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ORIGINAL ARTICLE

Associations between psychological factors and accelerometer-measured physical activity in urban Asian adults

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Abstract

Objectives Examine the association between psychological variables and accelerometer-measured moderate-to-vigorous physical activity (MVPA) in urban Asians.

Methods A population-based cross-sectional study was conducted in Singapore. Participants wore an accelerometer for 7 days to measure physical activity (PA). Demographic, anthropometric and psychological data were also collected. Psychological variables included PA guideline knowledge, motivational profile for PA self-regulation (5 subscales), perceived barriers to PA (4 subscales) and perceived social support for PA. Regression models with adjustment for socio-demographic variables were fitted.

Results External regulation ($b = -13.03$, 95% CI -34.55; -1.50) and perceived daily life barriers ($b = -12.63$, 95% CI -24.95; -0.32) were significantly associated with fewer weekly MVPA minutes. A significant interaction between perceived social support and age ($p = 0.046$) was found. Social support was significantly negative associated with MVPA minutes in younger (< 28 years), but not in older participants.

Conclusions Considering levels of self-determination to engage in PA and perceived daily life barriers may be important for planning PA interventions in urban Asian populations. Caution is required when promoting social support for PA as it was associated with lower MVPA in younger people.

Keywords Exercise · Health behavior · Health promotion · Personal autonomy · Cognition · Movement · Self-determination

Introduction

The benefits of physical activity (PA) in terms of health and well-being are well documented. For example, PA may reduce the risk of non-communicable diseases (NCDs) such as cardiovascular disease, type 2 diabetes and dementia (Lear et al. 2017; Reiner et al. 2013; Sallis et al. 2016). In addition, being active has been linked to

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improvements in mental health including the reduction of the likelihood for developing depression (White et al. 2017) and an up to 70% risk reduction for all-cause mortality (Lee et al. 2018). As such, the World Health Organization recommends that adults should accumulate 150 min of moderate-to-vigorous physical activity (MVPA) in bouts of at least 10 min per week (World Health Organization 2010).

To develop effective PA interventions, factors that impact activity levels need to be identified (Bauman et al. 2012; Lakerveld et al. 2014). Empirical and theoretical evidence highlights the great importance of psychological factors such as cognitions and attitudes as these are proposed to directly impact PA behavior (even if there is a supportive environment, the individual still needs to be motivated to make a change) (Bauman et al. 2012; Cortis et al. 2017). This is especially the case for most MVPA, as it is the result of predominantly conscious decision processes that can be altered by addressing underlying psychological constructs (Hagger and Chatzisarantis 2014). For example, popular cognitive and motivational theories of behavior change commonly used in PA research highlight the importance of various psychological factors such as knowledge, motivation, perceived social support and risk perceptions (Bandura 2001; Schwarzer 2008). Taking an empirical angle, a recent umbrella systematic literature review summarized the global evidence on psychological constructs as determinants of PA and discovered that 61 distinct factors that were grouped into 10 categories have been studied (Cortis et al. 2017). From theory and empirical research, a number of factors seem to be worth studying: PA recommendation knowledge can impact actual PA behavior because it can lead individuals to initiate self-regulatory strategies to close the gap between recommended and actual activity levels (Carver and Scheier 2002; Hunter et al. 2014). PA motivational self-regulation has also been highlighted as a crucial factor. The self-determination theory suggests that higher levels of external regulation are detrimental for the (sustainable) attainment of behavior (Deci and Ryan 2010). When an individuals' primary motivation to initiate behavior rests on external rewards (e.g., earning health points, receive shopping vouchers) and pressures (e.g., being active to please someone else), the behavior itself has little personal value. As a result, the behavior is often abandoned when rewards and/or pressures are removed. More internal/intrinsic regulation, on the contrary, facilitates the initiation and maintenance of PA. Perceived PA barriers have also been put forward as important psychological factors as they are proposed to be able to block action even if people are self-determined (Cortis et al. 2017). Finally, many behavior change theories that are commonly applied in PA research suggest that social support is associated with more PA participation. The rationale is that perceived social support enhances self-efficacy and mobilizes relevant resources, which then increases the chances for PA (Bandura 2001; Schwarzer 2008).

Despite increasing research interest in psychological correlates of PA, the vast majority of studies have been carried out in Europe, North America and Australia. Limited research is available from other parts of the world, including Asia which is home to more than 60% of the global population (Carlin et al. 2017; Cortis et al. 2017). For example, in the aforementioned review, less than 3% of the more than 700 included primary studies were conducted in Asia (Cortis et al. 2017). Of these, the vast majority included only children and/or adolescents, and only two studies (one from Japan and one from Israel) investigated psychological correlates of PA in adults (Arai and Hisamichi 1998; Armon et al. 2013). These studies captured personality traits (e.g., neuroticism) which are generally difficult to change (Roberts and Mroczek 2008). In addition, PA in the two studies was measured only subjectively which is not ideal due to the known measurement errors associated with self-reported PA levels (e.g., recall bias, social desirability bias, cognitive challenge, interpretation bias) (Dyrstad et al. 2014).

Singapore is a Southeast Asian city-state which is home to three major ethnic groups of Asia: Chinese, Malays and Indians, making it an ideal location to conduct such studies on the Asian continent. The research on psychological correlates of PA in Singapore has been limited to children and youth (Hagger et al. 2005; Lee et al. 2010), and no studies on adults exist. The aim of this study was to examine the associations between selected psychological factors and accelerometer-measured MVPA in adults residing in this multi-ethnic urban Asian setting.

Methods

Data from a population-based cross-sectional study, Singapore Health 2, conducted between April 2014 and April 2015 were used for this analysis. A total of 15,000 households were randomly selected to take part in the study. One member of each household who was between 18 and 79 years old and a Singapore citizen or permanent resident was randomly selected to participate. Following an invitation letter and a screening phone call, a home-interview was conducted with eligible participants. This was followed by a health screening with a health care professional at the study center. Pregnant women, persons who were mentally severely disabled and/or ill, suffered from a stroke or another injury that lead to speech loss, and those who were bedridden or wheelchair bound were excluded.

Of the 2686 participants who took part in the overall study, those that reported no serious mobility limitations were invited to take part in the PA sub-study. Participation involved accelerometer-based measurement of PA and assessment of correlates of PA via questionnaires. A total of 895 participants agreed to take part (33.3% of the overall study population).

The study was approved by the Institutional Review Board of the National University of Singapore (NUS IRB: 13-515) and has been performed in accordance with the ethical standards set by the Declaration of Helsinki and its later amendments. Written informed consent was obtained from all participants prior to data collection.

Measures

Accelerometer-measured PA

PA was measured with the ActiGraph™ wGT3X-BT triaxial accelerometer (ActiGraph, Pensacola, Florida, USA) that was worn above the right hip using an elastic belt. Its validity has been established (Sasaki et al. 2011). The device was initialized at a sample rate of 30 Hz to monitor free-living PA. Participants were instructed to wear the accelerometer for at least seven consecutive days (excluding during contact sports and water activities) and fill in daily wear logs. An instruction sheet was provided to facilitate adequate device use.

The utilized wear time validation procedures have been described elsewhere (Chu et al. 2018). Briefly, information in the daily logs provided to participants was used. Sleep periods were removed and a non-wear algorithm applied to identify valid wear time during waking hours. Using this algorithm, data were excluded if at least 90 min of consecutive zero counts was registered. Movement artifacts leading to $\leq$ 2-min interruptions of non-wear within a 90-min non-wear interval were excluded from analysis (Choi et al. 2011). Invalid days with less than 10 h of wear time were excluded. Data from participants who provided fewer than four valid days were excluded (Hansen et al. 2014).

Based on vector magnitude, MVPA was defined as $\geq$ 2690 counts per minute using previously published cut-points (Sasaki et al. 2011). Bouts of at least 10 min in MVPA were derived and used for analysis. Accelerometer data processing and analysis were conducted using ActiLife™ (Version 6).

Socio-demographic and anthropometric variables

Socio-demographic variables included age, sex, marital status (married/not married), ethnicity (Chinese/Malay/Indian/Other), employment status (employed/unemployed) and highest level of education (below A level/A level and above). Self-reported weight and height were used to determine the body mass index (BMI). Weight and height self-reports have reasonable validity (Dahl et al. 2010). Participants' BMI was categorized based on cut-offs for Asians: < 18.5 kg/m^2 (underweight), 18.5–22.9 kg/m^2 (normal weight), 23.0–27.4 kg/m^2 (overweight), $\geq$ 27.5 kg/m^2 (obese) (WHO Expert Consultation 2004). Underweight participants were included in the normal weight category due to small numbers. We also collapsed the overweight and obese categories.

Psychological variables

Similar to previous research, knowledge of PA recommendations was assessed with one item. ("According to health experts, what is the minimum amount of moderate-intensity activity needed per week to gain health benefits?") Participants indicated their response in hours and/or minutes (Hunter et al. 2014; Knox et al. 2015). Three categories reflecting the level of recommendation knowledge were derived: correct (150 min per week), underestimation ($<$ 150 min per week), overestimation ($>$ 150 min per week) (Knox et al. 2015).

The motivational profile for PA regulation was assessed with the widely used Behavioral Regulations in Exercise Questionnaire 2 (BREQ 2). This instrument has 19 items that participants responded to using a 5-point scale from "not true for me" to "very true for me" (e.g., "I value the benefits of exercise") (Markland and Tobin 2004; Teixeira et al. 2012). BREQ 2 is based on the self-determination theory which posits that people are on a level-like continuum between complete non-self-determined and complete self-determined motivation in terms of regulating behavior. The five levels of self-determination are amotivation (Cronbach's $\alpha = 0.73$), external regulation (Cronbach's $\alpha = 0.72$), introjection (Cronbach's $\alpha = 0.69$), identification (Cronbach's $\alpha = 0.76$) and intrinsic regulation (Cronbach's $\alpha = 0.88$) with the latter levels indicating stronger self-determination (Deci and Ryan 2010).

Perceived PA barriers were measured using 20 items derived from earlier studies (Booth et al. 1997; Dishman et al. 2005; Ziebland et al. 1998). A principal axis factor analysis with oblique rotation (direct oblimin) was conducted on these items to reduce the set of items into a smaller set of factors that represent different barrier facets. Sampling adequacy was established with the Kaiser–Meyer–Olkin measure (KMO = 0.89 overall, KMO $>$ 0.83 all variables) (Hutcheson and Sofroniou 1999) indicating that the factor analysis will be appropriate to derive distinct factors. Two items did not map well on any factor as indicated by low factor loadings (0.301, 0.180), and these

were removed leading to 18 items being carried forward for analysis. Four factors were retained due to the convergence of the scree plot and Kaiser's criterion on this value. Internal consistency was adequate, and hence, items map well on the established factors: external barriers (Cronbach's $\alpha = 0.79$), daily life barriers (Cronbach's $\alpha = 0.74$), danger perceptions (Cronbach's $\alpha = 0.70$), internal barriers (Cronbach's $\alpha = 0.81$) (Tavakol and Dennick 2011). Factor loadings of the rotated solution and items of the above factors are presented in Electronic Supplementary Material 1. Scores of items that belonged to a factor were averaged to create factor composite scores which were used in our analyses. A higher score on a barrier factor indicates more perceived inhibition to be active.

A widely used, valid and reliable scale captured perceived PA social support. Participants were asked to indicate how often family or friends (a) participated with them in PA, (b) offered to do PA with them and (c) encouraged PA in the last month. A 5-point Likert scale anchored at "never" (score of 1) and "very often" (score of 5) was provided. A composite score was derived by calculating the mean of the six item responses for each participant (Sallis et al. 1987).

Statistical analysis

Only participants with complete data were included in the analyses. Descriptive analysis for demographic, anthropometric, PA and psychological variables was conducted using proportions, means and standard deviations (SD) where appropriate. Comparisons of PA and psychological variables were conducted by age group using analysis of variance (ANOVA) or x^2 test.

Linear regression models were used to examine the association between the psychological variables and weekly MVPA minutes. First, models were fitted separately for each variable as the only predictor (Model 1). Second, all psychological variables were included into the model with adjustment for age, sex, ethnicity, employment status and highest level of education as these variables were reported to be important socio-demographic covariates (Model 2) (Bauman et al. 2011, 2012; Win et al. 2015). To investigate if the effects of perceived PA barriers and perceived social support on MVPA differ by age as suggested by previous studies (Lindsay Smith et al. 2017; Moschny et al. 2011; Scarapicchia et al. 2016), interaction analyses were carried out. In the interaction analysis models that included an additional two-way interaction term between age, each barrier facet and social support variable were fitted into Model 2 resulting in five separate models with an interaction term (Model 3). For the models with significant interaction effects, the effects of the barrier and social support variable on MVPA for each age (ranging from 20 to 70) were plotted.

All continuous psychological variables were z-standardized to facilitate interpretation. A p value of < 0.05 was considered statistically significant. All analyses were carried out using IBM SPSS 24 (Armonk, NY, USA).

Results

A total of 746 participants agreed to wear the accelerometer and adhered to minimum wear time criteria (83.4% of those who were enrolled). Eight participants were excluded due to missing data on psychological measures leaving 738 participants for inclusion in the analyses. Table 1 provides the descriptive statistics of the sample characteristics in an age-stratified manner. Briefly, participants' mean age was 45.5 ± 14.5 years, and the majority of participants were ethnic Chinese (66.4%), female (58.4%), attained at least an A level education (55.1%), currently married (60.6%), employed (77.5%) and overweight or obese (58.8%).

Table 2 provides the descriptive statistics of the outcome (MVPA minutes) and psychological variables according to age. Overall, the mean time spent in MVPA was 109.5 ± 131.8 min per week. A small minority of 4.3% provided the correct amount of MVPA-based recommendations, and participants generally indicated higher levels of more self-determined forms of motivational regulation versus less self-determined forms. Daily life and internal barriers received higher scores compared to the other two barrier factors. Mean perceived social support was medium.

In terms of age, there was a trend of decreasing MVPA with increasing age ($p = 0.031$). Younger people scored higher on non-self-determined forms of motivational regulation (i.e., external regulation, introjection). In addition, external, daily life and internal barriers scores were higher in younger versus older people (all $p < 0.001$). Finally, younger people perceived more PA-related social support compared to older ones ($p < 0.001$).

Psychological correlates of total weekly minutes in MVPA

In Model 1, external regulations and danger perception were found to be significantly negative associated with weekly MVPA minutes. The adjusted analysis (Model 2) revealed that external regulation ($b = -13.03$, 95% CI -34.55; -1.50) and perceived daily life barriers ($b = -12.63$, 95% CI -24.95; -0.32) were significantly associated with less time spent in MVPA (Table 2). Specifically, when external regulation and perceived daily life barriers scores increased by one standard deviation

Table 1 Descriptive statistics of socio-demographic variables and body mass index stratified by age (Singapore 2014–2015)

Variables	Total (n = 738)	18–29 years (n = 124; 16.8%)	30–49 years (n = 317; 43.0%)	50+ years (n = 297; 40.2%)
Sex; n (%)				
Male	307 (41.6)	54 (17.6)	132 (43.0)	121 (39.4)
Female	431 (58.4)	70 (16.2)	185 (42.9)	176 (40.8)
Ethnicity; n (%)				
Chinese	490 (66.4)	68 (55.6)	201 (63.4)	220 (74.1)
Malay	120 (16.3)	37 (29.8)	43 (13.6)	40 (13.5)
Indian	101 (13.7)	18 (14.5)	52 (16.4)	31 (10.4)
Other	27 (3.7)	0 (0)	21 (6.6)	6 (2.0)
Highest educational level; n (%)				
Below A level	331 (44.9)	34 (27.4)	94 (29.7)	203 (68.4)
A level and above	407 (55.1)	90 (72.3)	223 (70.3)	94 (31.6)
Marital status; n (%)				
Currently married	447 (60.6)	9 (7.3)	241 (76.0)	197 (66.3)
Not currently married	291 (39.4)	115 (92.7)	76 (24.0)	100 (33.7)
Employment status; n (%)				
Employed	572 (77.5)	120 (96.8)	273 (86.1)	179 (60.3)
Not employed	166 (22.5)	4 (3.2)	44 (13.9)	118 (39.7)
Body mass index; n (%)				
Normal ($\leq$ 22.9 kg/m^2)	304 (41.2)	76 (61.3)	118 (37.2)	110 (37.0)
Overweight (23–27.4 kg/m^2)	294 (39.8)	29 (23.4)	140 (44.2)	125 (42.1)
Obese ($\geq$ 27.5)	140 (19.0)	19 (15.3)	59 (18.6)	62 (20.9)

(external regulation: 0.82; perceived daily life barriers: 0.89), the time spent in weekly MVPA decreased by 13.0 and 12.6 min, respectively. No other main effects were observed (Table 3).

Interaction analysis

From the interaction analyses, the interaction between perceived social support and age was significant (p = 0.046), but this was not observed for the barrier variables (external barriers: p = 0.444; daily life barriers: p = 0.807; danger perceptions: p = 0.172; internal barriers: p = 0.684).

In an additional analysis, the association between social support and weekly MVPA minutes was examined according to age. This analysis revealed that social support was negatively associated with MVPA minutes in younger age groups with a suggestion of a positive association for adults aged 53 and above (53 years: b = 0.46, 95% CI − 10.77; 11.69). For participants aged 28 years and younger, greater social support was significantly associated with fewer MVPA minutes (28 years: b = − 17.06, 95% CI − 34.07; − 0.06). See Fig. 1 and Electronic Supplementary Material 2 for more detailed information.

Discussion

From the results of this study, higher levels of externally regulated PA motivation as well as stronger perceptions of daily life PA barriers were associated with less time spent in MVPA. Additionally, the association between perceived social support for PA and MVPA changed with age. Perceived social support was associated with less MVPA in young adults, but it was associated with more MVPA in older adults.

Although the relationship between less self-determined forms of motivation and MVPA is not always consistent (Teixeira et al. 2012), our study results align with most of the available literature reporting a negative association between externally regulated PA motivation and MVPA. For example, an intervention study conducted in Singapore revealed a negative impact of promoting PA through external rewards. Participants received monetary incentives for attaining activity goals. They increased activity levels and maintained them until the rewards were removed which led to decreases in MVPA (Finkelstein et al. 2016). In contrast, the self-determination theory postulates that if the behavior itself is valuable to the individual, more sustainable behavioral patterns are likely to develop (Deci and Ryan 2010; Silva et al. 2014). However, a significant relationship between more self-determined forms of

Table 2 Physical activity and related psychological variables stratified by age (Singapore 2014–2015)

Variables	Total (n = 738)	18–29 years (n = 124; 16.8%)	30–49 years (n = 317; 43.0%)	50 + years (n = 297; 40.2%)	p value comparing age groups
Minutes in MVPA per week; mean ± SD	109.5 ± 131.8	136.6 ± 149.9	107.9 ± 135.2	99.8 ± 118.3	0.031
Psychological variables					
Knowledge of PA recommendations; *n* (%)					
Correct	32 (4.3)	4 (3.2)	15 (4.7)	13 (4.4)	0.922
Underestimation	208 (28.2)	33 (26.6)	88 (27.8)	87 (29.3)	
Overestimation	498 (67.5)	87 (70.2)	214 (67.5)	197 (66.3)	
Motivational regulation for PA; mean ± SD[a]					
Amotivation	0.56 ± 0.77	0.59 ± 0.78	0.54 ± 0.74	0.56 ± 0.82	0.862
External regulation	0.69 ± 0.82	0.86 ± 0.78	0.68 ± 0.82	0.62 ± 0.82	0.021
Introjection	1.23 ± 1.06	1.51 ± 0.92	1.24 ± 1.07	1.10 ± 1.08	0.002
Identification	2.67 ± 0.92	2.58 ± 0.81	2.70 ± 0.84	2.68 ± 1.04	0.495
Intrinsic regulation	2.55 ± 1.13	2.49 ± 1.01	2.62 ± 1.09	2.49 ± 1.22	0.343
PA barriers; mean ± SD[b]					
External barriers	1.81 ± 0.76	2.08 ± 0.74	1.82 ± 0.76	1.69 ± 0.75	< 0.001
Daily life barriers	2.48 ± 0.89	2.76 ± 0.81	2.68 ± 0.86	2.13 ± 0.86	< 0.001
Danger perceptions	1.47 ± 0.60	1.40 ± 0.45	1.45 ± 0.55	1.52 ± 0.69	0.146
Internal barriers	2.14 ± 0.90	2.36 ± 0.79	2.28 ± 0.92	1.90 ± 0.87	< 0.001
Perceived social support (score); mean ± SD[b]	2.25 ± 0.93	2.49 ± 0.77	2.37 ± 0.93	2.03 ± 0.95	< 0.001

MVPA moderate-to-vigorous physical activity, *PA* physical activity

[a]Scores from 0 to 4

[b]Scores from 1 to 5

motivational regulation and MVPA was not found in our analysis, which was surprising considering existing evidence (Teixeira et al. 2012).

There was evidence that perceived PA barriers are associated with time spent being active. However, in contrast to available research, the current study examined specific barrier facets facilitating deeper investigation into the kinds of barriers that might be associated with MVPA. Daily life barriers such as lack of time were negatively associated with MVPA minutes. Similar associations were reported in other studies that included working-age adults (Salmon et al. 2003; Ziebland et al. 1998). These results might be explained by this groups' strong work and family commitments which are energy-sapping and time-consuming. Additionally, the strong cultural emphasis on achievement in educational and professional pursuits leading many Singaporeans to work long hours (Thein et al. 2010) might explain why daily life PA barriers are particularly influential in Singapore. Promoting MVPA that can be integrated into one's daily routines might be an option. Interestingly and in contrast to previous studies, external barriers such as costs and availability of and/or access to facilities/space were not significantly associated with MVPA (Choi et al. 2017; Salmon et al. 2003). This finding might indicate that with the efforts of the government to provide easy-to-access outdoor gyms, walk ways, public swimming pools and open spaces, some commonly reported barriers have minimal impact in Singapore.

Perceived social support on its own was not significantly associated with weekly MVPA minutes. However, a significant interaction between age and social support on MVPA time was discovered. Perceived social support for PA was associated with less MVPA in people up to the age of 52 years. This association was only significant in people aged up to 28 years. Although most cross-sectional studies report a positive relationship between perceived social support and PA (Bauman et al. 2012), results from longitudinal studies are less conclusive. For example, a recent review of prospective studies found no consistent link between perceived social support and PA in healthy adults. While in some studies, perceived social support was associated with more PA, other studies reported null findings or inverse associations (Scarapicchia et al. 2016). As such, the relationship between social support and PA in the overall population is not yet fully understood.

Table 3 Linear regression analysis of psychological variables on total weekly bouted moderate-to-vigorous physical activity minutes (Singapore 2014–2015)

Predictor	Model 1			Model 2		
	Beta coeff	95% CI	*p* value	Beta coeff	95% CI	*p* value
Knowledge						
Correct	Reference			Reference		
Under-estimators	− 12.88	− 34.05; 8.29	0.233	18.20	− 31.63; 68.03	0.474
Over-estimators	12.46	7.87; − 32.79	0.239	2.76	− 45.00; 50.51	0.910
Motivational profile (standardized scores)						
Amotivation	− 3.38	− 12.92; 6.15	0.486	1.55	− 10.02; 13.13	0.792
External regulation	− 10.64	− 20.15; − 1.13	0.028*	− 13.03	− 34.55; − 1.50	0.027*
Introjected regulation	2.96	− 6.58; 12.49	0.543	9.06	− 2.89; 21.02	0.137
Identified regulation	− 2.77	− 12.30; 6.77	0.569	− 3.02	− 18.75; 12.72	0.707
Intrinsic regulation	− 1.63	− 11.17; 7.91	0.737	− 4.01	− 19.61; 11.59	0.614
Perceived barriers (standardized scores)						
External barriers	− 4.13	− 13.66; 5.40	0.395	0.21	− 11.83; 12.25	0.973
Daily life barriers	− 6.99	− 16.52; 2.53	0.150	− 12.63	− 24.95; − 0.32	0.044
Danger perceptions	− 9.76	− 19.27; − 0.25	0.044*	− 3.84	− 14.86; 7.18	0.494
Internal barriers	− 3.55	− 13.09; 5.98	0.465	2.08	− 11.55; 15.71	0.765
Social support perceptions (standardized scores)	− 2.45	− 11.99; 7.09	0.614	− 3.48	− 14.06; 7.10	0.519

Model 1: only one predictor included into the linear regression model; Model 2: all psychological predictors as well as age (continuous), sex (dichotomous), ethnicity (categorical), employment status (dichotomous) and education level (dichotomous) included into the linear regression model

*$p < 0.05$

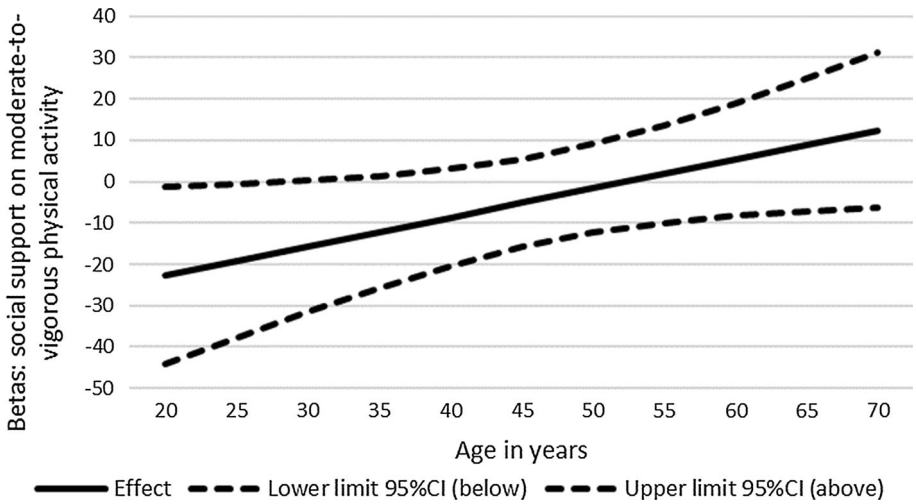

Fig. 1 Effect of social support on weekly moderate-to-vigorous physical activity minutes (Betas) at different ages (Singapore 2014–2015)

To our knowledge, no other study has reported that more perceived social support was significantly associated with less MVPA in younger people. Existing studies either find a positive or no relationship (Dowda et al. 2003). However, there is research suggesting that specific modes of social support under specific circumstances might be detrimental (Gleason et al. 2008). For example, receiving support for a behavior that is not desired (e.g., being physically active) can be perceived as prescriptive. This might be especially problematic in younger adults who generally perceive themselves as healthy and less in need to change their behaviors. As a non-confirmatory action to such negatively perceived support, they might reduce PA. Even if some behavior change is desired, there can still be a mismatch between the kind of social support received and the kind of social support needed, and this might have negative effects.

However, as data used in this study were collected in a cross-sectional fashion, it would be beneficial to conduct longitudinal research to provide stronger evidence of a causal link.

For older age groups and especially older adults, previous studies point to a positive relationship between perceived social support and PA as reported in a recent review (Lindsay Smith et al. 2017). In the current study, such an association was also observed. It was, however, not significant. This might be because the current study did not include an adequate number of older adults (only 10% were aged 65 and above), and/or older adults in the current study were generally not old enough. This study and other research show that activity levels of older adults commonly decrease as age increases due to the decline of cognitive and physical resources and a reduction of social networks (Kapteyn et al. 2018; Sun et al. 2013). Hence, with increasing age, social support might be more strongly associated with PA (Lindsay Smith et al. 2017). Alternatively, it might be that such a relationship between social support and PA in older adults does not exist when PA is measured objectively. Only four of the 25 studies included in the aforementioned review used an accelerometer or pedometer to assess PA. Results from these studies were mixed as there was no consistent pattern between perceived social support and PA (Lindsay Smith et al. 2017).

A strength of the current study is that it provides an overview of the association between important psychological factors and MVPA in an Asian population. This is an important research as it provides insights into modifiable factors that can directly impact PA behavior (Cortis et al. 2017). Also, accelerometer-measured PA data were used in this study; it is well established that objective data reflect actual levels of PA better than self-report data (Dyrstad et al. 2014; Kapteyn et al. 2018). Additionally, by using such objective data, it was possible to more reliably assess psychological MVPA correlates compared to most previous studies that reported mainly on correlates of self-reported PA (Choi et al. 2017). Despite these strengths, some limitations existed. First, only a limited number of potentially important psychological correlates of MVPA were assessed. Although we consulted the available literature to inform our choice of variables, it is possible that other important correlates were missed. This is because of the absence of relevant research on the Asian continent which prevented us from basing our study on earlier findings from Asia. Moreover, there is currently no consensus on which psychological factors are globally applicable predictors of PA. In a previous umbrella systematic literature review, the authors reported that, to date, 61 distinct psychological variables have been studied, and although some appear to be associated with PA, the evidence is inconclusive and not necessarily generalizable beyond geographic regions (Cortis et al. 2017). Second, this study only focused on MVPA, and although research suggests that the greatest health benefits can be gained through MVPA (Lee et al. 2018), recent studies highlighted that lighter PAs (e.g., walking) that are more common in daily life have various positive effects on many cardio metabolic outcomes, mortality, depression (Füzéki et al. 2017) and overall mental health (White et al. 2017). Studies that investigate the psychological correlates of light PA are hence warranted. Third, the cross-sectional design of the current study does not permit inferences about causal relationships between psychological factors and MVPA. Novel study methods such as ecological momentary assessments (EMA) to assess variation in psychological states within individuals over time could be employed to gain a more in-depth picture (Maher et al. 2016).

In sum, higher levels of external regulation and daily life barriers were associated with less MVPA. The association between social support and MVPA changed with age from negative in younger people to positive in older people. It is important to conduct further cross-sectional and longitudinal research in which both psychological and other factors that are potential determinants of PA are included. The results from these investigations can then inform strategies aimed at increasing MVPA in an effort to tackle the increasing burden of NCDs in Asian populations.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval Ethics approval for the Singapore Health 2 study was obtained from the National University of Singapore Institutional Review Board (reference number 13-515). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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