Walkable neighbourhoods, Physical activity and Wellbeing in Melbourne, Australia

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Abstract: The purpose of this study is to investigate, for the case of Melbourne, Australia, the link between walkable neighbourhoods and wellbeing and how this relationship may be mediated by physical activity. Employing data from the Household, Income and Labour Dynamics in Australia (HILDA) survey for 2013 and Geographic Information Systems (GIS), this study finds a link between a more walkable neighbourhood and wellbeing, mediated to a very marginal degree by physical activity. Across measures of life satisfaction, happiness, mental health and psychological distress this link is clearest for psychological distress. However, the nature of this relationship stands in stark contrast to earlier findings regarding walking and cycling behaviours. While more walkable neighbourhoods are associated with more total walking time, they are also associated with lower likelihood of engaging in the recommended level of physical activity. Hence, the mediated effect of walkable neighbourhoods on wellbeing is negative. Further, residual direct effect of walkable neighbourhoods of wellbeing is also negative. These findings suggest earlier evidence on walking and cycling behaviours and associated health promotional initiatives may be missing the broader pursuit. As such further research, perhaps considering alternative mechanisms to promote health and wellbeing and achieve desired public health outcomes. These findings may prove helpful to decision makers such as The Victorian Health Promotion Foundation (VicHealth) seeking to support the health and wellbeing of Victorians.

Keywords: Geographic Information Systems (GIS), Happiness, Household, Income and Labour Dynamics in Australia (HILDA) survey, Life satisfaction, Mental health, Psychological distress, Walkability, Wellbeing

1. Introduction

Physical activity is an important determinant of health and wellbeing. Engaging a moderate level of physical activity on most if not all days of the week promotes significant health and wellbeing benefits. A moderate level of physical activity not only lowers risk of; premature mortality, coronary heart disease, hypertension, colon cancer and diabetes; it also supports the health of muscles, bones and joints and improves mental health (US Department of Health, 1996). Scholars from a range of disciplines including public health, sociology, psychology and urban planning, acknowledging this link, have sought to understand how urban environments may influence physical activity and hence health and wellbeing. This search for understanding has led to an ever growing and increasingly rich body of evidence pointing to how cities may be healthier and happier places to live.

Urban environments through mixed use development, street connectivity, and good design, *inter alia*, are found to promote active travel to get to work, school, friends, shops and so on, enhancing both the feasibility and the attractiveness of walking and bicycling (Handy, Boarnet, Ewing, & Killingsworth, 2002). The incidental nature of walking for transport offers a practical means of integrating 30 min of moderate intensity activity at least 5 days a week into residents' daily lives. In doing so, walkable cities are thought to promote residents' health and wellbeing (Barton & Grant, 2006). This is a line of reasoning is confirmed by studies finding evidence that suggests residents from communities with higher density, greater connectivity, and more diverse land use mixes report higher rates of walking/cycling than low-density, poorly connected, and single land use neighbourhoods (Saelens, Sallis, & Frank, 2003).

Notwithstanding the many studies of neighbourhood walkability and physical activity, it is hard to deny the role of potentially omitted variables (Saelens et al., 2003). Furthermore, few studies have considered how walkable neighbourhoods may be linked to *total* physical activity (cf. Forsyth, Hearst, Oakes, & Schmitz, 2008; Forsyth, Oakes, Schmitz, & Hearst, 2007; Giles-Corti & Donovan, 2002, provide an exception) instead tending to focus exclusively on walking or cycling behaviours (Bentley, Jolley, & Kavanagh, 2010; Christian et al., 2011; Kinnafick & Thøgersen-Ntoumani, 2014; Saelens et al., 2003; Sugiyama, Leslie, Giles-Corti, & Owen, 2008). Despite these earlier and admirable efforts examining such behaviours there remains a paucity of research making an explicit link between walkable neighbourhoods, physical activity and wellbeing.

This study investigates the link between walkable neighbourhoods and wellbeing and how this relationship may be mediated by physical activity (the recommended amount of physical activity). In doing so, this study extends existing knowledge and provides evidence which may prove helpful to decision makers seeking to support the health and wellbeing of residents. In what follows, Section 2 describes the method and data employed while Section 3 reports the results obtained. Finally, Section 4 discusses the findings and concludes.

2. Method and data

The first stage of the analyses examines the relationship between the walkability of a neighbourhood and wellbeing, holding constant other factors (apart from physical activity). The second stage of the analyses assesses whether or not the walkability of a neighbourhood is related to physical activity, holding constant other factors. The third and final stage of the analyses evaluates the extent to which physical activity mediates any links between walkability of the neighbourhood and wellbeing observed in the first stage by adding the physical activity variable to the initial models (from the first stage) and examining any changes to these results.

2.1. Analytical approach

To begin with, the following base microeconometric wellbeing function is modelled using a cluster-specific fixed model for resident *r*, in location *k*.

$$\mathrm{WB}_{\mathrm{r,k}} = \omega + \sum_{\mathrm{j}=1}^{\mathrm{m}} \beta_{\mathrm{j}} \mathrm{x}_{\mathrm{j}_{\mathrm{r,k}}} + \kappa_k + \varepsilon_{\mathrm{r,k}} \quad (1)$$

Where $\mathrm{WB}_{\mathrm{r,k}}$ is a resident's wellbeing,[1] $\mathrm{x}_{\mathrm{j}_{\mathrm{r,k}}}$ represents socioeconomic variables *j* to *m* such as, age, gender and importantly a measure of walkability of the neighbourhood (although not a measure of physical activity). κ_{k} represents the Local Government Area (LGA)-specific fixed effects. Finally, $\varepsilon_{\mathrm{r,k}}$ is the error term.

[1] Captured by measures of: life satisfaction, happiness, mental health and psychological distress.

Subsequently, the following base microeconometric physical activity function is modelled, also using a cluster-specific fixed model.

$$\mathrm{PA}_{\mathrm{r,k}} = \omega + \sum_{\mathrm{j=1}}^{\mathrm{m}} \beta_{\mathrm{j}} \mathrm{x}_{\mathrm{j}_{\mathrm{r,k}}} + \kappa_{\mathrm{k}} + \varepsilon_{\mathrm{r,k}} \quad (2)$$

Where $\mathrm{PA}_{\mathrm{r,k}}$ is either whether or not a resident exercises as recommended or a resident's walking time, $\mathrm{x}_{\mathrm{j}_{\mathrm{r,k}}}$ is defined as in Equation 1.

Finally Equation 1 is augmented to include the physical activity variable yielding Equation 3.

$$\mathrm{WB}_{\mathrm{r,k}} = \omega + \sum_{\mathrm{j=1}}^{\mathrm{m}} \beta_{\mathrm{j}} \mathrm{x}_{\mathrm{j}_{\mathrm{r,k}}} + \kappa_{k} + \varepsilon_{\mathrm{r,k}} \quad (3)$$

Where $\mathrm{x}_{\mathrm{j}_{\mathrm{r,k}}}$ in Equation 3 now also includes the measure of physical activity.

2.2. Data

In terms of the socioeconomic data on residents of Melbourne, Australia this is obtained from wave 13 (2013) of the Household, Income and Labour Dynamics in Australia (HILDA) survey. These data are subset to the Greater Capital City Statistical Area of Melbourne. The physical activity variable is the Metabolic Equivalent of Task (MET) minutes per week (International Physical Activity Questionnaire) dichotomised to *'Exercising as recommended (MET)'* (1) or not (0) where exercising as recommended is defined as MET minutes per week greater than 840 and less than 10,000. That is, the equivalent of 30 or more min × week × 4 MET. To avoid measurement error due to over-reporting, those reporting energy expenditure of 10,000 MET (min/week) or more were excluded. Residents whose health limits their ability to walk 1 kilometre or more were also excluded (Giles-Corti & Donovan, 2002). Exercising as recommended was defined as the accumulation of the equivalent of 30 min or more of moderate physical activity on most days of the week (US Department of Health, 1996). Also from the HILDA survey is the key dependent variable is the life satisfaction variable. This measure is obtained from residents' responses to the question: '*All things considered, how satisfied are you with your life?*' The life satisfaction variable is an ordinal variable, the individual choosing a number between 0 (totally dissatisfied with life) and 10 (totally satisfied with life).

This data is linked to Geographic Information Systems (GIS) data through the resident's Census Collection District (CD). Using GIS a walkability index is calculated for based on the area within a 1200 metre radius of the centroid or centre point of the resident's CD. If CDs are assumed to be roughly circular, the radius at this at this median is 309 metre. This figure provides an indication of the upper bound of the measurement error introduced by need to satisfy confidentiality requirements. As such the neighbourhood or service area is defined at the median as the area within 1509 metres of the CD centroid.

Based on this definition the calculation of this walkability index follows earlier efforts by Christian et al. (2011) and Frank, Schmid, Sallis, Chapman, and Saelens (2005). There are three components which are standardised and then summed to construct the walkability index: net residential density, street connectivity and land use mix. *A priori* more walkable neighbourhoods are expected to be associated with greater wellbeing through promoting greater physical activity. The quartiles of the walkability index are used to reveal the nature of the relationship between residing in a more walkable neighbourhood and a resident's physical activity and wellbeing. Net residential density is measured by the number of dwellings per hectare zoned as residential obtained using the 2011 Australian Bureau of Statistics Mesh Blocks data on the number of dwellings (Australian Bureau of Statistics, 2012) and Vicmap planning scheme zones (The State of Victoria, 2015). Street connectivity is measured using the number of 3 or more way intersections employing roads data from the PSMA Australia Limited Transport and Topography dataset.

The land use mix variable is derived largely from the Vicmap planning scheme zones (The State of Victoria, 2015), sporting infrastructure land use was derived from the PSMA Australia Limited Transport and Topography dataset. The following Equation 3 was employed:

$$\mathrm{H} = -1 \left(\sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{p_i} \times \ln(\mathrm{p_i})\right) / \ln(\mathrm{n}) \quad (3)$$

Where H is the land use mix, p_i is land use *i* as a proportion of total summed area of land uses (including *i*) and *n* is the number of land use classes of interest. The different land use classes include: residential, commercial, education, health and community, industrial, primary and rural, public open space, sporting infrastructure and conservation zones. A detailed description of the variables and descriptive statistics are reported in Table 1.

Table 1: Key variables

Variable name	Definition	Mean (std. dev.)	%
Dependent variables			
Life satisfaction	Resident's life satisfaction (0-10)	8.0 (1.2)	
Happiness	Resident's happiness where 1 is happy none of the time in the last four weeks and 6 is happy all of the time in the last four weeks.	2.5 (1.0)	
Mental health	Resident's SF-36 Mental Component Summary (MCS) (0-100)	49.0 (9.7)	
Psychological distress	Resident's Kessler Psychological Distress Scale (K10) score (10-50)	15.2 (5.5)	
Independent variables			
Walkability	Resident's neighborhood walkability index defined as the sum of the standardised net residential density, street connectivity and land use mix within a 1200 metre radius of the centroid or centre point of the resident's Census Collection District (CD)	0.1 (1.5)	
Exercising as recommended (MET)	Resident has Metabolic Equivalent of Task (MET) minutes per week greater than 840 and less than 10,000. That is, the equivalent of 30 or more min × week × 4 MET		62.1%
Walking time	Resident's walking time per week in minutes	232.5 (301.0)	

Age, gender, ethnicity, partnered, number of children, health, educational attainment, employment status, manual work, income, social desirability bias, free time, social interaction, other household members engaged in physical activity, personality traits, years at current address, years interviewed and the SEIFA 2011 Index.

3. Results

To begin with, the estimated models for Equations 1, 2 and 3 show no signs of worrisome multicollinearity. The key coefficient estimates are reported in Tables 2 to 4. For Equation 1, reported in Table 2 (columns 1 to 4), while column 1 (life satisfaction), column 2 (happiness) and column 3 (mental health) reveal generally negative coefficient estimates for increasingly higher levels of walkability in the neighbourhood, holding factors apart from physical activity constant, these figures are not statistically significant at conventional levels. [2] However, column 4 (psychological distress) indicates that more walkable neighbourhoods are associated with higher levels of psychological distress, holding factors apart from physical activity constant.

[2] Though not reported in Table 2 estimating for life satisfaction the effect of "Walkability (Q4)" with all other quartiles as the base case reveals a coefficient estimate of -0.2391, statistically significant at the 10% level.

Table 2: Equation 1 model results (does not include physical activity)

	(1) Life satisfaction	(2) Happiness	(4) Mental health	(5) Psychological distress
	FE Ordered Logit[3]	FE Ordered Logit	FE[4]	FE
	Coefficient	Coefficient	Coefficient	Coefficient
	(standard error)	(standard error)	(standard error)	(standard error)
	[95% CI]	[95% CI]	[95% CI]	[95% CI]
Walkability (Q2)	-0.0247	0.1202	-0.2251	0.2094
	(0.1424)	(0.1758)	(0.6437)	(0.3352)
	[-0.3038,0.2543]	[-0.2244,0.4648]	[-1.5362,1.0860]	[-0.4733,0.8921]
Walkability (Q3)	0.1743	0.0865	-0.7099	0.5716*
	(0.1745)	(0.1789)	(0.5606)	(0.2920)
	[-0.1676,0.5163]	[-0.2642,0.4372]	[-1.8519,0.4320]	[-0.0231,1.1663]
Walkability (Q4)	-0.1943	-0.0328	-1.1212	0.7697*
	(0.1472)	(0.1727)	(0.8864)	(0.4354)
	[-0.4829,0.0943]	[-0.3713,0.3057]	[-2.9267,0.6842]	[-0.1173,1.6566]
Summary statistics				
Observations	9,108	6,583	1,572	1,572
Groups	33	33	33	33

[3] An extension of the conditional logit model, Baetschmann, Staub, and Winkelmann (2015) provide details of the fixed effect ordered logit model or "blow up and cluster" estimator.
[4] Fixed effects model estimated using within transformation.

Pseudo R^2	0.1925	0.2225		
ρ			0.0347	0.0548
R^2 within			0.4131	0.4278
R^2 between			0.3102	0.1528
R^2 overall			0.4138	0.4317

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ Standard errors in parentheses adjusted for clustering at the LGA level. See Table 1 for a description of variables included (does not include exercising as recommended).

The coefficient estimates for Equation 2 reported in Table 3 (column 1), point to an absence of a statistically significant link between a more walkable neighbourhood and engaging in the recommended amount of physical activity. However, further interrogation of the data reveals that the most walkable neighbourhoods (the fourth quartile as shown in column 2 of Table 3) compared to all others are negatively associated with engaging in the recommended amount of physical activity. A result statistically significant at the 5% level. The sensitivity of this result was investigated by omitting the top 5% and bottom 5% of observations by according to the walkability index revealing that this result was not an artefact of some extreme value. The result remains statistically significant and negative at the 5% level.

Further coefficient estimates for Equation 2 reported in Table 3 (columns 3 and 4) for walking time illustrate that more walkable neighbourhoods are linked to greater total walking time.

Table 3: Equation 2 model results

	(1) Exercising as recommended (MET)	(2) Exercising as recommended (MET)	(3) Walking time	(4) Walking time
	Conditional Logit Coefficient (standard error) [95% CI]	Conditional Logit Coefficient (standard error) [95% CI]	FE Coefficient (standard error) [95% CI]	FE Coefficient (standard error) [95% CI]
All quartiles				
Walkability (Q2)	0.2849 (0.1782) [-0.0644,0.6342]		24.1974 (20.0386) [-16.6199,65.0147]	
Walkability (Q3)	-0.1037 (0.1773) [-0.4512,0.2438]		46.4684* (25.0876) [-4.6334,97.5703]	
Walkability (Q4)	-0.2435 (0.1868) [-0.6097,0.1226]		12.4661 (29.9619) [-48.5643,73.4964]	
Fourth quartile				
Walkability (Q4)		-0.3099** (0.1557) [-0.6150,-0.0046]		-10.3994 (25.7750) [-62.9014,42.1025]

Summary statistics				
Observations	1,572	1,572	1,572	1,572
Groups	33	33	33	33
Pseudo R^2	0.0811	0.0782		
ρ			0.0876	0.0877
R^2 within			0.0575	0.0549
R^2 between			0.0259	0.0298
R^2 overall			0.0565	0.0517

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ Standard errors in parentheses adjusted for clustering at the LGA level. See Table 1 for a description of variables included.

The coefficient estimates for Equation 3 reported in Table 5 (columns 1 to 4), despite the inclusion of the physical activity variable, remain largely unchanged from Table 2. Column 1 (life satisfaction), column 2 (happiness) and column 3 (mental health) point to generally negative coefficient estimates for increasingly higher levels of walkability in the neighbourhood, holding factors including physical activity constant, these figures are not statistically significant at conventional levels. Also similar to Table 2, column 4 (psychological distress) indicates that more walkable neighbourhoods are associated with higher levels of psychological distress, holding factors including physical activity constant. The marginal effect of residing in a more walkable neighbourhood is marginally less negative (although not statistically significantly so) after adjusting for the psychological benefits, from physical activity, *forgone* (as suggested by Table 3).

Table 4: Equation 3 model results (includes physical activity)

	(1) Life satisfaction	(2) Happiness	(4) Mental health	(5) Psychological distress
	FE Ordered Logit	FE Ordered Logit	FE	FE
	Coefficient	Coefficient	Coefficient	Coefficient
	(standard error)	(standard error)	(standard error)	(standard error)
	[95% CI]	[95% CI]	[95% CI]	[95% CI]
Walkability (Q2)	-0.0299	0.1349	-0.2553	0.2273
	(0.1433)	(0.1750)	(0.6412)	(0.3337)
	[-0.3107,0.2509]	[-0.2082,0.4780]	[-1.5615,1.0508]	[-0.4524,0.9070]
Walkability (Q3)	0.1756	0.0797	-0.7010	0.5664*
	(0.1737)	(0.1810)	(0.5653)	(0.2951)
	[-0.1648,0.5159]	[-0.2751,0.4345]	[-1.8524,0.4504]	[-0.0347,1.1674]
Walkability (Q4)	-0.1898	-0.0485	-1.0955	0.7545*
	(0.1478)	(0.1746)	(0.8831)	(0.4326)
	[-0.4796,0.0999]	[-0.3908,0.2938]	[-2.8943,0.7032]	[-0.1267,1.6357]
Summary statistics				
Observations	9,108	6,583	1,572	1,572
Groups	33	33	33	33
Pseudo R^2	0.1927	0.2241		
ρ			0.0347	0.0550

R^2 within	0.4137	0.4284
R^2 between	0.3128	0.1542
R^2 overall	0.4142	0.4322

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ Standard errors in parentheses adjusted for clustering at the LGA level. See Table 1 for a description of variables included (includes exercising as recommended).

4. Discussion

The purpose of this study is to investigate the link between walkable neighbourhoods and wellbeing and how this relationship may be mediated by physical activity. Across measures of life satisfaction, happiness, mental health and psychological distress this link is clearest for psychological distress. The results indicate unexpectedly, a negative link between a more walkable neighbourhood and wellbeing contrary to *a priori* expectations, conceptual models (Barton & Grant, 2006) and earlier findings regarding walking and cycling behaviours. This result is mediated to a very marginal degree by physical activity, although in an unanticipated way. Specifically, physical activity mitigates the negative association between a more walkable neighbourhood and wellbeing by adjusting for the lower probability of engaging in the recommended levels of physical activity in more walkable neighbourhoods. These findings prove quite revealing in the context of existing evidence and suggest further research is needed regarding the mechanisms through which key public health outcomes may be promoted. Further, these findings may prove helpful to decision makers such as The Victorian Health Promotion Foundation (VicHealth) seeking to support the health and wellbeing of Victorians.

Most strikingly given the existing evidence on walking and cycling behaviours the findings of this study suggest that on average residents in more walkable neighbourhoods are no more likely or even less likely to engage in the recommended level of physical activity. Corroborating these unexpected findings are those reported by Forsyth et al. (2008) and Forsyth et al. (2007) for the Twin Cities, Minnesota. The authors make the important distinction between different measures of walking replete throughout the literature and *total* physical activity. The authors offer a generous and plausible interpretation of similar findings; suggesting that sedentary behaviours are *common* and both built and social environments support this. The authors conclude that: “It is certainly possible to design an environment to support transport or leisure walking. It may be possible to increase total walking. However, in terms of overall physical activity, the key public health outcome, there are few statistically significant associations. ” (Forsyth et al., 2008, p. 1989). In a similar sense, while it may be the case, that a greater number and diversity of destinations in local environments is associated with more walking (Bentley et al., 2010), overall more walkable neighbourhoods are either not linked to or linked to a lower likelihood of engaging in the recommended level of physical activity.

In all, the results suggest that at best, walkable neighbourhoods are not linked to physical activity or wellbeing and at worst, walkable neighbourhoods are associated with both lower levels of physical activity and lower levels of wellbeing. Further research is needed to assess alternative health promotion measures such as pricing or education (Forsyth et al., 2008).

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