Exploring factors associated with physical activity in older adults: An ecological approach

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Abstract

According to ecological models of behaviour, the physical environment can influence physical activity engagement via a series of mediating and moderating processes. The present study tested such a model to identify factors relevant to older people's engagement in moderate-to-vigorous physical activity (MVPA). Sociodemographic, psychological, physical, and environmental factors were assessed in 432 Western Australians aged 60+ years. MVPA was measured objectively using accelerometers. No environmental variables were related to engagement in MVPA either directly or indirectly. However, various individual-level factors were significant, indicating that these may be more important than environmental factors in locations such as Australia that have generally conducive environments and ambient conditions.

Keywords: physical activity, environmental factors, ecological models, accelerometers, older adults

Introduction

Populations are aging throughout the world, with the number of people over 60 years of age expected to double to 2.1 billion by the year 2050 (United Nations, 2017). In Australia, 21% of the population is currently aged 60 years and older (Australian Bureau of Statistics, 2017), with this figure forecast to increase to 28% by the year 2050 (United Nations, 2015). Population aging will increase health care costs due to the corresponding increases in age-related chronic diseases and disability (Goldman et al., 2013), making it important to develop and implement strategies that promote healthy aging.

Regular physical activity can delay the morbidity associated with aging and extend the years of active independent living (Bauman, Merom, Bull, Buchner, & Fiatarone Singh, 2016; Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017; Taylor, 2014). However, adults aged 60 years and older represent the least active population segment (Colley et al., 2011; Troiano et al., 2008). It is therefore important to understand the factors that determine physical activity participation among older adults to facilitate the development of effective interventions to promote activity in this age group. This is particularly the case for moderate to vigorous physical activity (MVPA); mortality has been found to be 28% lower in adults aged 60 years and older who engage in 150 minutes of MVPA per week relative to their sedentary counterparts (Hupin et al., 2015). Physical activity guidelines recommend that older adults should engage in at least 150 minutes of moderate-intensity, ≥75 minutes of vigorous-intensity physical activity, or an equivalent combination of MVPA (World Health Organization, 2010). However, only around one-third of older Australians achieve this level of physical activity (Australian Bureau of Statistics, 2015).

Physical activity is a complex behaviour; approximately 60 different motivators and barriers relevant to engagement in physical activity are reported in the literature (Baert, Gorus, Mets, Geerts, & Bautmans, 2011). These motivators and barriers exist at multiple levels, including individual, social, and environmental domains. An ecological approach involving consideration of multiple levels of influence has been proposed as being useful for examining determinants of physical activity in both the population in general and older people in particular (Sallis, Owen, & Fisher, 2015; Spence & Lee, 2003). Such frameworks provide a comprehensive approach to understanding the multiple and interacting factors that influence physical activity, and as such can inform the development of comprehensive interventions that may be most likely to result in behavioural change (Sallis et al., 2006).

Previous work on community-dwelling older adults has shown physical activity to be positively related to various sociodemographic factors such as younger age, male gender, marital status, higher education levels, and higher socio-economic status (Bauman, Sallis, Dzewaltowski, & Owen, 2002; Jefferis et al., 2014; McMurdo et al., 2012). Being in poor health (Buman et al., 2010; Lohne-Seiler, Hansen, Kolle, & Anderssen, 2014; Ortlieb et al., 2014) and being overweight/obese (Arnardottir et al., 2012; Davis et al., 2011) have been associated with lower levels of physical activity participation. Psychosocial factors such as quality of life (Prince et al., 2016), psychological well-being (Withall et al., 2014), social support (Bauman et al., 2002; Smith, Banting, Eime, O'Sullivan, & van Uffelen, 2017), purpose in life, (Holahan et al., 2011; Holahan & Suzuki, 2006), and personal growth (Holahan et al., 2011) have also all previously been reported to be positively associated with physical activity. Correspondingly, depression has been negatively associated with physical activity (Jefferis et al., 2014; Ku, Steptoe, Liao, Sun, & Chen, 2018; Loprinzi, 2013).

The physical environment is particularly relevant to older adults as a source of behavioural influence because age-related declines in physical capacity can make this population segment more vulnerable to any factors adversely impacting on mobility and accessibility (Lawton, 1985). Accordingly, researchers have increasingly focused their attention on the relationship between the environment and older adults' physical activity levels (Barnett, Barnett, Nathan, Van Cauwenberg, & Cerin, 2017; Bauman et al., 2012). Previous studies have examined the association between physical activity engagement in older adults and (i) built environment attributes such as neighbourhood walkability and access to services and parks (Bracy et al., 2014; Gong, Gallacher, Palmer, & Fone, 2014; Van Holle et al., 2014) and (ii) natural environmental factors such as seasons and the weather (Arnardottir et al., 2017; Chan & Ryan, 2009; Yasunaga et al., 2008). The findings have been mixed; walkability has been shown to be associated with engagement in moderate to vigorous physical activity (MVPA) in some studies (Carlson et al., 2012; King et al., 2011), while null effects have been reported in others (Chudyk, McKay, Winters, Sims-Gould, & Ashe, 2017; Thornton et al., 2016). Similarly, physical activity has been associated with access to parks in some studies (Gong et al., 2014; Michael, Perdue, Orwoll, Stefanick, & Marshall, 2010), while others found no association (Gómez et al., 2010; Kerr et al., 2014). In terms of methodological approaches, self-reported physical activity has been found to be more consistently associated with neighbourhood environmental factors than has objectively assessed physical activity (Barnett et al., 2017; Van Cauwenberg et al., 2011).

One of the core principles of the ecological framework as applied to physical activity is that the various factors influencing participation can interact across multiple levels (Sallis et al., 2015). For example, Spence and Lee (2003) proposed that environmental factors are likely to exert both direct and indirect effects on physical activity via physical and psychological moderators and mediators. Moderators of the environment-physical activity association (e.g., age, gender, socio-economic status, and health status) have previously been examined in older adults (King et al., 2011; Michael et al., 2010; Van Holle et al., 2014), with inconsistent results observed (Barnett et al., 2017). It appears that no study to date has examined potential mediators of the environment-physical activity association in older adults.

In response to Spence and Lee's (2003) call for the application of ecological models that include both moderation and mediation effects, and to provide greater insight into the potential role of the physical environment in influencing older people's physical activity, the present study tested an ecological model that included a range of factors that have been suggested in previous research to be related to seniors' activity levels. Given limited health promotion budgets and therefore the need to prioritise intervention options, the overall aim was to identify the most influential factors among a range of environmental and individual variables that could be the focus of future efforts to increase MVPA among community-dwelling older people.

Methods

Study Design and Sample

The present cross-sectional analysis is based on the baseline data collected as part of a larger study designed to assess factors influencing healthy aging in older Australians (Author, 2015). The present study involved four components of this larger study: a survey completed by participants, an assessment of participants' physical characteristics, activity assessment via accelerometry, and derivation of environmental characteristics. Adults aged 60+ years were recruited from the metropolitan area of Perth, Western Australia through notices in community newspapers and seniors' publications, radio announcements, flyers circulated at seniors' events and retirement villages, and notices distributed through local government and non-government organizations. Ethics approval for the study was obtained from a University Human Research Ethics Committee, and written informed consent was obtained from all participants prior to their participation.

Measures

Sociodemographic, psychosocial, and health-related factors were assessed via a questionnaire that was either posted in the mail or accessed online, depending on the preferences of the participants. Participants who completed the questionnaires were invited to attend an on-campus appointment, during which their height, weight, and waist girth were measured and accelerometers distributed. Participants were instructed on how to use the accelerometers, including how to record the time periods during which the accelerometers were not worn due to bathing and other water-based activities. Environmental variables were derived from the participants' postcodes and suburbs as outlined further below.

Individual-level variables

Sociodemographic variables

The sociodemographic variables included in the study were age, gender, education level (no formal school/primary school, high school, technical/trade, undergraduate, postgraduate), living status (living alone or with others), country of birth (English-speaking vs non-English-speaking), and socioeconomic status (SES). Participants' postcodes were used to calculate SES for the area in which they reside using the Index of Relative Socio-Economic Disadvantage from the Australian Bureau of Statistics (2011) Socio-Economic Index For Areas (SEIFA).This index is calculated using a number of variables including income, education level, employment, occupation, housing type, and other factors deemed relevant to socioeconomic disadvantage.

Health variables

Self-rated health was assessed with the question "How would you describe your physical health?", with responses ranging from 1 (*very good*) to 5 (*very bad*). Health status was assessed with a health history questionnaire that asked participants to report any diagnoses of chronic diseases. The total number of diseases reported was used in analyses. Participants were also asked about their smoking status (non-smoker, former smoker, current smoker) and their weekly alcohol consumption. Height, weight, and waist girth were measured by trained research associates during the on-campus interview. Body mass index (BMI) was calculated using height and weight data.

Psychosocial variables

The 24-item Social Provision Scale (Cutrona & Russell, 1987) was used to measure social support. Responses to each item (e.g., *There are people who enjoy the same social activities I do*) ranged from 1 (*strongly disagree*) to 4 (*strongly agree*). The 20-item Center for Epidemiological Studies Depression Scale (Radloff, 1977) was used to assess depressive symptomatology. Responses to each item (e.g., *I was bothered by things that usually don't bother me during the past week*) ranged from 0 (*rarely or none of the time*) to 3 (*most or all of the time*).

The Global Quality of Life Scale (Hyland & Sodergren, 1996) was used to assess quality of life (scale ranging from 0 (*no quality of life*) to 100 (*perfect quality of life*)). The 14-item Warwick-Edinburgh Mental Well-Being Scale (Tennant et al., 2007) was used to assess psychological well-being. Responses to each item (e.g., *I've been feeling optimistic about the future*) ranged from 1 (*none of the time*) to 5 (*all of the time*).

Environmental variables

Walkability

Area walkability was derived using Walk Score®, which is a freely accessible on-line tool (Front Seat Management, 2014). Based on publicly available data sources such as Google Maps, Education.com, and Open Street Maps, Walk Score uses a distance-decay algorithm to allocate points for a geographic location (determined by postcode) by calculating the shortest distance to 13 amenities such as shops, parks, schools, restaurants, and entertainment. The maximum points are assigned to a destination category within 0.4 km and the points decline as the distance approaches 1.6 km. The amenities are given equal weights and the points are totalled and normalised to produce a score ranging from 0 (*Very car dependent*) to 100 (*Walker's paradise*). The Walk Score has been validated against geographic information systems (GIS) measuring walkability (Carr, Dunsiger, & Marcus, 2011; Duncan, Aldstadt, Whalen, Melly, & Gortmaker, 2011), and has previously been used in the United States, Canada, and Australia (Cole, Dunn, Hunter, Owen, & Sugiyama, 2015; Hirsch, Winters, Clarke, Ste-Marie, & McKay, 2017; Sriram et al., 2016).

Public Open Spaces Density

Public Open Spaces (POS) refers to parks, school grounds/playing fields, conservation areas, bushland, and areas of residual green space (Bull et al., 2013). The percentage of total POS was calculated for each participant's suburb using the POS Tool (www.postool.com), which is a web-based geospatial tool allowing users to access data on the provision and distribution of POS across specific regions of Western Australia (Centre for the Built Environment and Health, 2013).

Seasons

In Western Australia, the average temperature during the data collection period (2014-2016) was 15 degrees Celsius in winter, 25 degrees in summer, 19 degrees in spring, and 19 degrees in autumn (Australian Bureau of Meteorology, 2017). Seasonality of the data collection period for individual participants was thus categorised as a binary variable representing more extreme and mild temperatures. The seasons were recoded as winter/summer (June-August/December-February) and spring/autumn (September-November/March-May).

Physical activity

Participants were instructed to wear the GT3X accelerometer (ActiGraph, Pensacola, Florida) attached to a belt on their hip over a 24-hour period for 7 consecutive days, removing it only for water-based activities. Non-wear time was calculated using a non-wear algorithm (Choi, Ward, Schnelle, & Buchowski, 2012) and was defined as periods of continuous zeros lasting more than 90 minutes. A valid day was defined as at least 10 hours of wear time (Tudor-Locke et al., 2015). The recording interval (epoch) was set at 60 seconds, and as per Migueles et al. (2017) all participants with ≥ 4 valid days of data were included in the analyses. Of the 432 participants in the study, 431 provided 7 days of data and 1 provided 6 days. Average minutes of MVPA per week were calculated using vector-magnitude cut-points that have been established in older adults (≥ 2752 counts per minute) (Santos-Lozano et al., 2013).

Statistical Analysis

Initial correlation analyses were conducted to assess the relationships between all variables. Significant associations identified between the independent and dependent variables under investigation were then specified and tested as per an ecological framework in a multivariate mediation model using M*Plus*. Mediation pathways were assessed using the indirect effects function available in M*Plus*. To test for moderation effects, possible interactions between each independent variable and age, gender, and SES were included in a secondary analysis of the model with a Bonferroni-adjusted alpha of .0009 used to control for the familywise error rate. To determine whether the ecological model provided an acceptable fit to the data, model fit statistics and path coefficients were inspected. A model is considered a 'good' fit if the comparative fit index (CFI) and Tucker-Lewis Index (TLI) are $\geq .95$, the Root Mean Square Error of Approximation (RMSEA) is $\leq .06$, and the Standardised Root Mean Square Residual (SRMR) is $< .08$.

Results

In total, 453 individuals were enrolled in the study, 432 of whom provided complete data and were therefore included in the final sample. Participants ranged in age from 60 to 95 years (M = 70.31 years, SD = 6.02) and 44% were male. Table 1 presents descriptive statistics for scores obtained by participants on the continuous variables under investigation.

Correlational analyses (see Table 1) revealed several demographic (age, gender, SES), health (BMI, waist girth, self-rated health, health status), lifestyle (smoking status, weekly alcohol consumption), psychological (quality of life, personal growth, purpose in life, depressive symptomatology), and environmental (walkability) variables to be significantly associated with MVPA. Correlations were small to moderate in size and negative in direction with the exception of SES, weekly alcohol consumption, quality of life, personal growth, purpose in life, and walkability. Three significant associations were identified between the distal environmental variables and the proximal health, lifestyle, and psychological variables (walkability to health status (negative association), POS density to alcohol consumption (positive association), and BMI (positive association)).

Insert Table 1 about here

Significant associations were combined into a multivariate mediational model. Given the strong correlation between waist girth and BMI, a covariance pathway was specified between these two variables. Prior to testing the model, the data were assessed to ensure the assumptions pertaining to path analysis were met. The specified relationships were linear in nature and the model was non-recursive. Although three of the continuous variables (MVPA, weekly alcohol consumption, BMI) were found to be moderately kurtotic, results obtained from an analysis in which the MLR estimator was specified in M*Plus* did not substantially differ from those obtained from an analysis in which the ML estimator was specified. As such, results have been presented for the latter (ML) analysis. A post-hoc power calculation revealed that the analysis was adequately powered (power = 1.0).

The tested model was a poor fit to the data (χ^2 (47) = 474.38, $p < .001$; CFI = 0.52, TLI = .45, SRMR = .09, RMSEA = .15, 90% CI for RMSEA = .14, .16), although it accounted for 22% of the variance in MVPA. Standardized parameter estimates are presented in Figure 1. Age, gender, self-rated health, waist girth, health status, smoking status, and depressive symptoms were uniquely associated with MVPA. POS suburb percentage was significantly associated with alcohol consumption, and walkability was significantly associated with health status. A test of indirect effects did not reveal the presence of any significant indirect (i.e., mediating) pathways. Results from the moderation analyses assessing possible interactions between each variable and age, gender, and SES did not emerge as significant.

Insert Figure 1 about here

Discussion

To counteract the personal and societal impacts of rapid population aging, urgent measures are required to promote healthy aging (World Health Organisation, 2015). By "compressing morbidity" and reducing disability, physical activity can improve quality of life and contribute significantly to healthy aging (Bauman et al., 2016; Crimmins, 2015). The development of effective interventions to increase physical activity levels among older people is therefore critical (Bauman et al., 2012), but requires a comprehensive knowledge of the factors influencing physical activity participation among members of this group.

Ecological models of physical activity suggest that aspects of the physical environment are likely to have both direct effects on physical activity and indirect effects via influence on other factors (e.g., psychological and biological characteristics). This study assessed these relationships in the context of older Australians to identify potential areas of focus for future physical activity promotion interventions. Contrary to expectations, an ecologically-framed mediated model found no significant effects of the included physical environment characteristics on MVPA, either directly or indirectly. However, certain individual-level factors were directly associated with MVPA, suggesting that factors other than the environment play a more influential role in influencing physical activity participation in older adults in this particular geographical context.

Previous research examining the relationship between physical activity participation and external environment attributes such as walkability and park access has shown mixed results. Some studies have demonstrated a positive association between accelerometer-derived MVPA among older people and these attributes (Carlson et al., 2012; Gong et al., 2014; King et al., 2011; Michael et al., 2010), while others have not (Chudyk et al., 2017; Gómez et al., 2010; Kerr et al., 2014; Thornton et al., 2016). The non-significant effect of these environmental variables on MVPA in the present study may be at least partly explained by the relatively limited variation in these factors (Van Cauwenberg et al., 2011). Perth is a highly liveable city with a largely stable, temperate climate (Badland, Christian, Giles-Corti, & Knuiman, 2011). Previous studies conducted in Perth have also reported non-significant associations between physical activity and built environmental attributes (Giles-Corti & Donovan, 2002), and physical activity and weather (Badland et al., 2011). In addition, physical activity is a broad construct encompassing various domains, including occupational, household, transportation-related, and leisure time physical activity (Sallis et al., 2006). It is possible that each domain could be related to different (or combinations of) environmental characteristics (Kerr, Rosenberg, & Frank, 2012), which could not be ascertained in the tested model.

The outcome that waist girth but not BMI was related to MVPA contributes to discussions on the relative usefulness of these two measures. Previous cross-sectional studies using BMI as a surrogate measure for obesity/overweight have identified an inverse relation with physical activity (Arnardottir et al., 2012; Davis et al., 2011; King et al., 2011). However, a systematic review of longitudinal studies involving older adults found the evidence regarding the association between physical activity and obesity/overweight as measured by BMI to be inconclusive (Koeneman, Verheijden, Chinapaw, & Hopman-Rock, 2011). Although few studies have examined the relationship between waist girth and physical activity in older adults, the available results consistently indicate a negative association between these two variables (Batsis, Zbehlik, Barre, Mackenzie, & Bartels, 2014; Jefferis et al., 2014; Nilsson, Wåhlin-Larsson, & Kadi, 2017). Due to the age-related changes in body composition and decreases in height from compression of vertebral bodies, BMI may not be the ideal anthropometric measure in older adults (Villareal & Shah, 2015; Zamboni et al., 2005). Waist girth, which is highly correlated to visceral adiposity and is closely linked to various medical pathologies such as insulin resistance, cardiovascular diseases, and certain cancers (Bigaard et al., 2003; Janssen, Katzmarzyk, & Ross, 2004), has been proposed to be relatively more important in older adults (Zamboni et al., 2005). This may go some way towards explaining the greater explanatory power of waist girth in the present study.

Self-rated health, health status, and the presence of depressive symptomatology were negatively related to the amount of time spent in MVPA in the present study. Poor physical and mental health have previously been identified as a barrier to physical activity engagement in both quantitative and qualitative studies with older adults (Baert et al., 2011; Bauman et al., 2012; Burton et al., 2017; Pettigrew et al., 2017). However, well-designed physical activity interventions have been shown to improve health outcomes such as functional ability (Liu & Latham, 2011), cardio-metabolic health (Sagar et al., 2015; Yang, Scott, Mao, Tang, & Farmer, 2014), pain associated with osteoarthritis (Fransen, McConnell, Hernandez-Molina, & Reichenbach, 2014), depression (Singh et al., 2005), and cognitive function (Gates, Singh, Sachdev, & Valenzuela, 2013). Given these potential health benefits for older people in poorer health, appropriate exercise programs catering to older adults with limitations should be made available and promoted to older people across a range of health status levels (Bauman et al., 2016).

Consistent with previous work with this age group, current smoking was also negatively associated with MVPA in the final model (Hansen, Ommundsen, Holme, Kolle, & Anderssen, 2014; Shimada, Lord, Yoshida, Kim, & Suzuki, 2007). A possible explanation could be that reduced physical capacities among smokers, especially with regard to pulmonary function (Willemse, Postma, Timens, & ten Hacken, 2004), may negatively affect the ability to engage in MVPA.

Study Implications

The tested mediated model using an ecological approach did not demonstrate a good fit to the data, indicating that factors other than the physical environment primarily influence older people's physical activity levels in this particular geographic context. Instead, the results highlight the importance of specific individual-level variables that could be the focus of future intervention efforts to increase physical activity among older people. Of the five variables found to be directly associated with physical activity, two (subjective health and health status) are somewhat difficult to modify. The other three (waist girth, smoking, and depressive symptoms) are more intermediary factors that could be potentially modifiable through interventions and could therefore constitute particular areas of focus.

In terms of waist girth, a combination of moderate caloric restriction and exercise has been recommended for weight loss in older adults to prevent the loss of bone density and skeletal muscle mass that occurs when only caloric restriction is instituted (Locher et al., 2016; Villareal & Shah, 2015; Waters, Ward, & Villareal, 2013). This combined approach has been found to be successful in achieving weight loss and improving physical function, cardiovascular, and metabolic outcomes in older adults (Beavers et al., 2014; Waters et al., 2013). The results of the present study indicate that including a focus on physical activity in weight loss programs has the potential to directly increase MVPA through the prescription of physical activity as a treatment and indirectly by facilitating the higher levels of activity that may ultimately result from reduced waist girth. In addition, weight loss (and smoking cessation) are likely to improve both objective and subjective health, further increasing the likelihood of increased MVPA in the future.

Population-level data show lower smoking cessation rates among older smokers compared to younger age groups (Centers for Disease Control and Prevention, 2011). However, interventions that include or specifically target older adults have demonstrated comparable or higher quitting rates among this age group compared to outcomes for younger smokers (Doolan & Froelicher, 2008). In particular, individual-level interventions that include a combination of behavioural counselling and smoking cessation medication have been shown to be effective in achieving favourable outcomes in older adults (Chen & Wu, 2015; Zbikowski, Magnusson, Pockey, Tindle, & Weaver, 2012). Older people are more likely than younger people to be in regular contact with health care providers, which provides an opportunity to identify smokers and offer efficacious smoking cessation counselling and medications (Doolan & Froelicher, 2008). Smoking cessation improves lung function (Willemse et al., 2004), which in turn is likely to increase the ability to engage in physical activity.

With regard to depression, awareness programs could be implemented to inform both professional and lay audiences that depressive symptoms are not a normal part of aging, potentially facilitating early diagnosis and the provision of adequate treatment (Fiske, Wetherell, & Gatz, 2009). In addition, physical exercise interventions have been demonstrated to be efficacious in the treatment of depressive symptoms in older adults (Blake, Mo, Malik, & Thomas, 2009). The findings of the present study indicate that prescribing physical activity for the treatment of depression among older people may not only increase MVPA directly but may also contribute to physical activity participation by reducing depressive symptoms.

Finally, given the challenges associated with encouraging behavioural change in older adults who have long-established lifestyle habits, comprehensive approaches to ensuring that older members of society are physically active should include a lifespan focus that is prevention-oriented rather than merely attempting to induce behavioural change in later life (Ekelund, 2014; Kuh, Richards, Cooper, Hardy, & Ben-Shlomo, 2014). As such, policies at the population level that aim to discourage smoking initiation, encourage maintaining optimum weight, and promote positive mental health at all life stages may have the added benefit of enabling higher levels of physical activity engagement with advancing age.

Limitations and Strengths

A primary limitation of the present study was its cross-sectional design, which precludes inferences of causality. Longitudinal research is required to test the causal pathways identified in this study to derive a more complete picture of the determinants of physical activity among older people. A further limitation is that domain-specific physical activity was not examined, which might have obscured the relationships between the assessed variables. For example, previous research has shown proximity to parks and recreational facilities to be associated with recreational physical activity (Sugiyama, Francis, Middleton, Owen, & Giles-Corti, 2010) and walkability to be associated with more utilitarian forms of physical activity such as transport-related walking (Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; King et al., 2011). Future research should therefore examine various domains of physical activity to identify any relationships that occur at that level. Measures of the perceived physical environment would be a further useful inclusion given that factors such as perceived safety and aesthetics can influence participation in physical activity (Barnett et al., 2017). Future studies could thus expand on the contribution of the present work by including both perceived and objective measures of environmental attributes. Finally, other social factors that have been shown to influence physical activity in older adults, such as social engagement and the presence of a variety of social networks (Franke, Tong, Ashe, McKay, & Sims-Gould, 2013; Litwin, 2012), were not assessed. Future research should therefore also include these additional social factors to provide a more complete assessment of the relevance of the social context within an ecological framework.

A key strength of the study was that an ecological approach was used to concurrently examine the influence of multiple levels of factors on physical activity, and a wide range of moderators and mediators was tested. In addition, physical activity was measured objectively, thus reducing the potential for recall bias (Tudor-Locke & Myers, 2001). This is particularly relevant for older people given increasing incidence of cognitive decline with age (Barnett, van den Hoek, Barnett, & Cerin, 2016). While the poor model fit indicates that caution should be exercised when interpreting the findings, the large proportion of variance explained by the model suggests that the results provide useful information for those tasked with improving physical activity levels among older people.

Conclusion

The findings of the present study are that individual-level factors may be more influential than social and environmental factors in determining physical activity participation among older adults in locations such as Australia that have generally conducive environments and ambient conditions. It appears to be especially important to address specific individual-level factors when formulating policies and designing future interventions to increase physical activity in older people, namely waist girth, tobacco use, and depression. Promoting weight loss and smoking cessation and facilitating early recognition and treatment of depressive symptoms may thus have multiple benefits by enhancing health in their own right while also increasing the likelihood of physical activity participation among members of this age group.

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Exploring factors associated with physical activity in older adults: An ecological approach

Abstract

According to ecological models of behaviour, the physical environment can influence physical activity engagement via a series of mediating and moderating processes. The present study tested such a model to identify factors relevant to older people's engagement in moderate-to-vigorous physical activity (MVPA). Sociodemographic, psychological, physical, and environmental factors were assessed in 432 Western Australians aged 60+ years. MVPA was measured objectively using accelerometers. No environmental variables were related to engagement in MVPA either directly or indirectly. However, various individual-level factors were significant, indicating that these may be more important than environmental factors in locations such as Australia that have generally conducive environments and ambient conditions.

Keywords: physical activity, environmental factors, ecological models, accelerometers, older adults

Introduction

Populations are aging throughout the world, with the number of people over 60 years of age expected to double to 2.1 billion by the year 2050 (United Nations, 2017). In Australia, 21% of the population is currently aged 60 years and older (Australian Bureau of Statistics, 2017), with this figure forecast to increase to 28% by the year 2050 (United Nations, 2015). Population aging will increase health care costs due to the corresponding increases in age-related chronic diseases and disability (Goldman et al., 2013), making it important to develop and implement strategies that promote healthy aging.

Regular physical activity can delay the morbidity associated with aging and extend the years of active independent living (Bauman, Merom, Bull, Buchner, & Fiatarone Singh, 2016; Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017; Taylor, 2014). However, adults aged 60 years and older represent the least active population segment (Colley et al., 2011; Troiano et al., 2008). It is therefore important to understand the factors that determine physical activity participation among older adults to facilitate the development of effective interventions to promote activity in this age group. This is particularly the case for moderate to vigorous physical activity (MVPA); mortality has been found to be 28% lower in adults aged 60 years and older who engage in 150 minutes of MVPA per week relative to their sedentary counterparts (Hupin et al., 2015). Physical activity guidelines recommend that older adults should engage in at least 150 minutes of moderate-intensity, ≥75 minutes of vigorous-intensity physical activity, or an equivalent combination of MVPA (World Health Organization, 2010). However, only around one-third of older Australians achieve this level of physical activity (Australian Bureau of Statistics, 2015).

Physical activity is a complex behaviour; approximately 60 different motivators and barriers relevant to engagement in physical activity are reported in the literature (Baert, Gorus, Mets, Geerts, & Bautmans, 2011). These motivators and barriers exist at multiple levels, including individual, social, and environmental domains. An ecological approach involving consideration of multiple levels of influence has been proposed as being useful for examining determinants of physical activity in both the population in general and older people in particular (Sallis, Owen, & Fisher, 2015; Spence & Lee, 2003). Such frameworks provide a comprehensive approach to understanding the multiple and interacting factors that influence physical activity, and as such can inform the development of comprehensive interventions that may be most likely to result in behavioural change (Sallis et al., 2006).

Previous work on community-dwelling older adults has shown physical activity to be positively related to various sociodemographic factors such as younger age, male gender, marital status, higher education levels, and higher socio-economic status (Bauman, Sallis, Dzewaltowski, & Owen, 2002; Jefferis et al., 2014; McMurdo et al., 2012). Being in poor health (Buman et al., 2010; Lohne-Seiler, Hansen, Kolle, & Anderssen, 2014; Ortlieb et al., 2014) and being overweight/obese (Arnardottir et al., 2012; Davis et al., 2011) have been associated with lower levels of physical activity participation. Psychosocial factors such as quality of life (Prince et al., 2016), psychological well-being (Withall et al., 2014), social support (Bauman et al., 2002; Smith, Banting, Eime, O'Sullivan, & van Uffelen, 2017), purpose in life, (Holahan et al., 2011; Holahan & Suzuki, 2006), and personal growth (Holahan et al., 2011) have also all previously been reported to be positively associated with physical activity~~ (Holahan et al., 2011; Holahan & Suzuki, 2006).~~. Correspondingly, depression has been negatively associated with physical activity (Jefferis et al., 2014; Ku, Steptoe, Liao, Sun, & Chen, 2018; Loprinzi, 2013).

The physical environment is particularly relevant to older adults as a source of behavioural influence because age-related declines in physical capacity can make this population segment more vulnerable to any factors adversely impacting on mobility and accessibility (Lawton, 1985). Accordingly, researchers have increasingly focused their attention on the relationship between the environment and older adults' physical activity levels (Barnett, Barnett, Nathan, Van Cauwenberg, & Cerin, 2017; Bauman et al., 2012). Previous studies have examined the association between physical activity engagement in older adults and (i) built environment attributes such as neighbourhood walkability and access to services and parks (Bracy et al., 2014; Gong, Gallacher, Palmer, & Fone, 2014; Van Holle et al., 2014),) and (ii) natural environmental factors such as seasons and the weather (Arnardottir et al., 2017; Chan & Ryan, 2009; Yasunaga et al., 2008). The findings have been mixed; walkability has been shown to be associated with engagement in moderate to vigorous physical activity (MVPA) in some studies (Carlson et al., 2012; King et al., 2011), while null effects have been reported in others (Chudyk, McKay, Winters, Sims-Gould, & Ashe, 2017; Thornton et al., 2016). Similarly, physical activity has been associated with access to parks in some studies (Gong et al., 2014; Michael, Perdue, Orwoll, Stefanick, & Marshall, 2010), while others found no association (Gómez et al., 2010; Kerr et al., 2014). In terms of methodological approaches, self-reported physical activity has been found to be more consistently associated with neighbourhood environmental factors than has objectively assessed physical activity (Barnett et al., 2017; Van Cauwenberg et al., 2011).

One of the core principles of the ecological framework as applied to physical activity is that the various factors influencing participation can interact across multiple levels (Sallis et al., 2015). For example, Spence and Lee (2003) proposed that environmental factors are likely to exert both direct and indirect effects on physical activity via physical and psychological moderators and mediators. Moderators of the environment-physical activity association (e.g., age, gender, socio-economic status, and health status) have previously been examined in older adults (King et al., 2011; Michael et al., 2010; Van Holle et al., 2014), with inconsistent results observed (Barnett et al., 2017). It appears that no study to date has examined potential mediators of the environment-physical activity association in older adults.

In response to Spence and Lee's (2003) call for the application of ecological models that include both moderation and mediation effects, and to provide greater insight into the potential role of the physical environment in influencing older people's physical activity, the present study tested an ecological model that included a range of factors that have been suggested in previous research to be related to seniors' activity levels. Given limited health promotion budgets and therefore the need to prioritise intervention options, the overall aim was to identify the most influential factors among a range of environmental and individual variables that could be the focus of future efforts to increase MVPA among community-dwelling older people.

Methods

Study Design and Sample

The present cross-sectional analysis is based on the baseline data collected as part of a larger study designed to assess factors influencing healthy aging in older Australians (Author, 2015). The present study involved four components of this larger study: a survey completed by participants, an assessment of participants' physical characteristics, activity assessment via accelerometry, and derivation of environmental characteristics. Adults aged 60+ years were recruited from the metropolitan area of Perth, Western Australia through notices in community newspapers and seniors' publications, radio announcements, flyers circulated at seniors' events and retirement villages, and notices distributed through local government and non-government organizations. In total, 453 individuals were enrolled in the study, 432 of whom provided complete data and were therefore included in the final sample. Participants ranged in age from 60 to 95 years (M = 70.31 years, SD =6.02) and 44% were male. Ethics approval for the study was obtained from a University Human Research Ethics Committee, and written informed consent was obtained from all participants prior to their participation.

Measures

Sociodemographic, psychosocial, and health-related factors were assessed via a questionnaire that was either posted in the mail or accessed online, depending on the preferences of the participants. Participants who completed the questionnaires were invited to attend an on-campus appointment, during which their height, weight, and waist girth were measured and accelerometers distributed. Participants were instructed on how to use the accelerometers, including how to record the time periods during which the accelerometers were not worn due to bathing and other water-based activities. Environmental variables were derived from the participants' postcodes and suburbs as outlined further below.

Individual-level variables

Sociodemographic variables

The sociodemographic variables included in the study were age, gender, education level (no formal school/primary school, high school, technical/trade, undergraduate, postgraduate), living status (living alone or with others), country of birth (English-speaking vs non-English-speaking), and socioeconomic status (SES). Participants' postcodes were used to calculate SES levelsfor the area in which they reside using the Index of Relative Socio-Economic

Disadvantage from the Australian Bureau of Statistics (2011) Socio-Economic Index For Areas.– (SEIFA).This index is calculated using a number of variables including income, education level, employment, occupation, housing type, and other factors deemed relevant to socioeconomic disadvantage.

Health variables

Self-rated health was assessed with the question "How would you describe your physical health?", with responses ranging from 1 (*very good*) to 5 (*very bad*). Objective healthHealth status was assessed with a health history questionnaire that asked participants to report any diagnoses of chronic diseases. The total number of diseases reported was used as a variable in analyses. Participants were also asked about their smoking status (non-smoker, former smoker, current smoker) and their weekly alcohol consumption. Height, weight, and waist circumferencegirth were measured by trained research associates during the on-campus interview. Body mass index (BMI) was calculated using height and weight data.

Psychosocial variables

The 24-item Social Provision Scale (Cutrona & Russell, 1987) was used to measure social support. Responses to each item (e.g., *There are people who enjoy the same social activities I do*) ranged from 1 (*strongly disagree*) to 4 (*strongly agree*). The 20-item Center for Epidemiological Studies Depression Scale (Radloff, 1977) was used to assess depressive symptomatology. Responses to each item (e.g., *I was bothered by things that usually don't bother me during the past week*) ranged from 0 (*rarely or none of the time*) to 3 (*most or all of the time*).

The Global Quality of Life Scale (Hyland & Sodergren, 1996) was used to assess quality of life (scale ranging from 0 (*no quality of life*) to 100 (*perfect quality of life*)). The 14-item Warwick-Edinburgh Mental Well-Being Scale (Tennant et al., 2007) was used to assess psychological well-being. Responses to each item (e.g., *I've been feeling optimistic about the future*) ranged from 1 (*none of the time*) to 5 (*all of the time*).

Environmental variables

Walkability

Area walkability was derived using Walk Score®, which is a freely accessible on-line tool (Front Seat Management, 2014). Based on publicly available data sources such as Google Maps, Education.com, and Open Street Maps, Walk Score uses a distance-decay algorithm to allocate points for a geographic location (determined by postcode) by calculating the shortest distance to 13 amenities such as shops, parks, schools, restaurants, and entertainment. The maximum points are assigned to a destination category within 0.4 km and the points decline as the distance approaches 1.6 km. The amenities are given equal weights and the points are totalled and normalised to produce a score ranging from 0 (*Very car dependent*) to 100 (*Walker's paradise*). The Walk Score has been validated against geographic information systems (GIS) measuring walkability (Carr, Dunsiger, & Marcus, 2011; Duncan, Aldstadt, Whalen, Melly, & Gortmaker, 2011), and has previously been used in the United States, Canada, and Australia (Cole, Dunn, Hunter, Owen, & Sugiyama, 2015; Hirsch, Winters, Clarke, Ste-Marie, & McKay, 2017; Sriram et al., 2016).

Public Open Spaces Density

Public Open Spaces (POS) refers to parks, school grounds/playing fields, conservation areas, bushland, and areas of residual green space (Bull et al., 2013). The percentage of total POS was calculated for each participant's suburb using the POS Tool (www.postool.com), which is a web-based geospatial tool allowing users to access data on the provision and distribution of POS across specific regions of Western Australia (Centre for the Built Environment and Health, 2013).

Seasons

In Western Australia, the average temperature ~~is 13~~during the data collection period (2014-2016) was 15 degrees Celsius in winter, ~~24~~25 degrees in summer, ~~17~~19 degrees in spring, and 19 degrees in autumn (~~Tourism Australia~~Australian Bureau of Meteorology, 2017). Seasonality of the data collection period for individual participants was thus categorised as a binary variable representing more extreme and mild temperatures. The seasons were recoded as winter/summer (June-August/December-February) and spring/autumn (September-November/March-May).

Physical activity

Participants were instructed to wear the GT3X accelerometer (ActiGraph, Pensacola, Florida) attached to a belt on their hip over a 24-hour period for 7 consecutive days, removing it only for water-based activities. Non-wear time was calculated using a non-wear algorithm (Choi, Ward, Schnelle, & Buchowski, 2012) and was defined as periods of continuous zeros lasting more than 90 minutes. A valid day was defined as at least 10 hours of wear time (Tudor-Locke et al., 2015). The recording interval (epoch) was set at 60 seconds, and as per Migueles et al. (2017) all participants with $\geq$ 4 valid days of data were included in the analyses. Of the 432 participants in the study, 431 provided 7 days of data and 1 provided 6 days. Average minutes of MVPA per week were calculated using vector-magnitude cut-points that have been established in older adults ($\geq$ 2752 counts per minute) (Santos-Lozano et al., 2013).

Statistical Analysis

Initial correlation analyses were conducted to assess the relationships between all variables. Significant associations identified between the independent and dependent variables under investigation were then specified and tested as per an ecological framework in a multivariate mediation model using M*Plus*. Mediation pathways were assessed using the indirect effects function available in M*Plus*. To test for moderation effects, possible interactions between each independent variable and age, gender, and SES were included in a secondary analysis of the model with a Bonferroni-adjusted alpha of .0009 used to control for the familywise error rate. To determine whether the ecological model provided an acceptable fit to the data, model fit statistics and path coefficients were inspected. A model is considered a 'good' fit if the comparative fit index (CFI) and Tucker-Lewis Index (TLI) are ≥ .95, the Root Mean Square Error of Approximation (RMSEA) is ≤ .06, and the Standardised Root Mean Square Residual (SRMR) is < .08.

Results

In total, 453 individuals were enrolled in the study, 432 of whom provided complete data and were therefore included in the final sample. Participants ranged in age from 60 to 95 years (M = 70.31 years, SD = 6.02) and 44% were male. Table 1 presents descriptive statistics for scores obtained by participants on the continuous variables under investigation.

Correlational analyses (see Table 1) revealed several demographic (age, gender, SES), health (BMI, waist girth, self-rated health, ~~number of diagnosed diseases~~health status), lifestyle (smoking status, weekly alcohol consumption), psychological (quality of life, personal growth, purpose in life, depressive symptomatology), and environmental (walkability) variables to be significantly associated with MVPA. ~~Two~~Correlations were small to moderate in size and negative in direction with the exception of SES, weekly alcohol consumption, quality of life, personal growth, purpose in life, and walkability. Three significant associations were identified between the distal environmental variables and the proximal health, lifestyle, and psychological variables (walkability to ~~total number of diseases;~~health status (negative association), POS density to alcohol consumption (positive association), and BMI~~).~~ (positive association)).

Insert Table 1 about here

Significant associations were combined into a multivariate mediational model. Given the strong correlation between waist girth and BMI, a covariance pathway was specified between these two variables. ~~The resulting~~Prior to testing the model, the data were assessed to ensure the assumptions pertaining to path analysis were met. The specified relationships were linear in nature and the model was non-recursive. Although three of the continuous variables (MVPA, weekly alcohol consumption, BMI) were found to be moderately kurtotic, results obtained from an analysis in which the MLR estimator was specified in M*Plus* did not substantially differ from those obtained from an analysis in which the ML estimator was specified. As such, results have been presented for the latter (ML) analysis. A post-hoc power calculation revealed that the analysis was adequately powered (power = 1.0).

The tested model was a poor fit to the data (χ^2 (47) = 474.38, p < .001; CFI = 0.52, TLI = .45, SRMR = .09, RMSEA = .15, 90% CI for RMSEA = .14, .16), although it accounted for 22% of the variance in MVPA.

Standardized parameter estimates are presented in Figure 1. Age, gender, self-rated health, waist girth, ~~total number of diseases~~health status, smoking status, and depressive symptoms were uniquely associated with MVPA. POS suburb percentage was significantly associated with alcohol consumption, and walkability was significantly associated with ~~number of diagnosed diseases.~~health status. A test of indirect effects did not reveal the presence of any significant indirect (i.e., mediating) pathways. Results from the moderation analyses assessing possible interactions between each variable and age, gender, and SES did not emerge as significant.

Insert Figure 1 about here

Discussion

To counteract the personal and societal impacts of rapid population aging, urgent measures are required to promote healthy aging (World Health Organisation, 2015). By "compressing morbidity" and reducing disability, physical activity can improve quality of life and contribute significantly to healthy aging (Bauman et al., 2016; Crimmins, 2015). The development of effective interventions to increase physical activity levels among older people is therefore critical (Bauman et al., 2012), but requires a comprehensive knowledge of the factors influencing physical activity participation among members of this group.

Ecological models of physical activity suggest that aspects of the physical environment are likely to have both direct effects on physical activity and indirect effects via influence on other factors (e.g., psychological and biological characteristics). This study assessed these relationships in the context of older Australians to identify potential areas of focus for future physical activity promotion interventions. Contrary to expectations, an ecologically-framed mediated model found no significant effects of the included physical environment characteristics on MVPA, either directly or indirectly. However, certain individual-level factors were directly associated with MVPA, suggesting that factors other than the environment play a more influential role in influencing physical activity participation in older adults in this particular geographical context.

Previous research examining the relationship between physical activity participation and external environment attributes such as walkability and park access has shown mixed results. Some studies have demonstrated a positive association between accelerometer-derived MVPA among older people and these attributes (Carlson et al., 2012; Gong et al., 2014; King et al., 2011; Michael et al., 2010), while others have not (Chudyk et al., 2017; Gómez et al., 2010; Kerr et al., 2014; Thornton et al., 2016). The non-significant effect of these environmental variables on MVPA in the present study may be at least partly explained by the relatively limited variation in these factors (Van Cauwenberg et al., 2011). Perth is a highly liveable city with a largely stable, temperate climate (Badland, Christian, Giles-Corti, & Knuiman, 2011). Previous studies conducted in Perth have also reported non-significant associations between physical activity and built environmental attributes (Giles-Corti & Donovan, 2002), and physical activity and weather (Badland et al., 2011). In addition, physical activity is a broad construct encompassing various domains, including occupational, household, transportation-related, and leisure time physical activity (Sallis et al., 2006). It is possible that each domain could be related to different (or combinations of) environmental characteristics (Kerr, Rosenberg, & Frank, 2012), which could not be ascertained in the tested model.

The outcome that waist ~~circumference~~girth but not BMI was related to MVPA contributes to discussions on the relative usefulness of these two measures. Previous cross-sectional studies using BMI as a surrogate measure for obesity/overweight have identified an inverse relation with physical activity (Arnardottir et al., 2012; Davis et al., 2011; King et al., 2011). However, a systematic review of longitudinal studies involving older adults found the evidence regarding the association between physical activity and obesity/overweight as measured by BMI to be inconclusive (Koeneman, Verheijden, Chinapaw, & Hopman-Rock, 2011). Although few studies have examined the relationship between waist ~~circumference~~girth and physical activity in older adults, the available results consistently indicate a negative association between these two variables (Batsis, Zbehlik, Barre, Mackenzie, & Bartels, 2014; Jefferis et al., 2014; Nilsson, Wåhlin-Larsson, & Kadi, 2017). Due to the age-related changes in body composition and decreases in height from compression of vertebral bodies, BMI may not be the ideal anthropometric measure in older adults (Villareal & Shah, 2015; Zamboni et al., 2005). Waist ~~circumference~~girth, which is highly correlated to visceral adiposity and is closely linked to various medical pathologies such as insulin resistance, cardiovascular diseases, and certain cancers (Bigaard et al., 2003; Janssen, Katzmarzyk, & Ross, 2004), has been proposed to be relatively more important in older adults (Zamboni et al., 2005). This may go some way towards explaining the greater explanatory power of waist ~~circumference~~girth in the present study.

~~Objectively and subjectively assessed~~

Self-rated health, health status, and the presence of depressive symptomatology were negatively related to the amount of time spent in MVPA in the present study. Poor physical and mental health have previously been identified as a barrier to physical activity engagement in both quantitative and qualitative studies with older adults (Baert et al., 2011; Bauman et al., 2012; Burton et al., 2017; Pettigrew et al., 2017). However, well-designed physical activity interventions have been shown to improve health outcomes such as functional ability (Liu & Latham, 2011), cardio-metabolic health (Sagar et al., 2015; Yang, Scott, Mao, Tang, & Farmer, 2014), pain associated with osteoarthritis (Fransen, McConnell, Hernandez-Molina, & Reichenbach, 2014), depression (Singh et al., 2005), and cognitive function (Gates, Singh, Sachdev, & Valenzuela, 2013). Given these potential health benefits for older people in poorer health, appropriate exercise programs catering to older adults with limitations should be made available and promoted to older people across a range of health status levels (Bauman et al., 2016).

Consistent with previous work with this age group, current smoking was also negatively associated with MVPA in the final model (Hansen, Ommundsen, Holme, Kolle, & Anderssen, 2014; Shimada, Lord, Yoshida, Kim, & Suzuki, 2007). A possible explanation could be that reduced physical capacities among smokers, especially with regard to pulmonary function (Willemse, Postma, Timens, & ten Hacken, 2004), may negatively affect the ability to engage in MVPA.

Study Implications

The tested mediated model using an ecological approach did not demonstrate a good fit to the data, indicating that factors other than the physical environment primarily influence older people's physical activity levels in this particular geographic context. Instead, the results highlight the importance of specific individual-level variables that could be the focus of future intervention efforts to increase physical activity among older people. Of the five variables found to be directly associated with physical activity, two (~~objective and~~ subjective health and health status) are somewhat difficult to modify. The other three (waist ~~circumference~~girth, smoking, and depressive symptoms) are more intermediary factors that could be potentially modifiable through interventions and could therefore constitute particular areas of focus.

In terms of waist ~~circumference~~girth, a combination of moderate caloric restriction and exercise has been recommended for weight loss in older adults to prevent the loss of bone density and skeletal muscle mass that occurs when only caloric restriction is instituted (Locher et al., 2016; Villareal & Shah, 2015; Waters, Ward, & Villareal, 2013). This combined approach has been found to be successful in achieving weight loss and improving physical function, cardiovascular, and metabolic outcomes in older adults (Beavers et al., 2014; Waters et al., 2013). The results of the present study indicate that including a focus on physical activity in weight loss programs has the potential to directly increase MVPA through the prescription of physical activity as a treatment and indirectly by facilitating the higher levels of activity that may ultimately result from reduced waist ~~circumference.~~girth. In addition, weight loss (and smoking cessation) are likely to improve both objective and subjective health, further increasing the likelihood of increased MVPA in the future.

Population-level data show lower smoking cessation rates among older smokers compared to younger age groups (Centers for Disease Control and Prevention, 2011). However, interventions that include or specifically target older adults have demonstrated comparable or higher quitting rates among this age group compared to outcomes for younger smokers (Doolan & Froelicher, 2008). In particular, individual-level interventions that include a combination of behavioural counselling and smoking cessation medication have been shown to be effective in achieving favourable outcomes in older adults (Chen & Wu, 2015; Zbikowski, Magnusson, Pockey, Tindle, & Weaver, 2012). Older people are more likely than younger people to be in regular contact with health care providers, which provides an opportunity to identify smokers and offer efficacious smoking cessation counselling and medications (Doolan & Froelicher, 2008). Smoking cessation improves lung function (Willemse et al., 2004), which in turn is likely to increase the ability to engage in physical activity.

With regard to depression, awareness programs could be implemented to inform both professional and lay audiences that depressive symptoms are not a normal part of aging, potentially facilitating early diagnosis and the provision of adequate treatment (Fiske, Wetherell, & Gatz, 2009). In addition, physical exercise interventions have been demonstrated to be efficacious in the treatment of depressive symptoms in older adults (Blake, Mo, Malik, & Thomas, 2009). The findings of the present study indicate that prescribing physical activity for the treatment of depression among older people may not only increase MVPA directly but may also contribute to physical activity participation by reducing depressive symptoms.

Finally, given the challenges associated with encouraging behavioural change in older adults who have long-established lifestyle habits, comprehensive approaches to ensuring that older members of society are physically active should include a lifespan focus that is prevention-oriented rather than merely attempting to induce behavioural change in later life (Ekelund, 2014; Kuh, Richards, Cooper, Hardy, & Ben-Shlomo, 2014). As such, policies at the population level that aim to discourage smoking initiation, encourage maintaining optimum weight, and promote positive mental health at all life stages may have the added benefit of enabling higher levels of physical activity engagement with advancing age.

Limitations and ~~strengths~~Strengths

A primary limitation of the present study was its cross-sectional design, which precludes inferences of causality. Longitudinal research is required to test the causal pathways identified in this study to derive a more complete picture of the determinants of physical activity among older people. A further limitation is that domain-specific physical activity was not examined, which might have obscured the relationships between the assessed variables. For example, previous research has shown proximity to parks and recreational facilities to be associated with recreational physical activity (Sugiyama, Francis, Middleton, Owen, & Giles-Corti, 2010) and walkability to be associated with more utilitarian forms of physical activity such as transport-related walking (Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; King et al., 2011). Future research should therefore examine various domains of physical activity to identify any relationships that occur at that level. Measures of the perceived physical environment would be a further useful inclusion given that factors such as perceived safety and aesthetics can influence participation in physical activity (Barnett et al., 2017). Future studies could thus expand on the contribution of the present work by including both perceived and objective measures of environmental attributes. Finally, other social factors that have been shown to influence physical activity in older adults, such as social engagement and the presence of a variety of social networks (Franke, Tong, Ashe, McKay, & Sims-Gould, 2013; Litwin, 2012), were not assessed. Future research should therefore also include these additional social factors to provide a more complete assessment of the relevance of the social context within an ecological framework.

A key strength of the study was that an ecological approach was used to concurrently examine the influence of multiple levels of factors on physical activity, and a wide range of moderators and mediators was tested. In addition, physical activity was measured objectively, thus reducing the potential for recall bias (Tudor-Locke & Myers, 2001). This is particularly relevant for older people given increasing incidence of cognitive decline with age (Barnett, van den Hoek, Barnett, & Cerin, 2016). While the poor model fit indicates that caution should be exercised when interpreting the findings, the large proportion of variance explained by the model suggests that the results provide useful information for those tasked with improving physical activity levels among older people.

Conclusion

The findings of the present study are that individual-level factors may be more influential than social and environmental factors in determining physical activity participation among older adults in locations such as Australia that have generally conducive environments and ambient conditions. It appears to be especially important to address specific individual-level factors when formulating policies and designing future interventions to increase physical activity in ~~seniors~~older people, namely waist ~~circumference~~girth, tobacco use, and depression. Promoting weight loss and smoking cessation and facilitating early recognition and treatment of depressive symptoms may thus have multiple benefits by enhancing health in their own right while also increasing the likelihood of physical activity participation among members of this age group.

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Table 1: *Correlations between variables*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	M (*SD*)[a]
1. Age	-	-.14**	-.03	-.14**	-.11*	-.05	.14**	-.09	.01	.02	-.06	-.05	-.04	.02	.05	-.05	-.07	-.17***	.02	-.02	70.31 (6.02)
2. Gender		-	-.06	.00	.06	-.37***	.08	.00	-.27***	.03	.08	-.04	.09	.03	.05	-.04	-.08	-.16***	.01	.04	N/A
3. SES			-	-.06	-.11*	-.07	-.15**	-.04	.05	.15**	.10*	.08	-.12*	.07	.04	.12*	.21***	.10*	.05	.01	1041.06 (46.62)
4. BMI				-	.38***	.83***	.25***	.01	-.06	-.28***	-.13**	-.16***	.18***	-.11*	-.09	.11*	-.07	-.23***	-.02	-.14**	27.85 (5.31)
5. SRH					-	.33***	.32***	.15**	-.10*	-.56***	-.22***	-.35***	.35***	-.25***	-.39***	.03	-.07	-.27***	-.05	-.02	2.18 (0.76)
6. Waist girth						-	.22***	.03	.06	-.26***	-.15**	-.14**	.10*	-.08	-.11*	.09	-.03	-.18***	.01	-.15**	95.82 (13.64)
7. Health status							-	.06	-.02	-.25***	-.17***	-.17***	.18***	-.09	-.10*	.03	-.12**	-.27***	.02	.00	2.52 (1.61)
8. Current smoker								-	-.01	-.19***	-.08	-.10*	.10*	.00	-.08	-.01	.07	-.13***	.03	-.03	N/A
9. Drinks per week									-	.00	-.10*	-.02	-.06	.00	-.04	.19***	-.01	.13**	.03	-.06	4.66 (6.51)
10. QOL										-	.29***	.47***	-.47***	.35***	.50***	-.03	.08	.17***	.00	-.07	77.97 (12.90)
11. Personal											-	.64***	-.36***	.36***	.44***	.04	.01	.10*	.01	-.06	68.54

growth																					(9.99)
12. Purpose in life												-	-.59***	.50***	.61***	.04	.01	.11*	-.01	-.07	65.56 (11.66)
13. Depression													-	-.44***	-.65***	-.04	.02	-.17***	.04	.08	8.90 (7.70)
14. Social support														-	.55***	-.07	-.05	-.05	-.04	-.04	78.52 (10.10)
15. PWB															-	-.05	-.04	.01	.06	-.05	54.30 (8.15)
16. POS																-	-.25***	.07	.03	-.12*	17.09 (12.94)
17. Walk score																	-	.13**	-.05	.04	51.65 (15.05)
18. MVPA																		-	-.03	-.07	212.12 (177.28)
19. Seasons																			-	-.06	N/A
20. COB																				-	N/A

Note. SES = socioeconomic status; BMI = body mass index; SRH = self-rated health; QOL = quality of life; PWB = psychological well-being; POS = public open spaces; MVPA = moderate-to-vigorous physical activity; COB = Country of birth. Gender: 1 = male, 2 = female.

[a]Means and standard deviations are provided only for continuous variables

*p < 0.05, **p < 0.01, ***p < 0.001

Table 1: *Correlations between variables*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	M (*SD*)[a]
1. Age	-	-.14**	-.03	-.14**	-.11*	-.05	.14**	-.09	.01	.02	-.06	-.05	-.04	.02	.05	-.05	-.07	-.17***	.02	-.02	70.31 (6.02)
2. Gender		-	-.06	.00	.06	-.37***	.08	.00	-.27***	.03	.08	-.04	.09	.03	.05	-.04	-.08	-.16***	.01	.04	N/A
3. SES			-	-.06	-.11*	-.07	-.15**	-.04	.05	.15**	.10*	.08	-.12*	.07	.04	.12*	.21***	.10*	.05	.01	1041.06 (46.62)
4. BMI				-	.38***	.83***	.25***	.01	-.06	-.28***	-.13**	-.16***	.18***	-.11*	-.09	.11*	-.07	-.23***	-.02	-.14**	27.85 (5.31)
5. SRH					-	.33***	.32***	.15**	-.10*	-.56***	-.22***	-.35***	.35***	-.25***	-.39***	.03	-.07	-.27***	-.05	-.02	2.18 (0.76)
6. Waist girth						-	.22***	.03	.06	-.26***	-.15**	-.14**	.10*	-.08	-.11*	.09	-.03	-.18***	.01	-.15**	95.82 (13.64)
7. ~~Total disease~~Health status							-	.06	-.02	-.25***	-.17***	-.17***	.18***	-.09	-.10*	.03	-.12**	-.27***	.02	.00	2.52 (1.61)
8. Current smoker								-	-.01	-.19***	-.08	-.10*	.10*	.00	-.08	-.01	.07	-.13***	.03	-.03	N/A
9. Drinks									-	.00	-.10*	-.02	-.06	.00	-.04	.19***	-.01	.13**	.03	-.06	4.66

per week																					(6.51)
10. QOL										-	.29***	.47***	-.47***	.35***	.50***	-.03	.08	.17***	.00	-.07	77.97 (12.90)
11. Personal growth											-	.64***	-.36***	.36***	.44***	.04	.01	.10*	.01	-.06	68.54 (9.99)
12. Purpose in life												-	-.59***	.50***	.61***	.04	.01	.11*	-.01	-.07	65.56 (11.66)
13. Depression													-	-.44***	-.65***	-.04	.02	-.17***	.04	.08	8.90 (7.70)
14. Social support														-	.55***	-.07	-.05	-.05	-.04	-.04	78.52 (10.10)
15. PWB															-	-.05	-.04	.01	.06	-.05	54.30 (8.15)
16. POS																-	-.25***	.07	.03	-.12*	17.09 (12.94)
17. Walk score																	-	.13**	-.05	.04	51.65 (15.05)
18. MVPA																		-	-.03	-.07	212.12 (177.28)
19. Seasons																			-	-.06	N/A
20. COB																				-	N/A

Note. SES = socioeconomic status; BMI = body mass index; SRH = self-rated health; QOL = quality of life; PWB = psychological well-being; POS = public open spaces; MVPA = moderate-to-vigorous physical activity.; COB = Country of birth. Gender: 1 = male, 2 = female.

[a]Means and standard deviations are provided only for continuous variables

*p < 0.05, **p < 0.01, ***p < 0.001

1

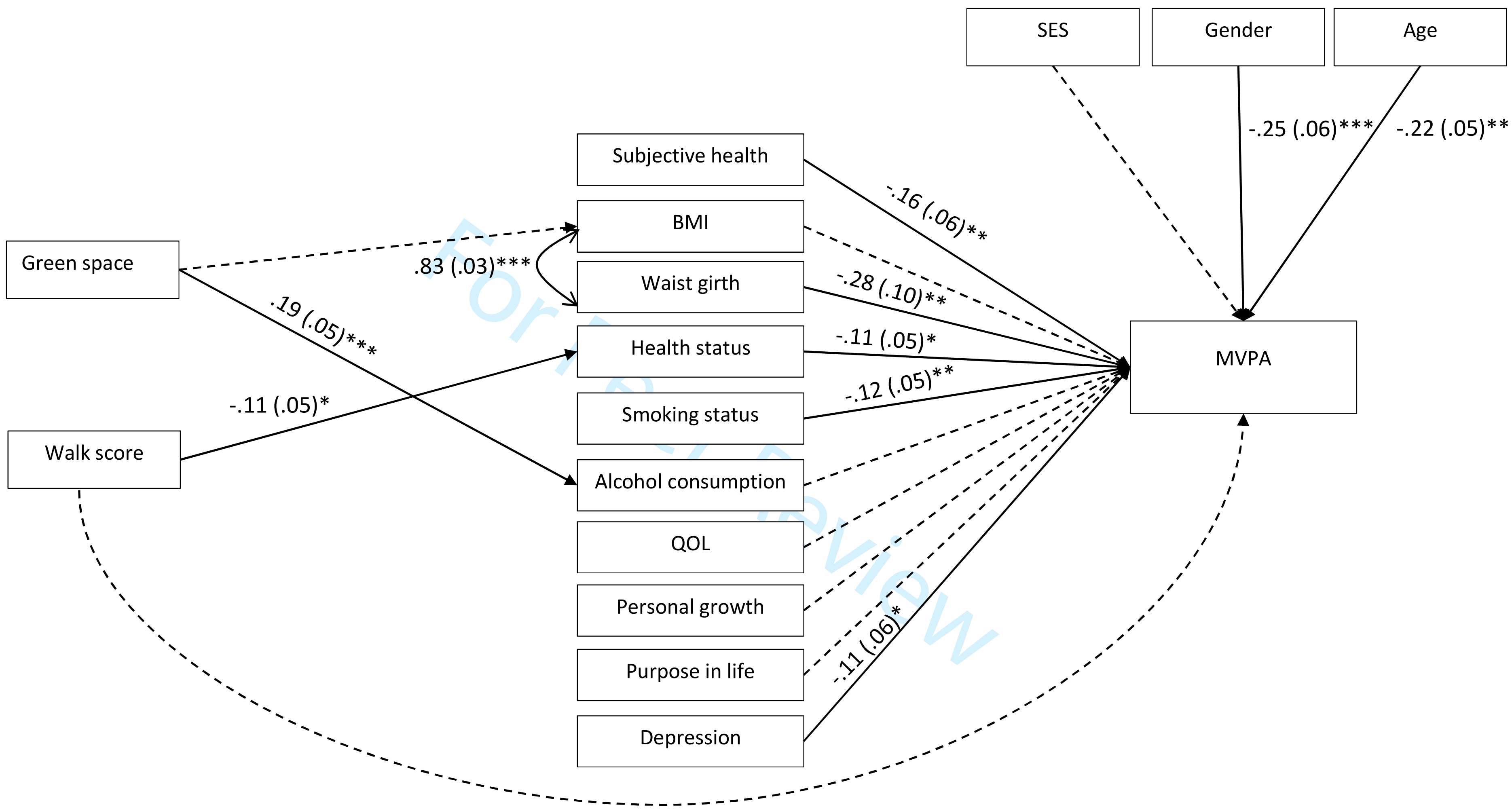
SES
Gender
Age
-.25 (.06)***
-.22 (.05)***
Subjective health
BMI
Waist girth
Health status
Smoking status
Alcohol consumption
QOL
Personal growth
Purpose in life
Depression
Green space
Walk score
MVPA
.83 (.03)***
.19 (.05)***
-.11 (.05)*
-.16 (.06)**
-.28 (.10)**
-.11 (.05)*
-.12 (.05)**
-.11 (.06)*

Figure 1. Standardized parameter estimates and standard errors for the tested ecological model. Solid lines depict significant paths. Broken lines depict non-significant paths (estimates not shown). *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.