

Associations between sedentary behavior and happiness: An analysis of influential factors among middle-aged and older adults from six low- and middle-income countries

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ABSTRACT

Objectives: Higher levels of sedentary behavior (SB) may be associated with decreased happiness but there are no studies on this topic. Thus, we investigated this association, and its influential factors among middle-aged and older adults using nationally representative datasets from six low-and middle-income countries (LMICs). **Study design:** Community-based cross-sectional data from the Global Ageing and Adult Health study were analyzed. SB was assessed with the Global Physical Activity Questionnaire. Multivariable ordinal logistic regression and mediation analyses were performed. **Main outcome measures:** Happiness was assessed with a cross-culturally validated single-item question (5-point scale) with higher scores indicating higher levels of happiness. **Results:** The final sample included 34,129 adults aged ≥ 50 years (mean age = $62.4 \pm \text{SD } 16$ years; 51.9% female). After adjusting for multiple confounders, increased time spent in SB (hours/day) was associated with lower happiness levels (OR=0.96; 95%CI=0.94-0.98). Mobility limitations, cognitive complaints, pain/discomfort, sleep problems and disability explained the largest proportion of the association between SB and happiness. **Conclusions:** SB was linked with lower levels of happiness in middle-aged and older adults from LMICs, although a high level of between-country heterogeneity was observed. Longitudinal and interventional studies among older people in LMICs are warranted to assess directionality and the potential for reduction in SB to improve mental well-being in this population.

Keywords: sitting time, happiness, wellbeing, low-and-middle-income countries, mental health.

INTRODUCTION

Sedentary behavior (SB) refers to waking behaviors characterized by an energy expenditure of ≤ 1.5 METs while in a sitting or reclining posture [1]. According to accelerometer-derived measures, middle-aged and older adults spend an average of 9.4 to 12.3 hours/day in SB [2,3]. Mounting evidence indicates that prolonged SB can be hazardous to adults' physical health (e.g., increased risk for incident cardiovascular disease, type 2 diabetes and premature mortality), independently of physical activity [4]. More recently, there is burgeoning evidence that excessive time spent in SB is also linked to adults' worse mental health status, such as increased risk for depression [5]. Nonetheless, research examining the influence of SB on psychological outcomes has been predominantly illness-oriented, and the influence of SB on subjective wellbeing remains under-investigated.

Happiness can be defined as a positive affect that encompasses feelings that reflect a state of pleasurable engagement with the environment [6]. It is considered a hedonic conception of wellbeing, and together with life satisfaction (evaluative wellbeing) and sense of purpose/meaning in life (eudemonic wellbeing), comprise the three dimensions of the construct of subjective well-being [7]. Happiness is considered to be a fundamental human goal, and its promotion is included in the public health agenda worldwide [8]. Furthermore, it has been well documented that happy people are healthier and live longer [9], factors that gain more relevance with increasing age.

To date, some studies have investigated how SB relates to different components or dimensions of wellbeing but with mixed results. For instance, a relatively recent systematic review examined the relationship between SB and health-related quality of life and found that higher SB was related to worse quality of life in the physical domain but not in the mental and social quality of life domains [10]. However, this review included studies from all age-groups and different health status groups (general population and chronically ill patients)

[10]. Evidence derived from general population studies conducted in middle-aged and older adults found that higher SB is associated with lower levels of wellbeing in Taiwanese adults [11], and lower quality of life among Korean and Spanish adults in cross-sectional and prospective studies, respectively [11–13]. In contrast, two other cross-sectional UK studies found no associations between SB and measures of wellbeing [14,15].

However, the existing literature has several important limitations. First, although studies on SB and several dimensions of wellbeing exist, to our knowledge, there are no studies specifically on SB and happiness. Second, available evidence on wellbeing is derived solely from single-country studies. Thus, multi-country studies from diverse context are needed to understand whether associations are context specific. Third, in these previous studies, several potential confounding factors were not taken into account when exploring relationships between SB and wellbeing (e.g., social cohesion, sleep, disability, physical activity), and thus, the reported associations may suffer from residual confounding. Relatedly, to our knowledge, no previous study has explored the extent to which potentially influential factors may explain the association between SB and wellbeing indicators. This knowledge may be important when designing future interventions particularly for middle- and older-aged adults as this segment of the population is projected to grow rapidly in the coming years, especially in low- and middle-income countries (LMICs) [16]. Next, the majority of previous studies on SB and wellbeing were conducted in high-income countries, and the findings may not be generalizable to LMICs as these countries are characterized by different occupational, socio-cultural structures, environmental factors and modes of transport [17].

Given the above-mentioned gaps in the literature, the purpose of this study was: to (a) examine the association between SB and happiness among middle-aged and older adults

employing nationally representative datasets from six LMICs; and (b) explore factors that may explain such a relationship.

METHODS

Sample and study design

Data from the Study on Global Ageing and Adult Health (SAGE) Wave 1 were analyzed

(<http://www.who.int/healthinfo/sage/en/>). This survey was undertaken in China, Ghana,

India, Mexico, Russia, and South Africa between 2007 and 2010. Based on the World Bank classification at the time of the survey, all these countries were LMICs. Details of the survey methodology have been published elsewhere [18]. Briefly, nationally representative samples were obtained using a multistage clustered sampling design method. The sample consisted of adults aged ≥ 18 years with oversampling of participants aged ≥ 50 years. Standard translation procedures were conducted to ensure comparability between countries, and trained interviewers conducted face-to-face interviews using a standard questionnaire. The survey response rates were: China 93%; Ghana 81%; India 68%; Mexico 53%; Russia 83%; and South Africa 75%. Sampling weights were calculated to adjust for the population structure as reported by the United Nations Statistical Division. Ethical approval was obtained from the WHO Ethical Review Committee and local ethics research review boards, and written informed consent was obtained from all participants.

Sedentary behavior

Total sedentary behavior was assessed with the Global Physical Activity Questionnaire

(GPAQ) [19]. Participants were asked to report the total time they usually spent (expressed in minutes per day) sitting or reclining including at work, at home, getting to and from places, or with friends (e.g., sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television). This did not include time spent sleeping. SB was

assessed as a continuous variable (hours per day), and also as a dichotomous variable (high SB ≥ 8 hours/day vs. low SB < 8 hours/day) in some analyses based on previous literature which have found that this threshold is associated with increased risk for negative health outcomes such as chronic physical conditions, poor mental health, and premature mortality [20–22].

Happiness (outcome)

Happiness levels were assessed with a widely used and a cross-culturally validated single-item question [23] “Taking all things together, how would you say you are these days? Are you...?” with answer options very unhappy, unhappy, neither happy or unhappy, happy, and very happy (coded 0 to 4, respectively).

Potential mediators

Potential mediators in the association between SB and happiness in the current study were selected based on previous research [24]. These included current smoking, alcohol use in the past 30 days, social cohesion, depression, anxiety, obesity, disability, mobility, pain/discomfort, sleep/energy, cognition and physical activity. A social cohesion index was created based on 9 questions on the participant’s involvement in community activities in the past 12 months [25] with higher scores corresponding to higher levels of social cohesion (range 0-100) (Cronbach’s $\alpha=0.79$) (actual questions can be found in supplementary **Table S1**). Questions based on the World Mental Health Survey version of the Composite International Diagnostic Interview [26] were used for the endorsement of past 12-month DSM-IV depression. In accordance with previous publications using a dataset with the identical question, those who claimed to have severe/extreme problems with worry or anxiety in the past 30 days were considered to have anxiety [27]. Obesity was defined as body mass index (BMI) $\geq 30 \text{ kg/m}^2$ based on measured weight and height. Disability was assessed with

six questions on the level of difficulty in conducting standard basic activities of daily living in the past 30 days [28]. Those who answered severe or extreme/cannot do to any of the six questions were considered to have disability [28]. Health status in the domains of mobility, pain/discomfort, sleep/energy, and cognition were assessed by scales ranging from 0-10 with higher scores indicating worse health status (items used to assess these variables are provided in supplementary **Table S2**). These health domains correspond to those in common health related quality of life outcome measures such as the Short Form-12 (SF-12) [29], the Health Utilities Index Mark 3 (HUI) [30] and the EUROQOL 5D [31]. Moreover, these domains have been used as indicators of functional health status in prior studies utilizing the exact same survey questions [32–34]. Physical activity was categorized as low, moderate, and high based on previously established algorithms of the GPAQ, which also include algorithms for cleaning data (e.g., implausible values) [35].

Control variables

The control variables included the following sociodemographic variables: age, sex, years of education received, wealth quintiles based on country-specific income, marital status (married/cohabiting, never married, separated/divorced/widowed), unemployment (engaged in paid work ≥ 2 days in last 7 days: Y/N), and setting (rural, urban). We did not assess their influence in the association between SB and happiness as these factors are often considered to be non-modifiable.

Statistical analysis

The difference in sample characteristics by SB levels was tested by Chi-squared tests for categorical variables and Student's t-tests for continuous variables. Multivariable ordinal logistic regression analysis was conducted to assess the association between SB (hours/day) (exposure) and happiness (outcome). Four models were built to assess the influence of

various factors in the association between SB and happiness: Model 1 - adjusted for age, sex, and country; Model 2 - adjusted for factors in Model 1 and education, wealth, marital status, employment status, and setting; Model 3 - adjusted for factors in Model 2 and smoking, alcohol consumption, social cohesion, depression, anxiety, obesity, disability, mobility, pain/discomfort, sleep/energy, and cognition; Model 4 –included all prior variables and physical activity (fully adjusted model). Furthermore, an interaction term was included (i.e., sex X SB or physical activity X SB) in the fully adjusted model to assess whether the association between SB and happiness differed by sex or level of physical activity.

Next, a mediation analysis using the *kmb* (Karlson Holm Breen) command in Stata [36] was conducted to quantify the degree to which several potentially influential factors may explain the association between high SB and happiness (i.e., smoking, alcohol consumption, social cohesion, depression, anxiety, obesity, disability, mobility, pain/discomfort, sleep/energy, cognition, physical activity). Each of these variables were included in the model individually, and it was therefore possible for the sum of the mediated percentage to exceed 100%. These regression and mediation analyses were conducted for the overall sample (≥ 50 years) and by age groups (50-64, ≥ 65 years).

Furthermore, we also conducted country-wise analysis using the overall sample to assess whether the findings on the association between SB and happiness are consistent across countries by calculating the Higgins's I^2 based on estimates from each country. The Higgins's I^2 represents the degree of heterogeneity that is not explained by sampling error with a value of $<40\%$ often considered as negligible and 40-60% as moderate heterogeneity [37]. A pooled estimate was obtained by random-effect meta-analysis.

The mediation analysis and country-wise analysis controlled for age, sex, education, wealth, marital status, employment status, setting, with the median analysis also adjusting for country. Adjustment for country was done by including dummy variables for each country in

the model as in previous SAGE publications [24]. The sample weighting and the complex study design were taken into account in all analyses. Those with missing or zero probability weights were excluded from the analysis (n=207). The level of statistical significance was set at $P<0.05$ and all statistical analyses were performed with Stata 14.1 (Stata Corp LP, College station, Texas).

RESULTS

Data for 42,489 individuals aged ≥ 18 years were available. After restricting to those aged ≥ 50 years, the final sample consisted of 34,129 adults (China n=13,175; Ghana n=4,305; India n=6,560; Mexico n=2,313; Russia n=3,938; South Africa n=3,838) [mean age (SD) 62.4 (16.0) years; 51.9% female]. More than half of the sample (57.3%) was aged 50-64 years. The prevalence of high SB (i.e., ≥ 8 hrs/day) was 10.8% for the overall sample, 7.7% for those aged 50-64 years, and 15.9% for participants aged ≥ 65 years. In terms of country-wise prevalence of high SB, the figures were: 8.6% (China); 9.2% (Ghana); 8.4% (India); 5.5% (Mexico); 21.2% (Russia); and 5.1% (South Africa). In the overall sample, 4.5% reported being very happy, 51.5% happy, 35.2% neither happy or unhappy, 7.7% unhappy, and 1.1% very unhappy. More information on the sample characteristics are provided in **Table 1**. There was a decreasing trend for the prevalence of high SB with higher levels of happiness in the overall and age-stratified samples (**Figure 1**).

In the models adjusted for age, sex and country (**Table 2**, Model 1), increasing time spent in SB (hours/day) was significantly associated with lower levels of happiness in the overall sample (OR=0.93; 95%CI=0.91-0.95) and by age groups [50-64 years (OR=0.94; 95%CI=0.92-0.97); ≥ 65 years (OR=0.92; 95%CI=0.90-0.95)]. After full adjustment for several behavioral and health-related factors, the OR was attenuated, but the negative association remained significant even in the fully adjusted model (Model 4). The interaction

analysis showed that sex and physical activity are not significant effect modifiers in the association between SB and happiness.

The mediation analysis showed that among those aged 50-64 years, the largest proportion of the association between SB and happiness was explained by mobility limitations (29.9%), problems with sleep and energy (23.0%), cognitive complaints (21.7%), and pain and discomfort (17.6%) (**Table 3**). Among those aged ≥ 65 years, the most important explanatory factors were mobility limitations (51.3%), followed by cognitive complaints (34.8%), pain and discomfort (31.4%), and disability (25.9%).

The country-wise associations between SB and happiness estimated by multivariable ordinal logistic regression are shown in **Figure 2**. The overall estimate was 0.93 (95%CI=0.89-0.96) with a high level of heterogeneity ($I^2=83.0\%$).

DISCUSSION

To the authors' knowledge, this is the first multi-country study investigating the relationship between SB and wellbeing, and the first study with a specific focus on happiness. In addition, this study provides preliminary evidence on the factors that influence the SB-happiness relationship. Overall, the results showed that increasing time spent in SB is significantly associated with lower levels of happiness across middle and late adulthood. The largest proportion of the association between SB and happiness was explained by mobility limitations, pain/discomfort, cognitive complaints, problems with sleep and energy, and disability.

Present findings on the association between SB and happiness are in line with the previous single-country cross-sectional and longitudinal studies conducted in smaller samples showing significant inverse associations between self-reported SB (total or leisure-time SB) and levels of wellbeing and overall quality of life [10–12]. However, our results are in

contrast with some studies that assessed SB through device-based measures, which found no significant associations between SB and wellbeing dimensions [14,15]. Although the reasons for the discrepant results are unknown, methodological approaches in SB measurement may play a role (i.e., self-report or device-based measurement). Furthermore, the context/domain where SB occurs may be relevant when examining relationships with wellbeing, since specific domains of SB may be more detrimental than others. For instance, a prospective study in Taiwanese older adults found that more time spent in specific leisure-time SB pursuits were related to higher subsequent life satisfaction (i.e., TV watching, social chatting and reading), while other forms of leisure-time SB were not (i.e., listening to radio, playing chess/cards) [38]. Future studies should assess how the measurement of SB or SB domains may influence the association between SB and happiness.

In our study, mobility limitations explained 38.8% of the association in the overall sample, with this figure being particularly pronounced in the older age group (51.3%). It is possible that mobility limitations may make an individual more sedentary [39], but SB may also lead to declines in functional abilities and mobility limitations by, for example, directly increasing the risk of chronic disorders (e.g., type 2 diabetes and cardiovascular disease) or by increasing the risk of metabolic syndrome [40,41]. In turn, declines in functional capacity have been associated with higher risk of unhappiness in older adults [42], possibly due to low resilience [43] and restrictions of personal freedom of choice linked to disruptions in daily functioning [44].

Pain and discomfort explained between 18-31% of the SB-happiness association. Pain and SB are known to be bi-directionally associated factors. Prolonged immobilization is a risk factor for musculoskeletal pain [45], while older adults with chronic pain may engage in SB as a positive coping strategy that keeps them functional [39]. Pain has been associated with depression [46], and this may directly lower happiness levels, or it may indirectly act via

sleep problems through either changes in positive and negative states and/or via changes in dopaminergic and opiodergic signaling [47].

Around a quarter of the SB-happiness association was explained by cognitive complaints. Although the influence of SB on cognition is unclear [48], SB may impair brain health by dysregulating glycemic control, a condition that when permanent, has been associated with brain damage and cognitive dysfunction [49]. In turn, cognitive complaints may lead to lower levels of happiness [50], possibly due to concerns about incipient dementia [51]. Next, sleep problems also explained the SB-happiness association to a similar degree. Poor sleep may be related to higher levels of SB via fatigue during waking hours [52], while prolonged SB may also increase risk for sleep problems through several mechanisms including metabolic syndrome, LED-backlit TV exposure (which may cause melatonin suppression), and depression [52].

There were some factors that explained a notably larger proportion of the SB-happiness association in those aged ≥ 65 years. Specifically, these were disability, mobility, and pain/discomfort but there was a particularly large difference for disability. This may be due to the fact that the prevalence of disability gradually increases with advancing age. It is also worth noting that the association between SB and happiness remained significant after adjustment for a wide range of influential factors including physical activity. This may mean that SB has a direct effect on happiness or that there are other factors not assessed in the current study that may also be important for the SB-happiness association (e.g., personality and genetic factors) [53].

Lastly, we found a high level of between-country heterogeneity in the SB-happiness association with the association being strongest in Ghana, and a non-significant result being found in Mexico. Although these country-wise findings are challenging to interpret, given the potential importance of physical conditions in this association, availability of health care may

partly explain this heterogeneity. Indeed, the strongest association was found in Ghana in our study, and this was the country with the lowest income level, and possibly the country with the lowest level of health care. Alternatively, this may also be attributable to cultural diversity as the construct of happiness may not be completely consistent across countries and cultures [54]. Finally, it is also possible that the type and mode of SB may differ by country. For example, in some settings, SB may mainly consist of activity that may enhance positive mental health (e.g., social gatherings), and this may offset the deleterious effects of other types of SB. Future studies should explore the reason why there may be heterogeneity in the SB-happiness relationship by setting, and studies with more detailed information on the types and modes of SB are needed in this respect.

Present findings indicate that reducing SB and addressing the co-existing conditions among highly sedentary adults may enhance happiness. More studies with clinical and non-clinical populations are needed to provide a better understanding of how addressing SB co-existing conditions may enhance happiness. Furthermore, hypothesized mechanisms underlying the associations between SB and happiness are predominantly theory-based and the evidence is scarce in this regard. Therefore, future studies are needed to provide a better understanding in this area. Finally, since there is initial evidence suggesting that frequent interruptions in leisure time SB may be related to lower odds of depression/anxiety symptoms [55], ongoing research may wish to explore whether the manner in which SB accumulates (i.e., breaks and bouts) is related to happiness or positive mental health indicators.

The study results should be interpreted in light of several limitations. First, given the cross-sectional nature of the study, causality and directionality of the relationships cannot be inferred. It is worth noting that a bi-directional association is also possible for SB and happiness. For example, people who report being happy may be more prone to have a healthy lifestyle (e.g., maintain a healthy body weight, avoid smoking and excessive drinking) and be

more active [56,57]. It is also possible that higher happiness levels may predict self-rated health [58] via influences in immune systems [59], which may ultimately increase movement behaviors and reduce SB levels. Longitudinal evidence is warranted to better understand the relationship between SB and happiness, and the exact contribution of influential factors. Second, SB was assessed through self-report, and thus, reporting bias may exist, especially in those participants with worse cognitive performance and lower capacity to recall their behaviors [60]. Future research should employ more sophisticated methods to accurately examine overall patterns of SB in combination with self-reported tools to capture domain-specific SB. Additionally, there is not yet a norm-referenced criterion for determining high versus low SB, and the criterion used in this study needs to be further explored. Finally, it is important to note that our mediation analysis was based on cross-sectional data and therefore, it is not possible to differentiate the factors as mediators or confounders. Relatedly, one should bear in mind that the mediators in this study were assessed individually. Thus, it is possible that the mediators affect one another, or there can be interactions between the effects of the mediators on happiness.

In conclusion, high levels of SB were significantly associated with lower levels of happiness across middle and late adulthood. Mobility limitations, pain and discomfort, cognitive complaints, problems with sleep and energy, and disability may potentially influence this relationship. Context-specific SB data will provide useful insights on specific domains and correlates of behavior that may be linked to happiness and overall wellbeing.

DECLARATIONS

Ethics approval and consent to participate

Ethical approval to conduct the study was obtained from the ethical boards at each study site.

Informed consent was obtained from all participants.

Competing interests

The authors declare that they have no competing interests.

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Availability of data and materials

The dataset supporting the conclusions of this article is available in:

<http://www.who.int/healthinfo/sage/en/>

Authors' contributions

MF and AK designed and conceptualized the study. MF and AK analyzed the data. MF, BO, JMH, BS, LS and AK, interpreted the data. MF wrote the first draft of the manuscript. All authors revised the manuscript for intellectual content and approved the final manuscript.

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Table 1

Sample characteristics (overall and by sedentary behavior levels)

Characteristic		Overall (n=34129) % or mean (SD)	High SB ≥8hrs/day No (N=30302)	Yes (n=2996)	p value
Age (years)		62.4 (16.0)	61.8 (15.5)	66.8 (17.5)	<0.001
Sex	Female	51.9	51.6	54.9	0.04
Education (years)		6.0 (8.9)	5.9 (8.9)	6.7 (8.3)	0.001
Wealth	Poorest	17.1	16.6	20.7	0.01
	Poorer	18.9	18.5	21.7	
	Middle	19.5	19.6	19.1	
	Richer	21.4	21.8	18.0	
	Richest	23.2	23.5	20.5	
Marital status	Married/cohabiting	75.8	77.2	64.0	<0.001
	Never married	1.7	1.7	2.2	
	Separated/divorced/widowed	22.5	21.1	33.8	
Unemployed	Yes	57.3	55.7	70.9	<0.001
Setting	Urban	46.0	45.4	51.5	0.04
Smoking	Yes	35.0	35.3	32.6	0.20
Alcohol consumption	Yes	18.6	18.5	19.1	0.75
Social cohesion index ^a		21.3 (23.3)	22.0 (23.5)	17.1 (19.8)	<0.001
Depression	Yes	6.1	5.8	8.7	0.002
Anxiety	Yes	8.1	7.5	13.6	<0.001
Obesity	Yes	11.3	10.5	17.9	<0.001
Disability	Yes	7.2	5.8	18.1	<0.001
Mobility ^b		3.3 (4.7)	3.1 (4.6)	4.8 (4.5)	<0.001
Pain and discomfort ^b		3.0 (4.5)	2.9 (4.5)	4.0 (4.2)	<0.001
Sleep and energy ^b		2.7 (4.5)	2.6 (4.5)	3.7 (4.4)	<0.001
Cognition ^b		3.1 (4.6)	2.9 (4.6)	4.1 (4.4)	<0.001
Physical activity	Low	28.1	25.9	45.5	
	Moderate	22.8	23.2	19.4	<0.001
	High	49.2	50.9	35.2	

Data are percentage unless otherwise stated.

Abbreviation: SD Standard deviation; SB sedentary behavior

^a The social cohesion index ranged from 0-100 with higher scores representing higher levels of social cohesion.^b Scores ranged from 0-10 with higher scores representing worse health status.

Table 2

Association between sedentary behaviour (hours/day) and happiness estimated by multivariable ordinal logistic regression

Sample	Model 1 OR [95%]	Model 2 OR [95%CI]	Model 3 OR [95%CI]	Model 4 OR [95%CI]
Overall	0.93 [0.91, 0.95]***	0.93 [0.91, 0.95]***	0.96 [0.94, 0.98]***	0.96 [0.94, 0.98]***
Age 50-64 years	0.94 [0.92, 0.97]***	0.94 [0.91, 0.96]***	0.96 [0.94, 0.99]*	0.96 [0.93, 0.99]*
Age ≥ 65 years	0.92 [0.90, 0.95]***	0.93 [0.91, 0.95]***	0.97 [0.94, 0.99]**	0.97 [0.94, 0.99]*

Abbreviation: OR Odds ratio; CI Confidence interval

Model 1 is adjusted for adjusted for age, sex, and country.

Model 2 is adjusted for variables in Model 1 and education, wealth, marital status, employment status, and setting.

Model 3 is adjusted for variables in Model 2 and smoking, alcohol consumption, social cohesion, depression, anxiety, obesity, disability, mobility, pain/discomfort, sleep/energy, and cognition.

Model 4 is adjusted for variables in Model 3 and physical activity (fully adjusted model).

*p<0.05; **p<0.01; ***p<0.001.

Table 3

Mediators in the association between high sedentary behaviour (hours/day) and happiness								
Mediators	Age (years)	Total effect OR [95%CI]	P-value	Direct effect OR [95%CI]	P-value	Indirect effect OR [95%CI]	P-value	Mediated % ^a
Smoking	50-64	0.93 [0.91,0.96]	<0.001	0.94 [0.91,0.96]	<0.001	1.00 [1.00,1.00]	0.388	NA
	≥65	0.93 [0.90,0.95]	<0.001	0.93 [0.90,0.95]	<0.001	1.00 [1.00,1.00]	0.871	NA
	All	0.93 [0.91,0.95]	<0.001	0.93 [0.91,0.95]	<0.001	1.00 [1.00,1.00]	0.491	NA
Alcohol consumption	50-64	0.93 [0.91,0.96]	<0.001	0.93 [0.91,0.96]	<0.001	1.00 [1.00,1.00]	0.805	NA
	≥65	0.93 [0.91,0.95]	<0.001	0.93 [0.91,0.95]	<0.001	1.00 [1.00,1.00]	0.066	NA
	All	0.93 [0.91,0.95]	<0.001	0.93 [0.91,0.95]	<0.001	1.00 [1.00,1.00]	0.069	NA
Social cohesion	50-64	0.93 [0.91,0.96]	<0.001	0.94 [0.91,0.96]	<0.001	1.00 [0.99,1.00]	0.013	4.3
	≥65	0.93 [0.90,0.95]	<0.001	0.94 [0.91,0.96]	<0.001	0.99 [0.99,1.00]	<0.001	10.8
	All	0.93 [0.91,0.95]	<0.001	0.93 [0.92,0.95]	<0.001	0.99 [0.99,1.00]	<0.001	7.0
Depression	50-64	0.93 [0.91,0.96]	<0.001	0.94 [0.91,0.96]	<0.001	0.99 [0.99,1.00]	0.019	8.2
	≥65	0.93 [0.90,0.95]	<0.001	0.93 [0.91,0.96]	<0.001	0.99 [0.99,1.00]	0.017	6.9
	All	0.93 [0.91,0.94]	<0.001	0.93 [0.92,0.95]	<0.001	0.99 [0.99,1.00]	<0.001	7.5
Anxiety	50-64	0.93 [0.91,0.96]	<0.001	0.94 [0.92,0.96]	<0.001	0.99 [0.99,1.00]	0.005	7.8
	≥65	0.93 [0.90,0.95]	<0.001	0.94 [0.91,0.96]	<0.001	0.99 [0.98,1.00]	0.002	12.6
	All	0.93 [0.91,0.95]	<0.001	0.94 [0.92,0.95]	<0.001	0.99 [0.99,1.00]	<0.001	10.0
Obesity	50-64	0.94 [0.91,0.96]	<0.001	0.94 [0.91,0.97]	<0.001	1.00 [0.99,1.00]	0.114	NA
	≥65	0.92 [0.90,0.94]	<0.001	0.92 [0.90,0.95]	<0.001	1.00 [1.00,1.00]	0.135	NA
	All	0.93 [0.91,0.95]	<0.001	0.93 [0.91,0.95]	<0.001	1.00 [1.00,1.00]	0.029	2.6
Disability	50-64	0.93 [0.91,0.96]	<0.001	0.94 [0.91,0.96]	<0.001	1.00 [1.00,1.00]	0.035	3.2
	≥65	0.93 [0.90,0.95]	<0.001	0.95 [0.92,0.97]	<0.001	0.98 [0.97,0.99]	<0.001	25.9
	All	0.93 [0.91,0.94]	<0.001	0.94 [0.92,0.96]	<0.001	0.99 [0.99,0.99]	<0.001	14.6
Mobility	50-64	0.93 [0.91,0.96]	<0.001	0.95 [0.93,0.98]	<0.001	0.98 [0.97,0.98]	<0.001	29.9
	≥65	0.92 [0.90,0.95]	<0.001	0.96 [0.94,0.99]	0.005	0.96 [0.95,0.97]	<0.001	51.3
	All	0.93 [0.91,0.94]	<0.001	0.95 [0.94,0.97]	<0.001	0.97 [0.97,0.98]	<0.001	38.8
Pain/discomfort	50-64	0.93 [0.91,0.96]	<0.001	0.94 [0.92,0.97]	<0.001	0.99 [0.98,0.99]	<0.001	17.6
	≥65	0.93 [0.90,0.95]	<0.001	0.95 [0.92,0.97]	<0.001	0.98 [0.97,0.98]	<0.001	31.4
	All	0.93 [0.91,0.95]	<0.001	0.94 [0.93,0.96]	<0.001	0.98 [0.98,0.99]	<0.001	23.6
Sleep/energy	50-64	0.93 [0.91,0.96]	<0.001	0.95 [0.92,0.97]	<0.001	0.98 [0.98,0.99]	<0.001	23.0
	≥65	0.92 [0.90,0.95]	<0.001	0.94 [0.91,0.97]	<0.001	0.98 [0.98,0.99]	<0.001	21.4

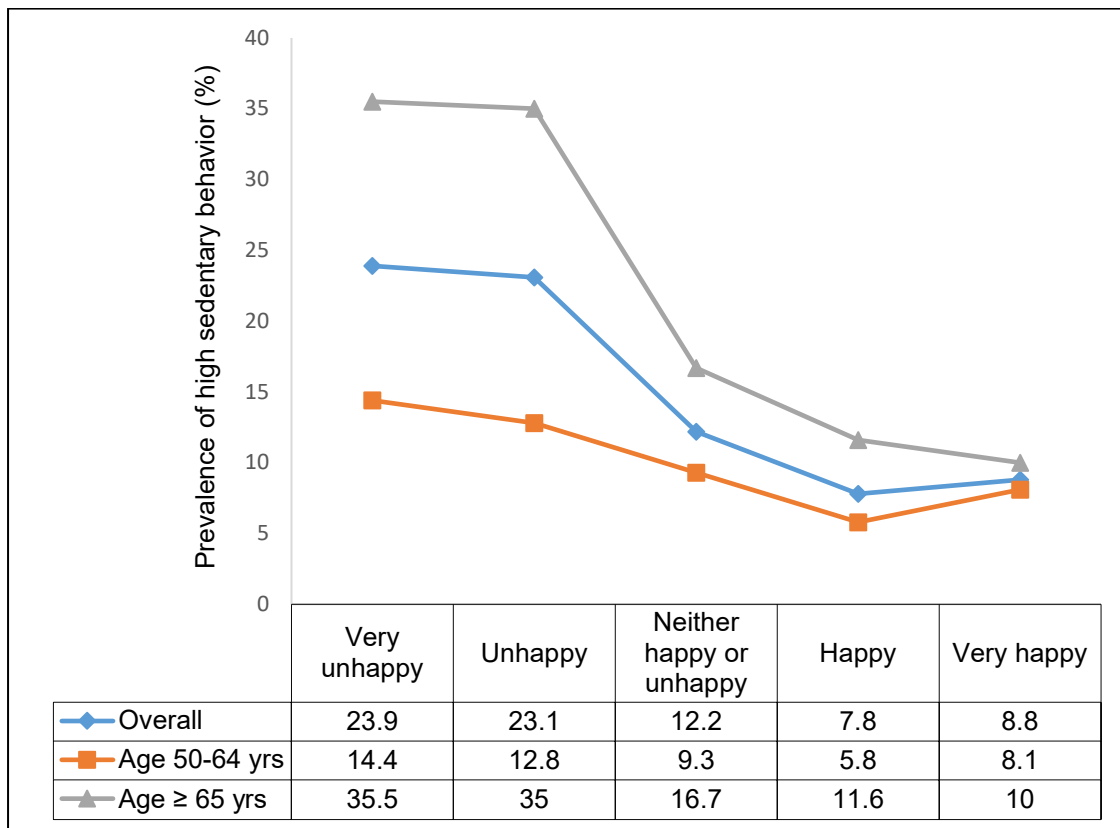
Cognition	All	0.93 [0.91,0.94]	<0.001	0.94 [0.93,0.96]	<0.001	0.98 [0.98,0.99]	<0.001	21.8
	50-64	0.93 [0.91,0.96]	<0.001	0.95 [0.92,0.97]	<0.001	0.99 [0.98,0.99]	<0.001	21.7
	≥65	0.93 [0.90,0.95]	<0.001	0.95 [0.93,0.98]	<0.001	0.97 [0.97,0.98]	<0.001	34.8
Physical activity	All	0.93 [0.91,0.95]	<0.001	0.95 [0.93,0.96]	<0.001	0.98 [0.98,0.98]	<0.001	27.3
	50-64	0.94 [0.91,0.96]	<0.001	0.93 [0.91,0.96]	<0.001	1.00 [1.00,1.00]	0.914	NA
	≥65	0.93 [0.91,0.95]	<0.001	0.94 [0.91,0.96]	<0.001	0.99 [0.99,1.00]	0.001	12.5
	All	0.93 [0.91,0.95]	<0.001	0.93 [0.92,0.95]	<0.001	1.00 [0.99,1.00]	0.015	4.7

Abbreviation: OR Odds ratio; CI Confidence interval

Models are adjusted for age, sex, education, wealth, marital status, setting, employment, and country.

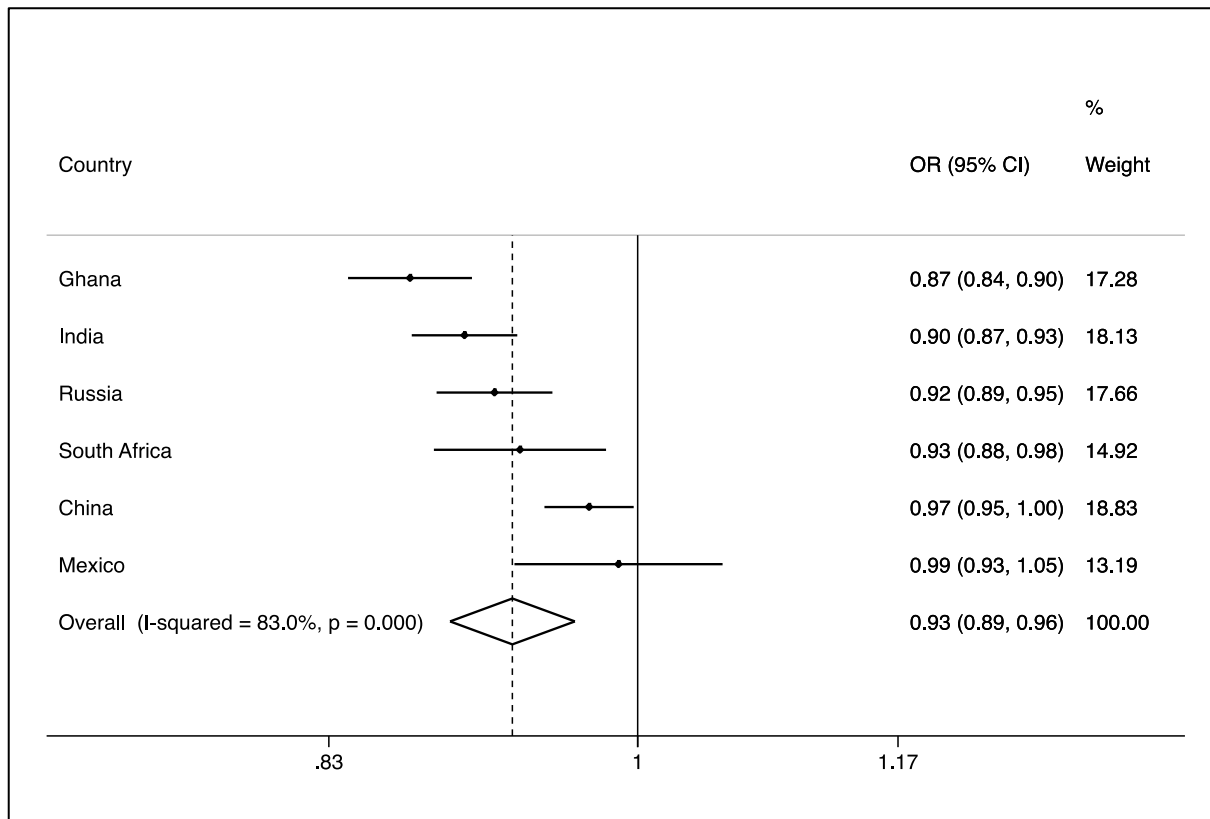
^a Mediated percentage was calculated only when the indirect effect was significant (p<0.05).

Figure 1



Prevalence of high sedentary behavior (≥ 8 hours/day) by age groups and overall sample

Figure 2



Country-wise association between sedentary behavior (hours/day) and happiness estimated by ordinal logistic regression

Abbreviation: OR Odds ratio; CI Confidence interval

Models are adjusted for age, sex, education, wealth, marital status, employment, and setting.

Overall estimate was obtained by meta-analysis with random effects.

APPENDIX

Table S1

Questions used to assess social cohesion

How often in the last 12 months have you ...

- (1) attended any public meeting in which there was discussion of local or school affairs?
- (2) met personally with someone you consider to be a community leader?
- (3) attended any group, club, society, union or organizational meeting?
- (4) worked with other people in your neighborhood to fix or improve something?
- (5) had friends over to your home?
- (6) been in the home of someone who lives in a different neighbourhood than you do or had them in your home?
- (7) socialized with coworkers outside of work?
- (8) attended religious services (not including weddings and funerals)?
- (9) gotten out of the house/your dwelling to attend social meetings, activities, programs or events or to visit friends or relatives?

Table S2

Questions used to assess health status

Mobility	(1) Overall in the last 30 days, how much difficulty did you have with moving around? (2) Overall in the last 30 days, how much difficulty did you have in vigorous activities, such as running 3 km (or equivalent) or cycling?
Pain and discomfort	(1) Overall in the last 30 days, how much of bodily aches or pains did you have? (2) Overall in the last 30 days, how much bodily discomfort did you have?
Cognition	(1) Overall in the last 30 days, how much difficulty did you have with concentrating or remembering things? (2) Overall in the last 30 days, how much difficulty did you have in learning a new task (for example, learning how to get to a new place, learning a new game, learning a new recipe etc.)?
Sleep and energy	(1) Overall in the last 30 days, how much of a problem did you have with sleeping, such as falling asleep, waking up frequently during the night or waking up too early in the morning? (2) Overall in the last 30 days, how much of a problem did you have due to not feeling rested and refreshed during the day (e.g. feeling tired, not having energy)?