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Cognitive resources moderate the adverse impact of poor perceived neighborhood conditions on self-reported physical activity

Boris Cheval[1,2*], Amanda L. Rebar[3], Matthew W. Miller[4,5], Stefan Sieber[6], Dan Orsholits[6], Gergo Baranyi[7], Delphine Courvoisier[8], Stéphane Cullati[8,9], David Sander[1,2], Aïna Chalabaev[10], Matthieu P. Boisgontier[11*]

[1] Swiss Center for Affective Sciences, University of Geneva, Geneva, Switzerland. [2] Laboratory for the Study of Emotion Elicitation and Expression (E3Lab), Department of Psychology, University of Geneva, Geneva, Switzerland. [3] Physical Activity Research Group, School of Health, Medical and Applied Sciences, Central Queensland University, Rockhampton, QLD, Australia. [4] School of Kinesiology, Auburn University, USA. [5] Center for Neuroscience, Auburn University, USA. [6] Swiss NCCR "LIVES – Overcoming Vulnerability: Life Course Perspectives", University of Geneva, Switzerland. [7] Center for Research on Environment Society and Health, School of GeoSciences, University of Edinburgh, Edinburgh, United Kingdom. [8] Department of General Internal Medicine, Rehabilitation and Geriatrics, University of Geneva, Switzerland. [9] Institute of Sociological Research, University of Geneva, Switzerland. [10] SENS laboratory, University Grenoble Alpes, Grenoble, France. [11] Department of Physical Therapy, University of British Columba, Canada. *Corresponding authors: Campus, Biotech, Chemin des mines 9, 1202, Genève, Switzerland; boris.cheval@unige.ch; @ChevalBoris (B. Cheval). Faculty of Medicine, 212-2177 Wesbrook Mall, Vancouver, British Columbia V6T 1Z3, Canada; matthieu.boisgontier@ubc.ca; @MattBoisgontier (M.P. Boisgontier).

Abstract

Poor neighborhood conditions are associated with lower levels of physical activity in older age, but socio-ecological models put forth that physical activity is dependent on both environmental and individual factors. Older adults' abilities to overcome environmental physical activity barriers may partially rely on cognitive resources. However, evidence on the moderating role of these cognitive resources in environmental barrier and physical activity behavior associations is still lacking. We analyzed cross-national and longitudinal data on 28,876 adults aged 50 to 96 years in SHARE survey. Lack of access to local services and neighborhood nuisances were used as indicators of poor neighborhood conditions. Delayed recall, verbal fluency, and time orientation were used as indicators of cognitive resources. Confounder-adjusted linear mixed models were conducted to test associations between neighborhood conditions and self-reported physical activity, as well as the moderating role of the cognitive resources. We found that poor neighborhood conditions, especially low access to local services, were associated with less frequent engagement in physical activity and with a steeper decline of engagement in physical activity across aging. Moreover, cognitive resources robustly reduced the adverse influence of poor neighborhood conditions on physical activity. These findings suggest that cognitive resources can temper the detrimental effect of poor neighborhood conditions on physical activity. Public policies should target both individual and environmental factors to tackle the current pandemic of physical inactivity more comprehensively.

Keywords. Neighborhood; physical activity; cognitive resources; aging

Introduction

For more than 50 years, it has been recognized that engagement in physical activity, and its health benefits are dependent on both individual and contextual factors (Bronfenbrenner, 1979, 1986). Socio-ecological frameworks posit that physical activity is the result of individuals anticipating and reacting to contextual factors that surround them (Sallis et al., 2015; Sniehotta et al., 2017). For example, individuals' decision whether to cycle or drive to their local stores highly depends on the proximity of shops to their home, and the perceived pleasantness and safety of the neighborhood. There is a strong body of evidence supporting the facet of socio-ecological frameworks linking the level of physical with environmental factors. Two systematic reviews and one meta-analysis showed that individuals surrounded by safe areas with well-maintained facilities with public spaces for walking, cycling, and other physical activities are more likely to be physically active than individuals living in a neighborhood without such facilities and spaces (Chastin et al., 2015; Rees-Punia et al., 2018; Van Cauwenberg et al., 2011). However, most relevant research adopting a socio-ecological framework is cross-sectional (Piro et al., 2006; Sallis et al., 2018; Smith et al., 2019; Van Cauwenberg et al., 2014), with only a handful set of longitudinal studies available (Lee et al., 2009; Li et al., 2005; Michael et al., 2010; Xiao et al., 2018). To effectively test socio-ecological models, large-scale longitudinal evidence is needed (Rebar and Rhodes, 2019).

Furthermore, the premise of socio-ecological frameworks that physical activity is the consequence of a complex and time-dependent interaction between environmental and individual factors has rarely been tested (Ding and Gebel, 2012). Multiple individual-level variables, such as cognitive resources, could moderate the adverse effect of poor neighborhood conditions on engagement in physical activity (Carlson et al., 2012; Ding and Gebel, 2012; Van Holle et al., 2015). This hypothesis is consistent with recent theoretical (B Cheval et al., 2018b), neurobehavioral (B Cheval et al., 2018c), and epidemiological findings (B Cheval et al., 2018a) showing that cognitive resources are critical in counteracting an automatic attraction to effort minimization, in turn facilitating engagement in physical activity. The neurobehavioral study revealed that avoiding stimuli depicting sedentary behaviors (vs. physical activity) was associated with higher cortical activity in the frontal lobe of the brain (B Cheval et al., 2018c). Crucially, this activity was associated with inhibitory control and conflict monitoring, which may be required when neighborhood conditions encourage individuals to be physically inactive. The epidemiological study involving 105,206 individuals showed that cognitive resources explained the overall level of engagement in physical activity and its age-related decline (B Cheval et al., 2018a). However, whether cognitive resources moderate the effect of neighborhood conditions on physical activity is still unknown (Figure 1).

This study aimed to investigate, for the first time, whether cognitive resources moderate the impact of neighborhood conditions on engagement in physical activity and its trajectory across aging. In line with the socio-ecological model (Sallis et al., 2015; Sniehotta et al., 2017) and the theory of energetic cost minimization (B Cheval et al., 2018b), we hypothesized that poor neighborhood conditions are associated with lower engagement in physical activity (H1a) and faster decline of this engagement across aging (H1b). We also hypothesized that cognitive resources would moderate these effects with weaker associations between neighborhood conditions and physical activity behavior in individuals with greater cognitive resources (H2a) and an increasing influence of these cognitive resources across aging (H2b).

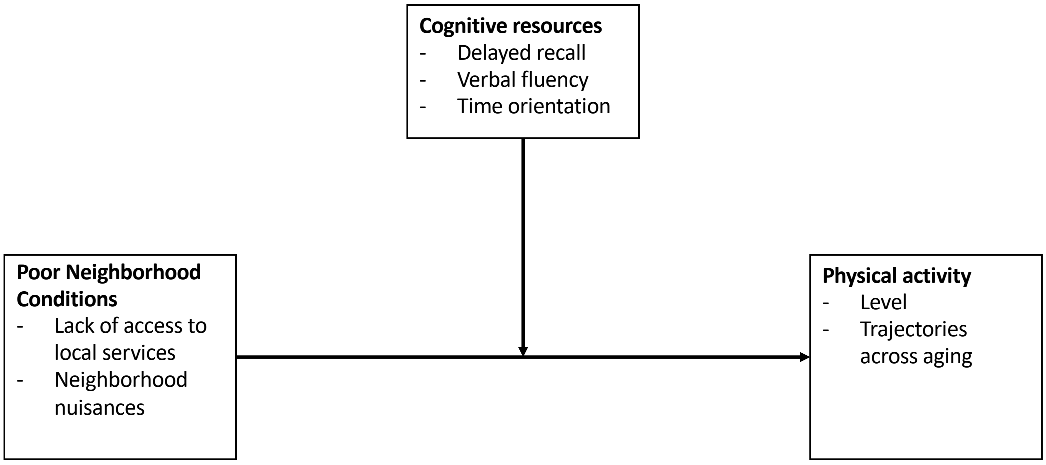

Figure 1. Diagram of the performed analyses

Methods

Study population and design

Our analyses used data from participants aged 50 years or older, who were included in the Survey of Health, Ageing and Retirement in Europe (SHARE) (Börsch-Supan et al., 2013), a dataset consisting of 6 repeated measurements performed every 2 years between 2004 and 2015. Neighborhood conditions were collected once (either on measurement 1 or 2). Physical activity and cognitive function (delayed recall, verbal fluency, and time orientation) were assessed at measurements 1, 2, 4, 5, and 6. Participants with at least one measure of physical activity and cognitive functioning were included in the study. Local ethics committees approved SHARE. All participants provided written informed consent prior to participating in the study. Supplemental materials 1 provides more details on all measures described below.

Measures

Physical activity

Physical activity was assessed using the following item: "How often do you engage in activities that require a low or moderate level of energy such as gardening, cleaning the car, or doing a walk?". Participants answered on a 4-point scale: 1, more than once a week; 2, once a week; 3, one to three times a month; 4, hardly ever, or never (Boisgontier et al., 2018; Boris Cheval et al., 2018; de Souto Barreto et al., 2017; Lindwall et al., 2011). In the models, this variable was reversed such that higher values indicated more engagement in physical activity.

Neighborhood conditions

Neighborhood conditions were assessed with four yes/no items. Two items assessed accessibility of local services ("*sufficient supply of facilities such as pharmacy, medical care, grocery and the like within reasonable distance*"; "*sufficient possibilities for public transportation*") and two items assessed neighborhood nuisances ("*pollution, noise or other environmental problems*"; "*vandalism or crime*"). For neighborhood nuisances, participants who answered "yes" to either item were categorized as living in a neighborhood with nuisances. For accessibility to local services, participants who answered "yes" to either item were categorized as living in a neighborhood with access to facilities.

Cognitive resources

Cognitive resources were measured using three indicators (delayed recall, verbal fluency, and time orientation). In the 10-word delayed recall test (Harris and Dowson, 1982), participants listened to a list of ten words that were read out loud by the interviewer. Immediately after reading the wordlist, participants were asked to recall as many words as possible. This was asked again after a delay during which the verbal fluency and numeracy tests took place. The delayed recall score is the number of words that the respondent is able to recall, which ranges from 0 to 10. In the verbal fluency test (Rosen, 1980), participants named as many different animals as they could think of in 60 seconds. The score that we used consisted of the total number of correctly named animals. In the time orientation questionnaire (Brandt et al., 1988), participants indicated the day of the month, the month, the year, and the day of the week. The score was the total number of correct answers.

Covariates

The covariates and confounders included in the statistical models were gender (male, female), education (primary, secondary, tertiary), household's ability to make ends meet (easily, fairly easily, with difficulty, with great difficulty), measurement occasions (1, 2, 4, 5, and 6), birth cohort [war (between 1914 and 1918 and between 1939 and 1945), Great Depression (between 1929 and 1938), no war and no economic crisis (before 1913, between 1919 and 1928, and after 1945)], chronic conditions (e.g., hypertension, diabetes), and country of residence (Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Ireland, Israel, Italy, Netherlands, Poland, Spain, Sweden, Switzerland). Participants' attrition [no dropout, dropout (participants who did not respond to both wave 5 and 6), death] was also controlled for.

Statistical analysis

Data were analyzed using linear mixed-effects models to account for the nested structure of the data (i.e., repeated observations within a single participant) (Boisgontier and Cheval, 2016). The models included linear and quadratic terms for age, as well as the a priori covariates and confounders as fixed effects. Age was centered at the midpoint of the sample's age range (73 years) and was then divided by 10 (for a simpler interpretation and reduced risk of model convergence issues). Thus, the coefficients yielded effects of the physical activity rate of change over a 10-year period. The models included random intercepts and slopes, allowing for variability in slope and intercept estimates at the participant level. These random effects estimated each participant's engagement in physical activity and the rate of change of this engagement over time.

Model 1a tested the association between neighborhood conditions and engagement in physical activity. Interaction terms between neighborhood conditions and linear and quadratic age were included in Model 1b to test whether neighborhood conditions moderated the trajectory of physical activity over age. A statistically significant interaction indicated that the evolution of physical activity across age was dependent on the neighborhood characteristics.

Model 2a tested whether cognitive resources moderated the association between neighborhood conditions and engagement in physical activity. Interaction terms (i.e., three-way interactions) between neighborhood characteristics, cognitive resources, and linear and quadratic age were included in Model 2b to test whether cognitive resources moderated the influence of neighborhood conditions on the trajectory of physical activity across aging. The models were fitted with one indicator of cognitive resources at a time but were also fitted in a fully-adjusted model that included the three indicators of cognitive resources. Statistical analyses were performed using the lme4 and lmerTest packages of the R language (Bates et al., 2015; Kuznetsova, 2016; R Core Team, 2017).

Four sensitivity analyses were performed: 1) including additional covariates likely to influence both cognitive resources and physical activity: partner status (i.e., living with a partner vs. living alone), smoking behavior (i.e., pack-year smoking), body mass index, depression and self-rated health; 2) excluding participants with dementia; 3) excluding participants who died during the survey; 4) excluding participants who dropped out during the survey. Supplemental materials 1 provides more details on the covariates used in the sensitivity and main analyses.

Results

Table S1 reports participants' characteristics as a function of their baseline engagement in physical activity. To improve the clarity of this table participants were classified as physically active (scored 1 or 2) or inactive (scored 3 or 4). The final sample included 28,876 participants living in 15 European countries. Physically active participants showed better delayed recall, time orientation and verbal fluency, higher education, were younger, and were less likely to be a woman, to have 2 or more chronic conditions, and to drop out or die during the survey than physically inactive participants.

Neighborhood conditions and physical activity

Table S2 presents the models used to examine the engagement in physical activity as a function of neighborhood conditions and its trajectory across aging.

In Model 1a, lack of access to local services, but not neighborhood nuisances, was negatively associated with engagement in physical activity. In Model 1b, lack of access to local services was also associated with steeper linear and quadratic decrease of physical activity across aging. In this model, both neighborhood nuisances and lack of access to local services were negatively associated with level of physical activity, thereby suggesting that at 73 years (intercept), neighborhood nuisances are also significantly associated with lower engagement in physical activity. Yet, consistent, with Model 1a, the effect size was larger for lack of access [-0.066 (SE=0.015)] than for neighborhood nuisance [-0.033 (SE=0.014)].

Cognitive resources as a moderator

Table S3 presents the models used to examine the moderating effect of cognitive resources on the association between neighborhood conditions and physical activity and its evolution across aging.

In Model 2a, delayed recall, verbal fluency, and time orientation moderated the association between lack of access to local services and the level of engagement in physical activity. The negative association between lack of access to local services and physical activity was more pronounced in participants with lower levels of verbal fluency, delayed recall, and time orientation. In addition, delayed recall and verbal fluency also moderated the association between neighborhood nuisances and engagement in physical activity: The negative association between neighborhood nuisances and physical activity was more pronounced in participants with lower levels of verbal fluency or delayed recall (Figure 2). In the fully adjusted model, delayed recall and time orientation still moderated the association between lack of access to local services and level of physical activity, and verbal fluency marginally moderated the association between neighborhood nuisances and level of physical activity.

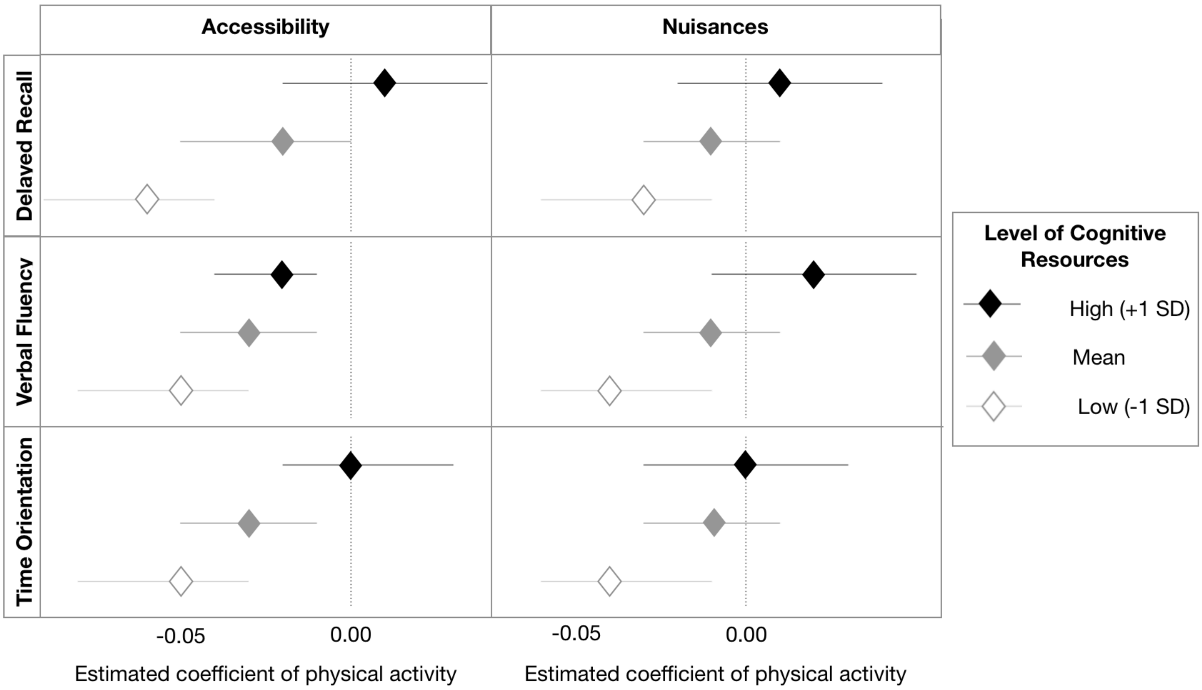

Figure 2. Associations of neighborhood conditions with the levels of physical activity at old age: The moderating role of cognitive resources Notes. Lozenge = the estimated coefficient of the effect of neighborhood conditions on engagement in physical activity depending on the level of cognitive resources. SD = standard deviation; Horizontal bars = 95% confidence interval

Model 2b testing trajectories of physical activity across aging showed that lower levels of delayed recall or verbal fluency were associated with more dramatic linear and accelerated decrease of physical activity across aging, whereas lower levels of time orientation were associated with higher linear (but not accelerated) decrease of physical activity across aging. Delayed recall did not moderate the association between neighborhood conditions and physical activity, whereas both verbal fluency and time orientation moderated the association between neighborhood nuisances and the quadratic change of physical activity across aging: The moderating effect of verbal fluency or time orientation on the association between neighborhood nuisances and physical activity was particularly pronounced as adults aged. The associations remained significant in the fully-adjusted model including the three cognitive resources.

Sensitivity analysis

Results of sensitivity analyses adjusting for additional covariates likely to influence both cognitive resources and physical activity were consistent with the main analyses. Results excluding participants who dropped out, died, or had dementia were also consistent with the main analyses (Table S4).

Discussion

Main findings

Results of this longitudinal study showed that cognitive resources robustly tempered the adverse influence of poor neighborhood conditions on engagement in physical activity. Cognitive resources also moderated the effect of neighborhood conditions on declining trajectories of physical activity across age. These effects remained significant after adjusting for multiple socioeconomic and health-related covariates.

Comparison with previous studies

Neighborhood conditions affect physical activity

As hypothesized, results showed that poor neighborhood conditions were associated with lower engagement in physical activity (H1a) and with a steeper and accelerated decline of this engagement across aging (H1b). These associations were observed for the lack of access to local services and, to a lesser extent, for neighborhood nuisances (i.e., perceived pollution, crime), and were found to be robust even after accounting for potential socioeconomic (e.g., income, education) social (partnership status) and health-related covariates (smoking, body mass index, mental and physical health). These findings are consistent with the socio-ecological framework of physical activity (Sallis et al., 2015; Sniehotta et al., 2017) and previous studies showing an association between neighborhood conditions and physical activity (Chastin et al., 2015; Li et al., 2005; Michael et al., 2010; Piro et al., 2006; Rees-Punia et al., 2018; Sallis et al., 2018; Smith et al., 2019; Van Cauwenberg et al., 2011; Van Cauwenberg et al., 2014; Xiao et al., 2018). Importantly, this large-scale prospective study extends the existing evidence given that most of the previous studies were cross-sectional, of more homogenous age ranges, and did not investigate potential individual moderators of the association between neighborhood factor and physical activity (Van Cauwenberg et al., 2011; Xiao et al., 2018). Overall, our findings confirmed that older adults' physical activity – and its decline across aging – is not only influenced by individuals' factors, but also by environmental factors (Satariano and McAuley, 2003).

Cognitive resources as a moderator

Results also showed that cognitive resources reduced the adverse influence of poor neighborhood conditions on physical activity (H2a). Specifically, the adverse effect of the lack of access to local services on physical activity was more pronounced in individuals with lower levels of verbal fluency, delayed recall, or time orientation. Individuals with higher levels of verbal fluency or delayed recall seem to be buffered from the adverse effect of neighborhood nuisances on physical activity. Moreover, the moderating effect of verbal fluency and time orientation increased as adults aged (H2b), thereby suggesting cognitive resources may explain differences in the decline of engagement in physical activity. Overall, these findings are consistent with previous evidence demonstrating that cortical activity associated with inhibition and conflict monitoring in particular (B Cheval et al., 2018c) and cognitive control abilities in general (Buckley et al., 2014) are critical for the successful regulation of physical activity. These results support a recent theory (B Cheval et al., 2018b) contending that cognitive resources are required to counteract an automatic attraction to effort minimization, especially in modern societies, where opportunities to minimize energy expenditure are ubiquitous. The interaction between individual and environmental factors is also consistent with the socio-ecological models of physical activity arguing that multiple levels (i.e., from individual to environment and social policy) may work together to influence behaviors (Rhodes et al., 2018; Sallis et al., 2006).

Public health implications

Socio-ecological models put forth that effective health promotion efforts must account for both individual and environmental factors. This study provides evidence that the individual factor of cognitive resources may be worth targeting in physical activity interventions for people who face perceived barriers at the neighborhood level. Cognitive resources may be important for problem-solving in overcoming such barriers. Because cognitive resources can act to catalyze the successful self-regulation of physical activity, interventions aiming at improving cognitive resources, such as computerized cognitive training (Kueider et al., 2012) or working memory training (Harrison et al., 2013; Jaeggi et al., 2008), should be implemented more often to increase physical activity. Interventions specifically designed to improve executive functions, such as inhibitory control and conflict monitoring, seem especially promising as these functions are involved in the counteraction of an automatic attraction to effort minimization (B Cheval et al., 2018c). Moreover, as physical activity has shown to improve cognitive function (Erickson et al., 2011), engaging in regular physical activity may trigger a “virtuous circle” in which physical activity strengthens cognitive resources, which in turn increase the level of physical activity. Considering environmental factors fostering higher engagement in physical activity, such as access to recreation facilities, pedestrian infrastructure, and walkability, may particularly benefit individuals with lower cognitive resources, such as older adults, and therefore be critical in preventing the age-related decline of physical activity. Finally, a recent study showed that neighborhood characteristics may impact the effectiveness of an intervention promoting physical activity in older adults at disability risk (King et al., 2017), thereby confirming the need to consider both individual and environmental factors.

Strengths and weaknesses

The strengths of this study include the large sample size, a follow-up of 10 years with repeated measurement, which allowed examining the trajectories of physical activity over from 50 to 96 years, the use of three different indicators of cognitive resources, the use of multiple sensitivity analyses leading to the same results, and the control of multiple sociodemographic and health-related covariates. Adjusting for socioeconomic conditions was required because individuals’ socioeconomic resources represent an important predictor of physical activity (Boris Cheval et al., 2018; Kim and Cubbin, 2017) and could have therefore explained the moderating role of cognitive resources. This adjustement allows for generalizability of the study findings across heterogeneous socioeconomic backgrounds. However, there are limitations to this study which need to be addressed in future research. First, physical activity was measured using a self-report questionnaire, which may reduce the validity of the estimated levels of physical activity (Prince et al., 2008). Moreover, the item used was not designed to specifically assess physical activity in the neighborhood, such as walking to the shops. Nevertheless, focusing on physical activity that is specifically related to active movement in the neighborhood would more likely strengthens than weakens the effect of neighborhood conditions on physical activity. Second, this study assessed perceived neighborhood but not objective conditions, which are related but distinct constructs (Orstad et al., 2016). As such, the current design cannot exclude reverse causality as age, cognitive resources, or usual physical activity are also likely to influence these perceptions. However, a systematic review suggested that perceived neighborhood conditions were more strongly associated with physical activity than the objective conditions (Orstad et al., 2016). Another study even showed that the effect of objective neighborhood conditions on physical activity is mediated by the perceived ones, thereby suggesting that this subjective environment represents a more proximal predictor of physical activity than the objective one (Orstad et al., 2018). Finally, one study showed that above objective neighborhood conditions, differences in individuals’ perception may be particularly relevant to predict physical activity (Prochaska et al., 2018). To more comprehensively test socio-ecological models, perceived and objective assessments of contexts (and their interactions) are important to investigate. Third, in this study we argue that cognitive resources predict physical activity, whereas previous studies also reported a protective effect of physical activity on cognitive function (Loprinzi et al., 2017; Sofi et al., 2011), thereby suggesting a bidirectional relationship between cognitive resources and physical activity. Future studies should formally test for this potential reciprocal association.

Conclusion

Socio-ecological models emphasize the need to optimize both individual and environmental factors in physical activity promotion efforts (Sallis et al., 2015; Sniehotta et al., 2017). This study supports that claim, showing that poor neighborhood conditions are associated with lower engagement in physical activity and with a steeper decline of this engagement across aging, and that cognitive resources temper the adverse impact of these environmental conditions. Cognitive resources may be particularly relevant to target within interventions when neighborhood conditions are poor, especially as adults age. On a larger scale, this study highlights the necessity for policy-makers to organize the environment such that it provides opportunities to be active. They should promote safe and well-maintained infrastructures and provide ubiquitous, attractive, and easily accessible spaces facilitating physical activity such as walkways, stairs, and cycle paths. This general, multi-level, and multi-dimensional approach to promote an activity-friendly environment would participate to curing the pandemic of physical inactivity (Kohl et al., 2012).

Contributors

B.C and M.P.B designed the analyses. B.C. and M.P.B analyzed the data. B.C. and M.P.B drafted the manuscript. All authors critically appraised and approved the final version of the manuscript.

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Preprint agreement

All authors have read and approved this version of the manuscript for pre-print.

Competing interests

The authors declare no conflict of interests

Ethical approval

This study was part of the SHARE study, approved by the relevant research ethics committees in the participating countries, and all participants provided written informed consent.

Data sharing

This SHARE dataset is available at http://www.share-project.org/data-access.html

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