability measures[a]	
Effective walkable area	0.47 (0.14)
Road density	10.27 (4.07)
Footpath density	0.74 (0.86)
Junctions	5.40 (1.16)
Cul-de-sacs	2.23 (1.01)
Connected node ratio	0.71 (0.10)
Walkability index	0.00 (3.32)
Physical activity measures	
Average number of steps/day	6585.8 (3177.8)
Average number of purposeful steps/day	4651.3 [3087.7, 6778.6]
Average minutes/day in MVPA	20.4 [9.5, 38.2]
Average minutes/day in sedentary behaviour	542.63 (99.35)
	Number (%)
Sex	
Men	457 (64.7)
Women	249 (35.3)
Ethnicity	
White European	631 (89.4)
Non-White	75 (10.6)
Current smoker	
No	643 (91.1)
Yes	63 (8.9)
Total	**706 (100.0)**

Abbreviations: BMI, Body Mass Index; IQR, Interquartile Range; MVPA, Moderate-to-Vigorous Physical Activity; SD, Standard Deviation.

Missing data: 36 Social deprivation score; 1 BMI; 1 Weight; 0 for all other variables.

[a] All measured using a 800m road network buffer, which represents a 10 minute walk.

Table II. Coefficients (95% confidence interval) showing the association between neighbourhood walkability[a] and objectively-measured physical activity at baseline.

Physical activity measure	Unadjusted[b] (n=706)	Adjusted Model 1[c] (n=670)	Adjusted Model 2[d] (n=669)
Average steps/day	-59.19 (-133.81, 15.43)	-33.79 (-108.47, 40.88)	-17.89 (-95.35, 59.57)
Log average purposeful steps/day[e]	0.00 (-0.04, 0.05)	0.01 (-0.05, 0.06)	0.01 (-0.03, 0.06)
Log MVPA time (Log average mins/day)[e]	-0.02 (-0.04, 0.00)	-0.02 (-0.04, 0.01)	-0.01 (-0.04, 0.02)
Sedentary time (Average mins/day)	1.52 (0.02, 3.02)*	1.01 (-1.35, 3.37)	0.64 (-1.35, 2.62)

Abbreviations: MVPA, Moderate-to-vigorous physical activity.

* $P < 0.05$.

[a] Composite index measured using a 800m road network buffer, which represents a 10 minute walk.

[b] Estimates were unadjusted for confounders, but accounted for change in average wear time and practice-level clustering.

[c] Estimates accounted for practice-level clustering and were adjusted for change in average wear time, ethnicity, age, sex, and social deprivation score.

[d] Estimates accounted for practice-level clustering and were adjusted for the variables in Model 2 plus body mass index and smoking.

[e] Data were skewed so the model was fitted using log transformed data.

Table III. Adjusted coefficients (95% confidence interval)[a] showing the association between neighbourhood walkability[a] and change in physical activity from baseline to follow-up.

Physical activity measure	**Follow-up time point**		
	12 months (n = 540)	**24 months (n = 518)**	**36 months (n = 493)**
Average steps/day	-9.00 (-93.00, 75.00)	-17.47 (-103.87, 68.93)	-3.26 (-87.12, 77.61)
Average purposeful steps/day	-8.51 (-96.23, 79.22)	-18.17 (-107.97, 71.63)	60.82 (-106.46, 228.11)
MVPA time (Average mins/day)	-0.11 (-0.81, 0.59)	-0.30 (-1.16, 0.57)	-0.04 (-0.63, 0.55)
Sedentary time (Average mins/day)	0.78 (-1.33, 2.89)	-0.42 (-2.16, 1.32)	0.49 (-2.01, 2.99)

Abbreviations: MVPA, Moderate-to-Vigorous Physical Activity.

[a] Estimates accounted for practice-level clustering and were adjusted for average wear time, treatment allocation, ethnicity, age, sex, social deprivation score, body mass index, and smoking.

[b] Composite index measured using a 800m road network buffer, which represents a 10 minute walk.

Table IV. Adjusted coefficients (95% confidence interval)[a] showing the association between neighbourhood walkability[b] and change in steps/day from baseline to 36 month follow-up stratified by treatment allocation.

Physical activity measure	Treatment allocation	
	Usual care (n=259)	**Intervention (n=234)**
Average steps/day	19.68 (-100.20, 139.57)	-63.38 (-206.95, 80.18)
Average purposeful steps/day	25.77 (-99.04, 150.58)	42.97 (-327.63, 413.58)

[a] Estimates accounted for practice-level clustering and were adjusted for average wear time, treatment allocation, ethnicity, age, sex, social deprivation score, body mass index, and smoking.

[b] Composite index measured using a 800m road network buffer, which represents a 10 minute walk.