Title: Neighborhood disadvantage, individual-level socioeconomic position and physical function: a cross-sectional multilevel analysis

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ABSTRACT:

Introduction: Understanding associations between physical function and neighborhood disadvantage may provide insights into which interventions might best contribute to reducing socioeconomic inequalities in health. This study examines associations between neighborhood-disadvantage, individual-level socioeconomic position (SEP) and physical function from a multilevel perspective.

Methods: Data were obtained from the HABITAT multilevel longitudinal (2007-13) study of middle-aged adults, using data from the fourth wave (2013). This investigation included 6,004 residents (age 46-71 years) of 535 neighborhoods in Brisbane, Australia. Physical function was measured using the PF-10 (0 – 100), with higher scores indicating better function. The data were analyzed using multilevel linear regression and was extended to test for cross-level interactions by including interaction terms for different combinations of SEP (education, occupation, household income) and neighborhood disadvantage on physical function.

Results: Residents of the most disadvantaged neighborhoods had significantly lower function (men: β -11.36 95% CI -13.74, -8.99; women: β -11.41 95% CI -13.60, -9.22). These associations remained after adjustment for individual-level SEP. Individuals with no post-school education, those permanently unable to work, and members of the lowest household income had significantly poorer physical function. Cross-level interactions suggested that the relationship between household income and physical function is different across levels of neighborhood disadvantage for men; and for education and occupation for women.

Conclusion: Living in a disadvantaged neighborhood was negatively associated with physical function after adjustment for individual-level SEP. These results may assist in the development of policy-relevant targeted interventions to delay the rate of physical function decline at a community-level.

Keywords: Physical function; neighborhood; multilevel modelling; socioeconomic position

Introduction

Physical function is defined as difficulty in performing activities that require physical capacity, ranging from activities of daily living (e.g., housework, shopping, walking and climbing stairs) to more vigorous activities that require increasing degrees of mobility, strength or endurance.[1] Difficulty with physical function, represented by the inability to perform usual activities of everyday life, is a serious problem among older persons.[2-4] The magnitude of this problem is likely to become considerably greater with continuing increases in longevity and in the size of the oldest population in most developed countries.[2,5] In addition, physical function is associated with an increased risk of falling, cognitive decline and all-cause mortality.[2]

According to the World Health Organization,[6] the rate of physical function decline is not typically the result of a single cause, but arises from an interaction of risk factors in various domains, both individual and environmental. Traditionally, research on the determinants of physical function has been based on individual-level factors.[7-10] More recently, interest in the effects of neighborhood context on physical health has received growing attention; and multiple studies have shown that poor health is partly a function of residing in socioeconomically disadvantaged areas.[11-13] Research suggests that the external environment, such as the neighborhood, is of particular importance for physical function in older adults as they tend to have a longer duration of exposure to neighborhood influences than younger individuals, possibly due to retirement.[14] Older adults are also a sub-group with declining physical and mental health, shrinking social networks, loss of social support and increased fragility that may reduce their ability to cope with environmental demands.[14] It is possible that heterogeneity in physical function among this group may be explained by both individual- and neighborhood-level factors, underlining the importance of any associations between physical function and neighborhood characteristics.[15]

Several studies (three single-level and one multi-level)[16-19] have examined the association between neighborhood disadvantage and physical function. Findings from these studies are mixed. Among the single-level studies, one[17] found no association between neighborhood disadvantage and physical function, while the other two[18,19] showed that residents of socioeconomically disadvantaged neighborhoods exhibited lower function than their counterparts from more advantaged neighborhoods. However, these two ecological studies used data that were aggregated to a single geographical scale, hence they couldn't provide a quantification of the variation between areas, or show whether and how much of the variation was due to the clustering of individuals (a compositional effect) or the environmental characteristics of the areas (a contextual effect). Given the lack of multilevel studies, the question of whether the neighborhood socioeconomic environment influences physical function after adjustment for individual-level socioeconomic position (SEP) remains. The only known multilevel study of neighborhood disadvantage and physical function[16] found no significant association between these factors; and whilst this work provided an important advancement in this field, the study assumed a uniform effect of the neighborhood environment across individual-level SEP. It is possible however that the socioeconomic context of the neighborhood environment may affect people differently even if they have similar individual-level socioeconomic characteristics. For example, an individual with low educational attainment living in a more advantaged neighborhood might have better physical function than an individual with the same educational attainment living in a more disadvantaged neighborhood. This may be due to the benefit of the collective material and social resources in their neighborhood, such as services, job opportunities and social supports.[20-22]

This cross-sectional study investigates associations between neighborhood disadvantage, individual-level SEP, and self-reported physical function; and further examines whether the relationship between individual-level SEP and physical function differs by level of neighborhood disadvantage. It is hypothesized that those residing in more disadvantaged neighborhoods and those from lower socioeconomic groups will exhibit poorer physical function than their counterparts from more advantaged backgrounds.

Methods

This study received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. Nos. 3967H & 1300000161).

Study population

Data were obtained from the **H**ow **A**reas in **B**risbane **I**nfluence Heal**T**h and **A**c**T**ivity (HABITAT) multilevel longitudinal (2007-13) study in Brisbane, Australia. Brisbane is the capital city of the state of Queensland, and the third largest city in Australia with a population of approximately 2.3 million[23] and a median age of 35 in 2014.[24] The average disposable income of Brisbane population was AU$52,000 per annum in 2011.[25]

Details about HABITAT's baseline sampling design have been published elsewhere.[26] Briefly, a multi-stage probability sampling design was used to select a stratified random sample (n=200) of Census Collector's Districts (CCD) in 2007, and from within each CCD, a random sample of people (on average 85 per CCD) aged 40-65 years. However, as participants moved to new residences over time, the number of CCDs increased to 535 in 2013.

The primary area-level unit-of-analysis for the HABITAT study is the CCD (hereafter referred to as 'neighborhoods'). At the time the study commenced in 2007, these were the smallest administrative units used by the Australian Bureau of Statistics (ABS) to collect census data, and contain an average of 200 private dwellings.

Data collection and response rates:

A structured self-administered questionnaire was developed that asked respondents about their neighborhood; participation in physical activity; correlates of activity, health and well-being; and socio-demographic characteristics. The questionnaire was sent to sampled residents during May-July in 2007, 2009, 2011 and 2013 using the mail survey method developed by Dillman.[27] After excluding out-of-scope respondents (i.e., deceased, no longer at the address, unable to participate for health-related reasons), the total number of usable surveys returned in each survey wave was 11,035 (68.3% response), 7,866 (72.3% response from eligible and contactable participants), 6,900 (66.7% response from eligible and contactable participants) and 6,520 (69.3% response from eligible and contactable participants), respectively.

Measures:

Neighborhood socioeconomic disadvantage: The neighborhood socioeconomic disadvantage measure was derived using weighted linear regression, using scores from the ABS' Index of Relative Socioeconomic Disadvantage (IRSD) from each of the previous six censuses from 1986 to 2011.[28] A neighborhood's IRSD score reflects each area's overall level of disadvantage measured on the basis of 17 socioeconomic attributes, including: education, occupation, income, unemployment, household structure and household tenure. HABITAT's original sample of neighborhoods was stratified by area-level socioeconomic disadvantage using the 2001 Census boundaries (the Census in Australia is every 5 years). This method honors the original geographic structure from the baseline sample, while also accommodating for the changes in area boundaries used by the ABS prior to 2011, changes in area-level sampling units at the 2011 Census, and changes in socioeconomic disadvantage over time. The derived socioeconomic scores from each of the HABITAT neighborhoods (n=535 in 2013) were then grouped into quintiles based on their IRSD scores with Q1 denoting the 20% most advantaged areas relative to the whole of Brisbane and Q5 the most disadvantaged 20%.

Education: Respondents were asked to provide information about their highest education qualification completed using a nine-category measure that was subsequently coded as (i) Bachelor degree or higher (the latter included postgraduate diplomat, master's degree, or doctorate), (ii) Diploma (associate or undergraduate), (iii) Vocational (trade or business certificate or apprenticeship), and (iv) No post-secondary school qualification.

Occupation: Respondents who were employed at the time of completing the survey were asked to indicate their job title and then to describe the main tasks or duties they performed. This information was subsequently coded to the Australian Standard Classification of Occupations (ASCO).[29] The ASCO is a skill-based measure that groups occupations according to levels of knowledge required, tools and equipment used, materials worked on, and goods and services produced. The occupational groupings are hierarchically ordered based on the relative skill levels across these different dimensions, with those occupations having the most extensive skill requirements located at the top of the hierarchy. For the purpose of this study, the original 9-level ASCO classification was recoded into 3 categories: (i) Managers/professionals, (ii) White-collar employees, (iii) Blue-collar employees. Respondents who were not employed were categorized as follows: (iv) Home duties, (v) Retired, (vi) Permanently unable to work, (vii) Missing/NEC (unemployed, students or other classifiable (not easily classifiable)).

Household income: Respondents were asked to indicate their total annual household income using a 14-category measure that was subsequently recoded into 6 groups for analysis: (i) AU$130,000 or more, (ii) AU$72,800-129,999, (iii) AU$41,600-72,799, (iv) AU$26,000-41,599, (v), Less than AU$25,999, and (vi) Missing.

Self-reported physical function: This was measured using the Physical Function Scale (PF-10), a component of the Short Form-36 (SF-36) Health survey[30]. The PF-10 was first included in the most recent wave of HABITAT survey (2013), so only cross-sectional analyses are possible at this point. The stem-question of the PF-10 asks: *"Does your health now limit you in these activities? If so, how much?"* Respondents were asked to indicate: *"Yes, limited a lot"* or *"yes, limited a little"* or *"no, not limited at all'* for each activity. The PF-10 measures a hierarchical range of difficulties, from vigorous activities such as lifting heavy objects to everyday activities such as bathing and dressing.[31] This measure has been extensively validated among community-dwelling adults using convergent validity calculated by Pearson Correlations using 3-performance based measures: single limb stance as an indicator of balance (r=0.42), Time Up and Go test as a measure of mobility (r=-0.70) and gait speed as an indicator of overall functional capacity (r=0.75).[32] The method of data cleaning for the physical function score was adapted from Ware and colleagues.[30] The raw physical function scores were calculated as the sum of (re-coded) scale items and transformed to a 0 to 100 scale according to the Equation 1:

Equation 1:

$$Physical\ function\ score = \frac{raw\ score - minimum\ possible\ raw\ score}{possible\ raw\ score\ range}\ X\ 100$$

The standard scoring system was used such that 0 represents minimal functioning and 100 represents maximal functioning. The scale used for this present study obtained high test-retest reliability (Cronbach's α= 0.89) in the sample. Although scores were somewhat negatively skewed toward maximal function, they are comparable with Australian population norms for this scale (age standardized mean = 83.6 for men and 81.5 for women).[33]

Statistical analysis

Participants who moved out of Brisbane in 2013 (n=391) or had missing data for physical function (n=92), sex (n=19) or education (n=14) were excluded. This reduced the analytic sample to n=6,004 (92.1% of the total sample). Characteristics and physical function profile of the analytic sample are presented in Table 1.

Table 1: Mean physical function (PF) scores (95% CI) for the socio-demographic variables used in the analysis[a]

	Men			Women		
N= 6,004	**N (%)**	**Mean PF score**	**95% CI**	**N (%)**	**Mean PF score**	**95% CI**
Total Sample	2,551	87.6	86.9, 88.3	3,453	83.7	83.0, 84.4
Age:						
46-50	571 (22.4)	92.2	91.0, 93.3	670 (19.4)	90.1	88.9, 91.3
51-55	551 (21.6)	88.9	87.6, 90.4	742 (21.5)	86.3	84.9, 87.7
56-60	520 (20.4)	86.8	85.3, 88.4	718 (20.8)	84.7	83.4, 86.0
61-65	488 (19.1)	85.5	83.8, 87.2	686 (19.9)	80.9	79.3, 82.5
66-71	421 (16.5)	83.2	81.4, 85.0	637 (18.4)	75.5	73.7, 77.3
Neighborhood disadvantage						
Q1 (most advantaged)	543 (21.3)	91.8	90.7, 92.9	734 (21.3)	88.1	86.9, 89.2
Q2	680 (26.7)	90.0	88.9, 91.1	907 (26.3)	85.9	84.8, 87.1
Q3	516 (20.2)	87.3	85.8, 88.7	664 (19.2)	83.7	82.2, 85.2
Q4	466 (18.3)	85.3	83.6, 87.1	656 (19.0)	81.4	79.8, 82.9
Q5 (most disadvantaged)	346 (13.5)	80.1	77.5, 82.6	492 (14.2)	76.1	73.8, 78.4
Education level:						
Bachelor degree or higher	930 (36.5)	90.9	90.0, 91.8	1,156 (33.5)	86.8	85.7, 87.7
Diploma	312 (12.2)	89.4	87.9, 91.0	398 (11.5)	84.3	82.3, 85.7
Vocational	533 (20.9)	86.4	84.7, 88.1	499 (14.5)	84.0	82.3, 85.7
No post school qualifications	776 (30.4)	83.9	82.4, 85.3	1,400 (40.5)	80.9	79.8, 82.0
Occupation						
Manager/Professionals	928 (36.4)	91.7	90.9, 92.6	1,042 (30.2)	89.6	88.7, 90.5
White Collar	328 (12.9)	90.7	89.3, 92.1	870 (25.2)	86.9	85.8, 87.9
Blue Collar	485 (19.0)	88.1	86.6, 89.6	162 (4.7)	86.5	83.9, 89.1
Home Duties	18 (0.7)	83.3	71.8, 94.8	277 (8.0)	83.3	80.9, 85.7
Retired	510 (20.0)	82.7	81.1, 84.5	784 (22.7)	76.4	74.8, 78.0
Permanently unable to work	57 (2.2)	56.3	48.8, 63.8	62 (1.8)	38.5	30.9, 46.0
Missing/NEC	225 (8.8)	84.3	81.3, 87.3	256 (7.4)	80.2	77.6, 82.8
Household income:						
$130,000 or more	676 (26.5)	92.5	91.6, 93.4	589 (17.0)	90.9	89.8, 92.0
$72,800-129,999	631 (24.7)	89.8	88.7, 90.9	794 (23.0)	87.0	85.7, 88.1
$41,600-72,799	328 (12.9)	87.8	86.0, 89.5	398 (11.5)	84.1	82.2, 85.9
$26,000-41,599	438 (17.2)	83.6	81.8, 85.5	665 (19.3)	79.1	77.5, 80.7
Less than $25,999	216 (8.5)	73.6	70.0, 77.2	391 (11.3)	73.6	71.2, 76.0
Missing	262 (10.2)	87.7	85.5, 89.9	619 (17.9)	83.7	81.9, 85.3

[a] Unadjusted data

A directed acyclic graph (DAG) was constructed to show contextual and/or temporal relationships between the socioeconomic indicators education, occupation, household income, neighborhood disadvantage, and physical function (Figure 1). The DAG formed the basis for the modelling strategy and specified the socioeconomic independent adjustment variables. As presented in Figure 1, education was conceptualized as a common prior cause of occupation, household income and neighborhood disadvantage; occupation as a confounder of income and neighborhood disadvantage, and household income as a confounder of neighborhood disadvantage. The analyses were stratified by gender as physical function score differs for men and women (women consistently report more functional limitations than their men counterparts).[2,34,35]

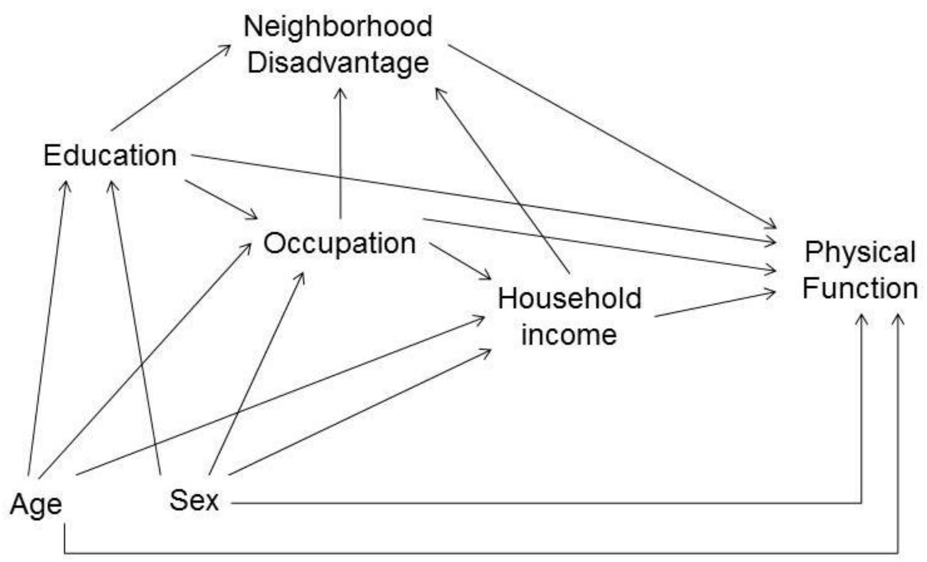

Figure 1: Directed acyclic graph conceptualising the relationships between neighborhood disadvantage, individual-level SEP and physical function

Multilevel modelling is the appropriate statistical technique for these analyses as it offers a robust and efficient approach to the examination of hierarchical data where individuals are nested (clustered) within neighborhoods.[36] Multilevel linear regression was undertaken in the following stages: Model 1) neighborhood disadvantage and physical function adjusted for age; Model 2) neighborhood disadvantage and physical function adjusted for age and individual-level SEP. Additional models were then undertaken for individual-level SEP; Model 3) education adjusted for age; Model 4) occupation adjusted for age and education; and Model 5) household income adjusted for age, education and occupation. The Variance Partition Coefficient (VPC) was calculated to estimate the percentage of total variance in physical function between neighborhoods.[37] For Model 1 and 2, the VPC was calculated by dividing the between neighborhood variance by the total variance, and is interpreted as the proportion of total residual variation that is due to differences between neighborhoods. The analysis was extended to test for cross-level interactions by including interaction terms for different combinations of individual-level SEP and neighborhood disadvantage on physical function score. The substantive focus of the interaction analyses is on whether associations between education, occupation, and household income differed across neighborhoods that varied in their level of socioeconomic disadvantage. The fit of interaction models was assessed using a deviance test[38] (alpha set at 0.05). Models 1-5 were analyzed with STATA 13.1[39] using the *runMLwiN* command,[40] while cross-level interaction models were analyzed using MLwiN v.2.30.[38]

Results

The overall means for physical function score for neighborhood disadvantage, age, education, occupation and household income are presented in Table 1. Mean physical function were lowest for women, persons aged 66-71, residents of the most disadvantaged neighborhoods, the least educated, those who were permanently unable to work, and members of the lowest income households.

The associations between neighborhood disadvantage, individual-level SEP and physical function for men and women are shown in Table 2.

Table 2: Multilevel linear regression for the association between neighborhood disadvantage and individual-level socioeconomic position on physical function in men and women in Brisbane

N=535 neighborhoods	**Men (n=2,551)**		**Women (n=3,453)**	
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
Neighborhood-level				
Disadvantage	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Q1 (most advantaged)[a]	1.00	1.00	1.00	1.00
Q2	-1.89 (-3.89, 0.10)	-0.74 (-2.67, 1.18)	**-1.92 (-3.78, -0.06)**	-1.57 (-3.38, 0.23)
Q3	**-4.19 (-6.32, -2.06)**	**-2.69 (-4.78, -0.60)**	**-3.85 (-5.86, -1.84)**	**-2.22 (-4.19, -0.23)**
Q4	**-6.28 (-8.45, -4.11)**	**-4.36 (-6.53, -2.19)**	**-5.86 (-7.87, -3.85)**	**-3.85 (-5.86, -1.83)**
Q5 (most disadvantaged)	**-11.36 (-13.74, -8.99)**	**-7.14 (-9.54, -4.73)**	**-11.41 (-13.60, -9.22)**	**-8.79 (-11.00, -6.59)**
Between neighborhood variance (SE)[b]	1.79 (2.47)	1.33 (2.25)	0 (0)	0 (0)
Between individual variance (SE)[c]	**285.36 (8.31)**	**255.92 (7.71)**	**358.97 (8.71)**	**315.15 (7.65)**
VPC (%)[d]	0.62	0.53	0	0
Individual-level				
Education		**Model 3**		**Model 3**
Bachelor degree or higher[a]		1.00		1.00
Diploma		-0.88 (-3.08, 1.31)		-1.48 (-3.68, 0.71)
Vocational		**-3.68 (-5.53, -1.84)**		-1.83 (-3.87, 0.21)
No post-school qualifications		**-5.93 (-7.59, -4.27)**		**-3.78 (-5.32, -2.25)**
Occupation		**Model 4**		**Model 4**
Manager/professional[a]		1.00		1.00
White collar		0.52 (-1.62, 2.66)		-1.39 (-3.19, 0.40)
Blue collar		-0.96 (-2.95, 1.03)		-1.22 (-4.33, 1.88)
Home duties		-7.04 (-14.65, 0.57)		**-4.16 (-6.68, -1.63)**
Retired		**-5.13 (-7.34, -2.93)**		**-7.96 (-10.06, -5.85)**
Permanently unable to work		**-32.21 (-36.68, -27.73)**		**-48.99 (-53.79, -44.2)**
Household income:		**Model 5**		
$130,000+[a]		1.00		
$72,800-129,999		-1.41 (-3.23, 0.41)		
$41,600-72,799		-2.22 (-4.51, 0.06)		
$26,000-41,599		**-4.07 (-6.36, -1.78)**		

Less than $25,999	**-10.19 (-13.07, -7.30)**

Note. PF score range from 0-100; boldface indicates $p<0.05$; missing category is included in the analysis but not reported in the table. Model 1: age and neighborhood disadvantage; Model 2: Model 1 and education, occupation and household income; Model 3: education and, age; Model 4: Model 3 and occupation; Model 5: Model 4 and household income.

[a] Reference group

[d] Variance Partition Component (VPC) = b/(b+c)

For men, there was no significant between-neighborhood variation in physical function in either the age-adjusted (Model 1, p=0.48) or fully-adjusted models (Model 2, p=0.56). Men living in more disadvantaged neighborhoods (Q3, Q4 and Q5) had lower physical function scores than their counterparts residing in more advantaged neighborhoods. These associations remained significant after adjustment for individual-level SEP, despite slight attenuation. Compared to individuals with a bachelor degree or higher, individuals who had no post-school education, or a vocational level of education attainment had a significantly lower physical function score. Individuals who are retired and permanently unable to work had significantly lower physical function scores than managers and professionals, while individuals in the lower income categories ($26,000-41,599 and <$25,999) had significantly lower physical function than their counterparts with incomes of $130000 or greater.

Similarly for women, there was no significant between-neighborhood variation in physical function for either age-adjusted (Model 1) or fully-adjusted models (Model 2). Women living in more disadvantaged neighborhoods (Q2, Q3, Q4 and Q5) had a significantly lower physical function score than their counterparts residing in more advantaged neighborhoods. These associations remained significant after adjustment for individual-level SEP, despite slight attenuation. Compared to individuals with a bachelor degree or higher, individuals who had no post-school education had a significantly lower physical function score. Individuals working as home duties, retired and permanently unable to work had significantly lower physical function scores than managers and professionals, while individuals in the lower income categories ($72,800-129,999, $41,600-72,799, $26,000-41,599 and <$25999) had significantly lower physical function scores than their counterparts with incomes of $130,000 or greater.

Other than the significant results demonstrated, it is important to note the magnitude of difference in physical function score in men and women. A previous review found a three point difference in physical function score measured by SF-36 to be clinically meaningful for effective intervention.[41] Education attainment and household income appear to be more important, in terms of physical function, in men than women. Men with the lowest education attainment appear to have lower physical function scores (2 points) than women, after adjusting for age. Similarly, men with the lowest household income had physical function scores that were 4 points lower than low income women. On average, men and women who reported being permanently unable to work had very low physical function scores (<60), but the magnitude of difference between men and women in this group was notable. Women who reported being permanently unable to work, had, on average, a physical function score that was 17 points lower than men.

Cross-level interactions were not significant between neighborhood disadvantage and education and occupation among men; and neighborhood disadvantage and household income among women. However, a significantly better model fit was found between neighborhood disadvantage and household income among men ($p=0.004$); and neighborhood disadvantage and education ($p=0.01$) and occupation ($p<0.001$) among women (Figure 2).

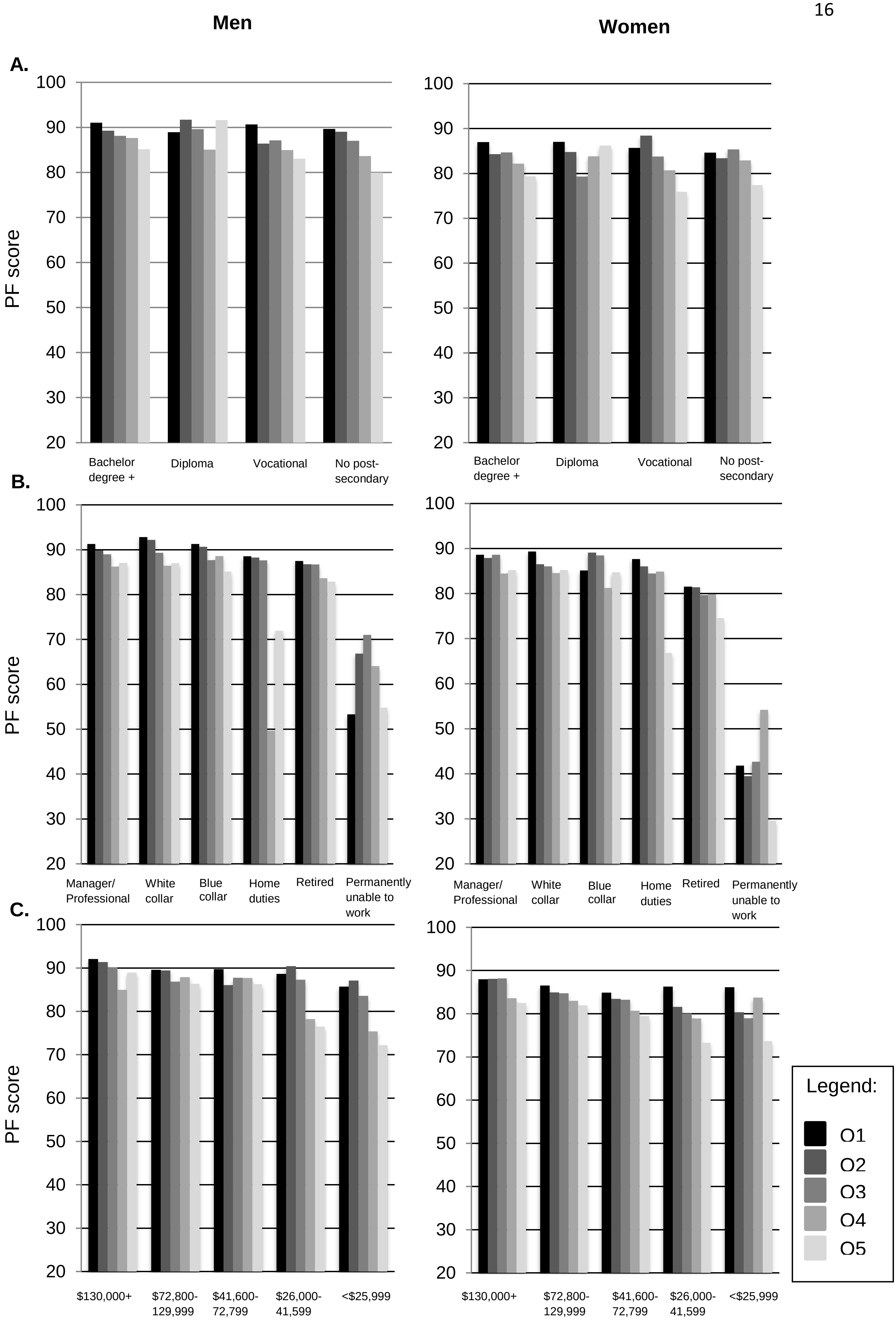

Figure 2: Cross-level interactions and mean physical function score between neighborhood disadvantage and A. education, B. occupation and C. household income. Q1 – most advantaged and Q5 – most disadvantaged neighborhoods.

Discussion

This study examined associations between neighborhood disadvantage, individual SEP and physical function. Significant and graded associations were found between neighborhood disadvantage and physical function for both men and women, after adjusting for individual level SEP, suggesting that the socioeconomic characteristics of the neighborhood environment may have important implications for physical function. The cross-level interaction models suggested that there was a protective effect of living in more socioeconomically advantaged neighborhoods on physical function. The findings of this study are consistent with previous single-level studies conducted in the United States and the United Kingdom,[18,19] which found that individuals living in more disadvantaged neighborhoods experienced poorer physical function than those in more advantaged neighborhoods. However, the only previous multilevel study[16] from the United States found no association between neighborhood disadvantage and physical function, after adjusting for individual-level factors. There are a number of possible explanations for the differences found between our study and those of Wight et al.[16]: including the sample age at the time at which data was collected, differences in the method of calculating area-level disadvantage, and geographical differences in the sampling of participants.

Consistent with prior research, men in our study were more likely to report better physical functioning than women.[42-44] The magnitude of difference in physical function score between men and women was notable in this study. Although this may due to the well-documented gender-based reporting bias on physical function,[45] it is also possible that this discrepancy could be attributed to the differences in biology, control over resources and their decision making power in family and community, as well as the roles and responsibilities that society assigns to them.[46]

Individuals in this study with higher levels of educational attainment, individuals with a higher level of occupation, and members of high income households reported higher physical function. Previous studies have shown that income and education are likely to be closely linked, but with one influencing the other via distinct aetiological pathways.[47,48] Educational attainment for example, may influence the acquisition of knowledge about appropriate health practices, which may facilitate or constrain one's ability to maintain good physical function; whereas household income is likely to reflect the availability of resources to access health facilities and services.[47,49]

This investigation is the first-known study to examine cross-level interactions between neighborhood disadvantage, individual level SEP and physical function. These models revealed that associations between individual socioeconomic indicators differed across levels of neighborhood disadvantage. This finding brings to light interesting trends for how individuals with the same individual-level characteristics fared while residing in disadvantaged neighborhoods, when compared with their counterparts in more advantaged neighborhoods. For example, participants with the lowest education attainment living in the most disadvantaged neighborhoods were observed to have the lowest physical function score, signifying double disadvantage. Double disadvantage has also been reported in other social epidemiological studies.[50-52] For instance, people with disability who live outside major cities may fare worse than their counterparts living in major cities, or people with no disability who live outside major cities.[50] These findings suggest that while individual- and neighborhood-level socioeconomic disadvantage may affect physical function independently, they also interact with one another to impact physical function in a collective way. Therefore, living in a socioeconomically advantaged neighborhood or having higher SEP attributes alone may not be enough to ensure better physical function.

The neighborhood environment has emerged as an important context for health, by either facilitating healthy behavior, or acting as a barrier.[14] A number of possible mechanisms may explain the significant associations found in our study. According to Ross and colleagues,[53] the lack of economic and social resources in disadvantaged neighborhoods predisposes residents to physical and social ailments due to limited opportunity, and lack of social integration and cohesion. Characteristics of disadvantaged neighborhoods exist in both physical (e.g., lack of proper parks, health services, and tree coverage) and social forms (e.g., crime, public smoking or drinking, and conflicts). For example, one study[15] reported that neighborhoods with multiple physical barriers such as poor access to public transport, inadequate lighting, trash and litter might trigger a pattern of disuse and subsequent decrements in functional health. On the other hand, neighborhoods with an adverse social climate may discourage social ties between neighbors that may influence behavior in ways that produce negative health outcomes.[54,55] For example, neighborhoods with greater social ties have higher levels of involvement in community activities, enabling residents to share ‘norms’ that influence health behaviors such as healthy eating and physical activity, both of which are important in the maintenance of physical function.[56,57] Also, the physical and social characteristics that exist in disadvantaged neighborhoods may influence physical function through different pathways such as physical activity,[57-59] diet[60] and smoking.[61,62] Several studies have suggested that particular neighborhood features, including the presence of parks, recreational facilities, sidewalks and pleasant landscaping may promote physical activity among older adults.[63-65] While the lack of access to health food stores and the social norm of smoking in the neighborhood are associated with poorer diet[66] and smoking behaviour,[67] respectively. Therefore, living in a disadvantaged neighborhood may not provide the environmental support for individual lifestyle behaviors that are needed to maintain good physical function.

Limitations

Several methodological and analytical issues need to be considered when interpreting and understanding this study's findings. First, the study is cross-sectional and thus claims about causality must be made with caveats. A longitudinal design would have added strength to the study findings. Second, the study data were obtained from the fourth wave of the HABITAT survey and sample attrition between baseline and 2013 may have implications for sample generalizability. The non-response rate in the HABITAT baseline study was 31.5%, and a comparison of the HABITAT baseline respondent sample with census data indicates an under-representation of men, those not in the workforce, those with low household income and those living in disadvantaged area.[68] Previous studies show that low SEP groups and residents of more deprived neighborhoods are least likely to participate in survey research.[69,70] As a result, the socioeconomic variation in the sample is likely to be less than that in the Brisbane population. Hence, it is likely that our results underestimate the 'true' magnitude of neighborhood disadvantaged in physical function. Third, the findings of this study may also be confounded by unobserved individual and neighborhood-level factors, such as social capital, or biased from the misclassification of self-reported responses. Fourth, the between neighborhood variance for Models 1 and 2 in women was estimated as zero. Even though this 'null finding' suggests that neighborhoods do not influence self-reports of physical function, this might be due to the study's statistical power to detect variance components.[71] In a multilevel analysis of neighborhood effects, the power to detect variance components is influenced by the number of neighborhoods sampled and the number of residents per neighborhood. In examining this issue, Diez Roux [71] and Snijder et al.[72] suggest that even when variance estimates are very small, this does not mean that the data imply absolute certainty that the population value of the variance estimate is equal to zero, or that the effects of neighborhood variables on individual-level outcomes are not worth investigating.

The findings from the current study can help to inform the development of policy-relevant interventions directed at both individual- and the neighborhood-level contexts to delay the rate of physical function decline in ageing populations. Specifically, this study identified those residing in more disadvantaged neighborhoods as having lower levels of physical function. This suggests that any targeted neighborhood-level intervention should focus on neighborhoods with greater levels of socioeconomic disadvantage. For example, smoking is associated with accelerated declines in physical function,[62] and previous work in Brisbane has shown that residents of more disadvantaged neighborhood are more likely to smoke.[67] Interventions such as decreasing the number of tobacco outlets, especially in disadvantaged neighborhoods, might contribute to a reduction of socioeconomic disparities in physical function. Establishing the mechanisms between neighborhood disadvantage and physical function is crucial to the design of community-based interventions, as these processes are more amenable to change and more sustainable compared to changing individuals' behavior that tend to be more challenging and short lived.[73,74] This remains a priority for future research in this field.

Conclusion

Living in a disadvantaged neighborhood was associated with poorer physical function, even after adjustment for individual-level factors. Future studies should explore the mechanisms that explain why residents of advantaged and disadvantaged neighborhoods differ in their functional status.

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References

1. Bruce B, Fries JF, Ambrosini D, et al. Better assessment of physical function: item improvement is neglected but essential. *Arthritis Research and Therapy.* 2009;11(6).
2. Beckett LA, Brock DB, Lemke JH, et al. Analysis of change in self-reported physical function among older persons in four population studies. *American Journal of Epidemiology.* 1996;143(8):766-778.
3. Payette H, Gaudreau P, Morais JA, Shatenstein B, Gray-Donald K. Trajectories of physical function decline and psychological functioning: the Quebec longitudinal study on nutrition and successful aging (NuAge). *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences.* 2011;66(suppl 1):i82-i90.
4. Glass TA, Balfour JL. Neighborhoods, aging, and functional limitations. *Neighborhoods and health.* 2003:303-334.
5. Fries JF. Aging, natural death, and the compression of morbidity. *Bulletin of the World Health Organization.* 2002;80(3):245-250.
6. World Health Organization. *Active Ageing: A Policy Framework.* 2002.
7. Lang IA, Llewellyn DJ, Alexander K, Melzer D. Obesity, physical function, and mortality in older adults. *Journal of the American Geriatrics Society.* 2008;56(8):1474-1478.
8. Lunney JR, Lynn J, Foley DJ, Lipson S, Guralnik JM. Patterns of functional decline at the end of life. *JAMA.* 2003;289(18):2387-2392.
9. Keating NL, Norredam M, Landrum MB, Huskamp HA, Meara E. Physical and mental health status of older long-term cancer survivors. *Journal of the American Geriatrics Society.* 2005;53(12):2145-2152.
10. LaCroix AZ, Guralnik JM, Berkman LF, Wallace RB, Satterfield S. Maintaining mobility in late life. II. Smoking, alcohol consumption, physical activity, and body mass index. *Am J Epidemiol.* 1993;137(8):858-869.
11. Diez Roux AV. Investigating neighborhood and area effects on health. *Am J Public Health.* 2001;91(11):1783-1789.
12. Diez Roux AV, Merkin SS, Arnett D, et al. Neighborhood of residence and incidence of coronary heart disease. *The New England Journal of Medicine.* 2001;345(2):99-106.
13. Pickett KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. *J Epidemiol Community Health.* 2001;55(2):111-122.

14. Kawachi I, Berkman LF. Neighborhoods and health. 2003.
15. Balfour JL, Kaplan GJ. Neighborhood environment and loss of physical function in older adults: Evidence from the Alameda County Study. *American Journal of Epidemiology.* 2002;155(6):507-515.
16. Wight RG, Cummings JR, Miller-Martinez D, Karlamangla AS, Seeman TE, Aneshensel CS. A multilevel analysis of urban neighborhood socioeconomic disadvantage and health in late life. *Social Science & Medicine (1982).* 2008;66(4):862-872.
17. Glymour MM, Mujahid M, Wu Q, White K, Tchetgen Tchetgen EJ. Neighborhood disadvantage and self-assessed health, disability, and depressive symptoms: longitudinal results from the health and retirement study. *Annals of epidemiology.* 2010;20(11):856-861.
18. Feldman PJ, Steptoe A. How neighborhoods and physical functioning are related: the roles of neighborhood socioeconomic status, perceived neighborhood strain, and individual health risk factors. *Annals of Behavioral Medicine : a publication of the Society of Behavioral Medicine.* 2004;27(2):91-99.
19. Beard JR, Blaney S, Cerda M, et al. Neighborhood characteristics and disability in older adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences.* 2009;64(2):252-257.
20. Yen IH, Kaplan GA. Neighborhood social environment and risk of death: multilevel evidence from the Alameda County Study. *Am J Epidemiol.* 1999;149(10):898-907.
21. Macintyre S, Ellaway A, Cummins S. Place effects on health: how can we conceptualise, operationalise and measure them? *Social Science & Medicine (1982).* 2002;55(1):125-139.
22. Stafford M, Marmot M. Neighbourhood deprivation and health: does it affect us all equally? *International Journal of Epidemiology.* 2003;32(3):357-366.
23. Australian Bureau of Statistics. Regional Population Growth, Australia, 2013-14. 2015; http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/3218.0Main%20Features302013-14. Accessed 1 March, 2016.
24. Australian Bureau of Statistics. Population by Age and Sex, Regions of Australia, 2014. 2015; http://www.abs.gov.au/ausstats/abs@.nsf/mf/3235.0. Accessed 1 March, 2016.

25. Australian Bureau of Statistics. Wage and Salary Earner Statistics for Small Areas, Time Series, 2005-06 to 2010-11 2013.
26. Burton NW, Haynes M, Wilson LA, et al. HABITAT: A longitudinal multilevel study of physical activity change in mid-aged adults. *BMC Public Health.* 2009;9:76.
27. Dillman DA. *Mail and internet surveys: The tailored design method.* Vol 2: Wiley New York; 2000.
28. Australian Bureau of Statistics. Census of population and housing: socio-economic indexes for areas (SEIFA), Australia, 2011. 2013; http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/2033.0.55.001main+features100052011. Accessed 5 November, 2014.
29. Australian Bureau of Statistics. Australian Standard Classification of Occupation. 1997; http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1220.01997?OpenDocument, 2014.
30. Ware JE, Kosinski M, Keller S. *SF-36 physical and mental health summary scales: a user's manual.* Health Assessment Lab.; 1994.
31. Haley SM, McHorney CA, Ware JE, Jr. Evaluation of the MOS SF-36 physical functioning scale (PF-10): I. Unidimensionality and reproducibility of the Rasch item scale. *J Clin Epidemiol.* 1994;47(6):671-684.
32. Bohannon RW, DePasquale L. Physical Functioning Scale of the Short-Form (SF) 36: internal consistency and validity with older adults. *Journal of Geriatric Physical Therapy (2001).* 2009;33(1):16-18.
33. Australian Bureau of Statistics. *1995 National Health Survey- SF-36 Population Norms, Australia.* Canberra1997.
34. Leveille SG, Penninx B, Melzer D, Izmirlian G, Guralnik JM. Sex differences in the prevalence of mobility disability in old age: the dynamics of incidence, recovery, and mortality. *Journals of Gerontology Series B.* 2000;55(1):S41-S50.
35. Oman D, Reed D, Ferrara A. Do elderly women have more physical disability than men do? *American Journal of Epidemiology.* 1999;150(8):834-842.
36. Tom A, Bosker TASRJ, Bosker RJ. *Multilevel analysis: An introduction to basic and advanced multilevel modeling.* Sage; 1999.
37. Goldstein H, Browne W, Rasbash J. Partitioning variation in multilevel models. *Understanding Statistics: Statistical Issues in Psychology, Education, and the Social Sciences.* 2002;1(4):223-231.

38. *MLwiN Version 2.3* [computer program]. University of Bristol: Centre for Multilevel Modelling; 2009.
39. *Stata Statistical Software: Release 13*: College Station, TX: StataCorp LP; 2013.
40. Leckie G, Charlton C. runmlwin- A Program to Run the MLwiN Multilevel Modeling Software from within Stata. *Journal of Statistical Software.* 2013;52(11):1-40.
41. Bize R, Johnson JA, Plotnikoff RC. Physical activity level and health-related quality of life in the general adult population: a systematic review. *Preventive Medicine.* 2007;45(6):401-415.
42. Murtagh KN, Hubert HB. Gender differences in physical disability among an elderly cohort. *American Journal of Public Health.* 2004;94(8):1406.
43. Kandrack MA, Grant KR, Segall A. Gender differences in health related behaviour: some unanswered questions. *Social Science & Medicine (1982).* 1991;32(5):579-590.
44. Verbrugge LM, Wingard DL. Sex differentials in health and mortality. *Women & Health.* 1987;12(2):103-145.
45. Louie GH, Ward MM. Sex Disparities in Self-Reported Physical Functioning: True Differences, Reporting Bias, or Incomplete Adjustment for Confounding? *Journal of the American Geriatrics Society.* 2010;58(6):1117-1122.
46. Östlin P, Eckermann E, Mishra US, Nkowane M, Wallstam E. Gender and health promotion: A multisectoral policy approach. *Health Promotion International.* 2006;21(suppl 1):25-35.
47. Brennan S, Turrell G. Neighborhood disadvantage, individual-level socioeconomic position, and self-reported chronic arthritis: A cross-sectional multilevel study. *Arthritis Care & Research.* 2012;64(5):721-728.
48. Turrell G, Sanders AE, Slade GD, Spencer AJ, Marcenes W. The independent contribution of neighborhood disadvantage and individual-level socioeconomic position to self-reported oral health: a multilevel analysis. *Community Dentistry and Oral Epidemiology.* 2007;35(3):195-206.
49. Kelleher J. Cultural literacy and health. *Epidemiology.* 2002;13(5):497-500.
50. McPhedran S. Regional living and community participation: are people with disability at a disadvantage? *Australian Social Policy.* 2010(9).
51. De Jong GF, Madamba AB. A double disadvantage? Minority group, immigrant status, and underemployment in the United States. *Social Science Quarterly.* 2001;82(1):117-130.

52. Gething L. Sources of double disadvantage for people with disabilities living in remote and rural areas of New South Wales, Australia. *Disability & Society.* 1997;12(4):513-531.

53. Ross CE, Mirowsky J. Neighborhood disadvantage, disorder, and health. *Journal of Health and Social Behavior.* 2001:258-276.

54. Baum F. The role of social capital in health promotion: Australian perspectives. 1999.

55. Evans RG, Barer ML, Marmor TR. *Why are some people healthy and others not?: The determinants of health of populations.* Cambridge Univ Press; 1994.

56. Spanier PA, Allison KR. General social support and physical activity: an analysis of the Ontario Health Survey. *Canadian Journal of Public Health.* 2000;92(3):210-213.

57. Wendel-Vos W, Droomers M, Kremers S, Brug J, van Lenthe F. Potential environmental determinants of physical activity in adults: a systematic review. *Obesity Reviews : an official journal of the International Association for the Study of Obesity.* 2007;8(5):425-440.

58. He XZ, Baker DW. Body mass index, physical activity, and the risk of decline in overall health and physical functioning in late middle age. *Am J Public Health.* 2004;94(9):1567-1573.

59. Manini TM, Pahor M. Physical activity and maintaining physical function in older adults. *British Journal of Sports Medicine.* 2009;43(1):28-31.

60. Demark-Wahnefried W, Clipp EC, Morey MC, et al. Physical function and associations with diet and exercise: Results of a cross-sectional survey among elders with breast or prostate cancer. *International Journal of Behavioral Nutrition and Physical Activity.* 2004;1(1):16.

61. LaCroix AZ, Guralnik JM, Berkman LF, Wallace RB, Satterfield S. Maintaining mobility in late life. II. Smoking, alcohol consumption, physical activity, and body mass index. *American Journal of Epidemiology.* 1993;137(8):858-869.

62. Nelson HD, Nevitt MC, Scott JC, et al. Smoking, alcohol, and neuromuscular and physical function of older women. *JAMA.* 1994;272(23):1825-1831.

63. Frank L, Kerr J, Rosenberg D, King A. Healthy aging and where you live: community design relationships with physical activity and body weight in older Americans. *Journal of Physical Activity & Health.* 2010;7 Suppl 1:S82-90.

64. Berke EM, Koepsell TD, Moudon AV, Hoskins RE, Larson EB. Association of the built environment with physical activity and obesity in older persons. *Am J Public Health.* 2007;97(3):486-492.

65. Li F, Harmer PA, Cardinal BJ, et al. Built environment, adiposity, and physical activity in adults aged 50-75. *American Journal of Preventive Medicine.* 2008;35(1):38-46.

66. Krukowski RA, West DS, Harvey-Berino J, Prewitt TE. Neighborhood impact on healthy food availability and pricing in food stores. *Journal of Community Health.* 2010;35(3):315-320.

67. Turrell G, Hewitt BA, Miller SA. The influence of neighbourhood disadvantage on smoking cessation and its contribution to inequalities in smoking status. *Drug and Alcohol Review.* 2012;31(5):645-652.

68. Turrell G, Hewitt B, Haynes M, Nathan A, Giles-Corti B. Change in walking for transport: a longitudinal study of the influence of neighbourhood disadvantage and individual-level socioeconomic position in mid-aged adults. *International Journal of Behavioral Nutrition and Physical Activity.* 2014;11(151):0151-0157.

69. Turrell G, Patterson C, Oldenburg B, Gould T, Roy M-A. The socio-economic patterning of survey participation and non-response error in a multilevel study of food purchasing behaviour: area-and individual-level characteristics. *Public Health Nutrition.* 2003;6(02):181-189.

70. Kavanagh AM, Goller JL, King T, Jolley D, Crawford D, Turrell G. Urban area disadvantage and physical activity: a multilevel study in Melbourne, Australia. *Journal of Epidemiology and Community Health.* 2005;59(11):934-940.

71. Diez Roux AV. Estimating neighborhood health effects: the challenges of causal inference in a complex world. *Social Science & Medicine (1982).* 2004;58(10):1953-1960.

72. Snijders TA, Bosker RJ. *Multilevel analysis: An introduction to basic and advanced multilevel modeling.* Sage; 1999.

73. Franco M, Bilal U, Diez-Roux AV. Preventing non-communicable diseases through structural changes in urban environments. *Journal of Epidemiology and Community Health.* 2014:jech-2014-203865.

74. Lorenc T, Petticrew M, Welch V, Tugwell P. What types of interventions generate inequalities? Evidence from systematic reviews. *Journal of Epidemiology and Community Health.* 2013;67(2):190-193.