

Moving more, aging happy: Findings from six low- and middle-income
countries

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ABSTRACT

Background: Low levels of wellbeing (including happiness) in the older population is a major global concern given rapid population ageing especially in low- and middle-income countries (LMICs). Physical activity may increase levels of happiness but data on the older population are scarce, while there are no data from LMICs. **Objective:** We investigated the relationship between physical activity and happiness, and the influential factors in this association among older adults employing nationally representative datasets from six LMICs. **Methods:** Community-based cross-sectional data from the Global Ageing and Adult Health study were analyzed. Physical activity was assessed with the Global Physical Activity Questionnaire. Participants were grouped into those who do and do not meet physical activity recommendations. Happiness was assessed with a cross-culturally validated single-item question (range 0-4) with higher scores indicating higher levels of happiness. Multivariable ordinal logistic regression and mediation analyses were performed. **Results:** The sample included 14,585 adults aged ≥ 65 years (mean age = $72.6 \pm SD 11.4$ years; 55% female). After adjusting for multiple confounders, meeting physical activity guidelines was positively associated with more happiness (fully adjusted model, OR=1.27; 95%CI=1.04-1.54). The physical activity-happiness association was largely explained by difficulties in mobility, cognitive impairment, disability, and social cohesion, which explained $\geq 20\%$ of the association. **Conclusions:** Meeting recommended physical activity levels was positively linked with happiness in older adults from LMICs. Longitudinal and interventional studies among older people in LMICs are warranted to assess directionality and the potential for physical activity promotion to improve mental well-being in this population.

Keywords: physical activity, wellbeing, mental health, happiness, older adults

KEYPOINTS

- In a sample of 14,585 older adults (≥ 65 years) from six low- and middle-income countries, meeting physical activity guidelines was positively associated with more happiness.
- Mobility limitations, cognitive complaints, disability and social cohesion explained the largest proportion of the association between physical activity and happiness.
- A moderate level of between-country heterogeneity was found.

INTRODUCTION

Owing to remarkable increases in life expectancy, the world population is aging at an unprecedented rate [1]. Currently, people aged 60 years or older account for 13% of the global population (962 million people), and this population is projected to reach nearly 2.1 billion in 2050 [2], with the greatest increase occurring in low- and middle-income countries (LMICs). With people living longer and adverse life conditions/events increasing with advanced age (e.g., chronic conditions, functional limitations, disability), emotional and psychological well-being may be compromised during later life. Thus, finding sustainable, scalable and low-cost strategies to promote and preserve mental wellbeing among this age group is crucial to improve wellbeing at the population level.

It is well-established that regular physical activity (PA) is a significant contributor to healthy aging [3] and that it has a positive role in the prevention of mental illness (e.g., depression, anxiety, dementia) [4–6]. Furthermore, increasing evidence suggests that PA is associated with positive mental well-being [3,7], but there is a paucity of studies specific to the construct of happiness.

Happiness is considered a hedonic state, and one of the three core aspects of subjective well-being, together with life satisfaction and sense of purpose/meaning in life [8]. According to Keyes's dual continuum model [9], the presence of positive mental health does not merely imply the absence of mental illness (and vice versa) because both mental health and mental illness reflect interrelated but distinct phenomena.

A recent systematic review on the relationship between PA and happiness identified 15 observational and 8 interventional studies on this topic [10], and found that most studies reported a positive association between PA and happiness. However, all these previous studies were conducted in high-income countries, and data from LMICs are lacking, while

there are only two small studies specifically on the older population [11,12]. This is an important research gap as the largest increase in the aging population is occurring in LMICs, and low cost-effective interventions such as promotion of PA is expected to have a large impact on overall health in this setting [13]. Furthermore, associations found in high-income countries may not be generalizable to LMICs due to differences in cultural, social, and environmental factors as well as subjective perceptions and modes of transport [14,15]. In addition, most previous studies were of small sample size and were conducted in a single country, while most studies did not use nationally representative samples. This severely limits generalizability beyond the setting in which the study was conducted. Finally, there is a paucity of research examining the factors that may influence the link between PA and happiness. The only two previous studies have identified social functioning and perceived health status as potential mediators [11,12]. However, these studies created a single composite variable for the construct “health status” that included several distinct variables, and thus, the individual influence of health variables, and other factors (e.g., social cohesion) that are likely to be important in the PA-happiness relationship [16] remains to be understood. This information may be crucial to improve the ability to design intervention strategies and influence behavior change.

Given the above-mentioned gaps in the literature and the fact that happiness is considered a fundamental human goal, the current study sought to investigate the association between complying with the recommended levels of PA by the WHO (i.e., 150 min/week of moderate-to-vigorous intensity PA) and happiness among older adults employing nationally representative datasets from six LMICs. Additionally, the extent to which various factors, which have not been explored before, may explain the association between PA and happiness was also examined.

METHODS

The survey

Data from the Study on Global Ageing and Adult Health (SAGE) 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, Ghana was the only low-income country, and China and India were lower middle-income countries although China became an upper middle-income country in 2010. The remaining countries were upper middle-income countries.

Details of the survey method have been published elsewhere [17]. Briefly, in order to obtain nationally representative samples, a multistage clustered sampling design method was used. The sample consisted of adults aged ≥ 18 years with oversampling of those aged ≥ 50 years. Trained interviewers conducted face-to-face interviews using a standard questionnaire. Standard translation procedures were undertaken to ensure comparability between countries. The survey response rates were: China 93%; Ghana 81%; India 68%; Mexico 53%; Russia 83%; and South Africa 75%. Sampling weights were constructed 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. Written informed consent was obtained from all participants.

Physical activity (exposure)

PA levels were assessed with the Global Physical Activity Questionnaire [18]. The total amount of moderate-to-vigorous PA in a typical week was calculated based on self-report. Those scoring ≥ 150 minutes of moderate-to-vigorous intensity PA were classified as meeting the recommended guidelines (code=1), and those scoring < 150 minutes were classified as not meeting the recommended guidelines (code=0) [19].

Happiness

Happiness levels were assessed with a widely used and a cross-culturally validated single-item question [20]. Specifically, happiness was assessed with the question “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).

Mediators

The mediators in the current study were selected based on their previously reported association with PA and happiness [10], and included current smoking (Y/N), alcohol use in the past 30 days (Y/N), social cohesion, depression, anxiety, obesity, disability, mobility, pain/discomfort, sleep/energy, and cognition. As in a previous SAGE publication [21], a social cohesion index was created based on 9 questions on the participant’s involvement in community activities in the past 12 months (e.g., attended religious services, club, society, union, etc) with answer options ‘never (coded=1)’, ‘once or twice per year (coded=2)’, ‘once or twice per month (coded=3)’, ‘once or twice per week (coded=4)’, and ‘daily (coded=5)’. The answers to these questions were summed and later converted to a scale ranging from 0-100 with higher scores corresponding to higher levels of social cohesion (Cronbach’s $\alpha=0.78$). Questions based on the World Mental Health Survey version of the Composite International Diagnostic Interview [22] 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 [23]. Obesity was defined as body mass index (BMI) $\geq 30\text{kg/m}^2$ based on measured weight and height [24]. Disability was assessed with six questions on the level of difficulty in conducting standard basic activities of daily

living (ADL) in the past 30 days (washing whole body, getting dressed, moving around inside home, eating, getting up from lying down, and using the toilet) [25]. Those who answered severe or extreme/cannot do to any of the six questions were considered to have disability [26]. Mobility, pain/discomfort, sleep/energy, and cognition were evaluated with two health-related questions each. The actual questions can be found in supplementary **Table S1**. Each item was scored on a five-point scale ranging from 'none' to 'extreme/cannot do'. For each separate domain, we used factor analysis with polychoric correlations to obtain a factor score which was later converted to scores ranging from 0-10 with higher values representing worse health function [27].

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). These variables were not considered as potential mediators as sociodemographic variables are often considered to be non-modifiable.

Statistical analysis

The analysis was restricted to those aged ≥ 65 years. The difference in sample characteristics by levels of PA and by country was tested by Chi-squared tests for categorical variables and Student's t-tests or one-way ANOVA for continuous variables. Multivariable ordinal logistic regression analysis was conducted to assess the association between meeting the PA recommendation (exposure) and happiness (outcome). In order to assess the influence of various factors in the association between PA and happiness, we constructed three models: 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 (fully adjusted model). We also assessed whether the association between meeting PA guidelines and happiness differs by sex and obesity by including an interaction term (i.e., sex X PA, obesity X PA) in the fully adjusted model [10].

Next, in order to gain an understanding on the extent to which various factors (i.e., smoking, alcohol consumption, social cohesion, depression, anxiety, obesity, disability, mobility, pain/discomfort, sleep/energy, and cognition) may explain the relation between PA and happiness, we conducted mediation analysis. We used the `khb` (Karlson Holm Breen) command in Stata for this purpose [28]. This method can be applied in logistic regression models and decomposes the total effect (i.e., unadjusted for the mediator) of a variable into direct (i.e., the effect of PA on happiness adjusted for the mediator) and indirect effects (i.e., the mediational effect). Using this method, the percentage of the main association explained by the mediator can also be calculated (mediated percentage). Each potential mediator was included in the model individually. The mediation analysis controlled for age, sex, education, wealth, marital status, employment status, setting, and country.

Furthermore, we also conducted analysis by country with full adjustment to assess whether the findings are consistent across countries. In order to assess the between-country heterogeneity that may exist in the association between PA and happiness, we calculated 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 [29]. A pooled estimate was obtained by random-effect meta-analysis.

Adjustment for country was done by including dummy variables for each country in the model as in previous SAGE publications [30]. The sample weighting and the complex study design were taken into account in all analyses. Results from the regression analyses are presented as odds ratios (ORs) with 95% confidence intervals (CIs). The level of statistical significance was set at $P < 0.05$.

RESULTS

A total of 14,585 participants aged ≥ 65 years were included in the analysis (China $n = 5360$; Ghana $n = 1975$; India $n = 2441$; Mexico $n = 1375$; Russia $n = 1950$; South Africa $n = 1484$). The mean age was 72.6 (SD, 11.4) and 55% were females. The overall prevalence of meeting PA guidelines was 65.5%. Of all participants, 4.1% reported being very happy, 48.5% happy, 36.6% neither happy or unhappy, 9.4% unhappy, and 1.3% very unhappy. For those participants not meeting PA guidelines, the prevalence of levels of happiness were as follows: 2.1% (very happy), 13.3% (happy), 37.9% (neither happy or unhappy), 43.7% (unhappy), and 3.0% (very unhappy). More information on the sample characteristics are provided in **Table 1** and supplementary **Table S2**. As illustrated in **Figure 1**, there was a linear increase in the prevalence of meeting PA guidelines with increasing levels of happiness in the overall and country-specific samples. Models adjusted for socio-demographic factors showed that meeting PA guidelines was significantly associated with greater levels of happiness (OR=1.50-1.53) (**Table 2**, Model 1 and 2). Full adjustment for a broad range of behavioral and health-related factors attenuated the OR but this remained significant (OR=1.27; 95%CI=1.04-1.54) (**Table 2**, Model 3). Interaction analysis showed that sex and obesity were not significant effect modifiers.

The results of the mediation analysis (**Table 3**) showed that the largest proportion of the association between meeting PA guidelines and happiness was explained by mobility limitations (38.8%), cognition (24.9%), disability (24%), social cohesion (20%), pain and discomfort (18.9%), problems with sleep and energy (18.1%), and to a lesser extent by anxiety (8.6%). Smoking, alcohol consumption, depression, and obesity did not significantly influence the PA-happiness association.

The associations between meeting PA guidelines and happiness by country estimated by multivariable ordinal logistic regression (**Figure 2**) indicated that overall, there was a moderate level of between-country heterogeneity ($I^2=44.7%$) with the overall estimate based on a meta-analysis being OR=1.36 (95%CI=1.12-1.65). The association was particularly strong in Ghana (OR=1.99; 95%CI=1.12-1.65).

DISCUSSION

Main findings

To the best of our knowledge, this is the first multinational study conducted exclusively among older people that employed a large representative dataset to examine associations between PA and happiness. The results revealed that after adjusting for multiple factors, meeting PA guidelines is positively associated with happiness. In addition, our results allow the extension of previous observational research in older adults derived exclusively from high-income countries by confirming that the association between PA and happiness is also generalizable to LMICs [11,12]. There were some geographical variations in this association, since a moderate level of between-country heterogeneity was found. Mobility explained the largest proportion of the PA-happiness association (38.8%), followed by cognition (24.9%),

disability (24.0%), social cohesion (20.0%), pain/discomfort (18.9%), sleep/energy (18.1%), and anxiety (8.6%).

Interpretation of the findings

Current findings are in line with most of the previous cross-sectional studies in younger populations [10], while they also support findings from another study in Spanish older adults (aged ≥ 50 years) which found that after adjusting for several covariates, self-reported PA during leisure-time was positively associated with happiness (n=765) [12]. Yet, our results partially contrasted with the findings from another small cross-sectional study in older adults from France (n=323; aged ≥ 60 years), which found that the positive significant association between total self-reported PA and happiness was no longer significant after adjustment for social functioning [11].

Previous studies in older adults found that health status may be a potential mediator in the PA-happiness relationship. However, these studies did not differentiate between individual health problems [11,12], and thus, the current study is the first to provide insight into specific health-related factors that may explain this relationship. The present study found that mobility explained the largest proportion of the association, while disability was also one of the most important influential factors. Regular engagement in PA protects against sarcopenia, improves physical performance and reduces risk of falls [31,32], factors that ultimately improve older adult functional capacity keeping them mobile and independent [33,34], while mobility difficulties/disability per se are also important barriers to PA among older adults [35]. Declines in functional capacity are associated to higher risk of unhappiness [36], possibly due to low resilience [37] and restrictions of personal freedom of choice linked to disruptions in daily functioning [38].

This study also found that pain/discomfort and sleep/energy explained nearly 20% of the association between PA and happiness. Chronic pain has been reported to be associated with low PA bi-directionally. Specifically, regular PA may improve pain severity, while older adults with chronic pain may be less active, due to fear-avoidance beliefs/behaviors (i.e., fear of falling, exacerbation of pain, and post-exertional discomfort), and low self-efficacy, factors that overall also decrease motivation for PA [39,40]. Furthermore, mounting evidence indicates that regular PA positively influences sleep outcomes [41], while sleep problems can lead to lower PA levels via fatigue. A strong link between sleep indicators (e.g., sleep problems, sleep quality, sleep duration) and benefits on various aspects of well-being has been reported [42,43], while chronic pain is often associated with increases in disability and sleep disturbances, factors that can lead to lower levels of happiness.

In the present study, cognitive function was also identified as an important influential factor. Being active decreases the risk for future cognitive decline [44] possibly through several pathways including muscle-induced peripheral factors [45]. These may increase the release of growth factors and, together with increases in angiogenesis and regulations in inflammatory pathways, positive changes in brain function and brain structure may occur [46]. In turn, cognitive complaints have been associated with lower levels of happiness [47], and this may be due to concerns about incipient dementia [48].

Next, social cohesion, which is fundamental to happiness and well-being [38], accounted for 20% of the association between PA and happiness. PA contributes to reduction in levels of loneliness [49], perhaps through increases in perceived support [50], while previous studies suggest that loneliness per se may also reduce the probability of being physically active [49].

Anxiety also explained a small proportion of the PA-happiness association. PA may decrease the risk of anxiety possibly by acting on inflammatory processes, stress responses, oxidative markers, and via alteration of neurotrophins and neurotransmitter releases [51,52]. In turn, according to a large study examining sociodemographic and health correlates of happiness, anxiety was one of the strongest correlates of unhappiness [53].

Overall, it is worth noting that after adjusting for a wide range of influential factors, the association between PA and happiness remained significant. This suggests that PA may have a direct effect on happiness levels via enhanced mood and its related biological-based pathways such as increases in monoamines, endogenous opioids release, hypothalamic-pituitary adrenal axis [51,52] and perhaps through release of endorphins, although limited empirical evidence exists and the long-term effects remain unknown [54]. In addition, other factors not assessed in the current study may be also important for the PA-happiness association such as personality and genetic factors, which have been found to explain approximately 50% of the variance in subjective well-being [55].

Finally, we found a moderate level of between-country heterogeneity in the PA-happiness association with the association being statistically significant in China and Ghana, although the significant finding in China is likely to be explained by the large sample size and more statistical power in this country. The reasons for the moderate level of between-country heterogeneity can only be speculated but given the potential importance of physical conditions in this association, it is possible that differences in the availability of health services to prevent or manage these conditions may be playing a role. For example, in Ghana, where the most pronounced association was found, it is possible that PA plays a more prominent role in reducing the impact of physical conditions on happiness via prevention than in other settings, where greater availability of health care may be able to mitigate the impact of chronic conditions on wellbeing.

Public health and policy implications

Present findings indicate that promoting PA and addressing the co-existing conditions (e.g., difficulties in mobility, disability, cognitive impairment, and low social cohesion) among those who do not meet PA guidelines may enhance happiness in older adults. The few small randomized controlled trials conducted to date have also shown that PA may enhance happiness while also improving underlying conditions such as chronic pain and loneliness [50,56].

There is scarce evidence on how to implement population-based interventions for increasing PA specifically among older adults in LMICs. However, general recommendations to promote PA in LMICs include the encouragement of active transportation modes to counteract rapid urbanization, together with improvements in walking infrastructures and road safety. Additionally, national policies need to promote participation in PA during leisure time (e.g., through creating more opportunities for PA in public spaces or community settings) [57].

Limitations and future research

The present study is not without limitations. First, given the cross-sectional design of the study, causality and directionality of the relationships cannot be inferred. To our knowledge, there is only one study that examined longitudinal relationships between PA and happiness in adults [58], which highlights the need for more longitudinal evidence to better understand the relationship between PA and happiness, and the exact contribution of influential factors. Second, PA was assessed through self-report, which entails well-documented limitations [59]. Future research should employ more sophisticated methods (e.g., accelerometry) to accurately examine key PA characteristics (i.e., type, duration, intensity, frequency). Finally, it is important to note that our mediation analysis was based on cross-sectional data and thus,

it is not possible to differentiate the factors as mediators or confounders. Mediation and confounding are identical statistically and can only be distinguished on conceptual grounds [60].

Conclusions

Current findings support a positive association between meeting PA guidelines and older adults' level of happiness in LMICs. Mobility limitations, cognitive complaints, disability, low levels of social cohesion, pain and discomfort, impairments in sleep and energy, and anxiety are important factors in this association. Therefore, intervention studies should potentially consider them when designing PA promotion programs aimed at improving well-being of the older population. Given that improvements in well-being in later life has been recognized as a public health priority across the international community, present findings strengthen the potential for PA promotion as a supportive strategy to improve older adults' positive psychological states in LMICs.

DECLARATIONS

Competing interests

The authors declare that they have no competing interests.

Compliance with Ethical Standards

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

Informed consent was obtained from all participants.

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Tables and Figures

Table 1 Sample characteristics (overall and by physical activity levels)

Characteristic		Overall % or mean (SD)	Meeting PA guidelines		p value
			No	Yes	
Age (years)		72.6 (11.4)	74.2 (13.3)	71.6 (9.9)	<0.001
Sex	Female	55.0	56.2	54.3	0.42
Education (years)		5.2 (9.3)	5.0 (9.6)	5.3 (9.1)	0.14
Wealth	Poorest	21.6	22.7	21.1	0.34
	Poorer	20.9	19.7	21.6	
	Middle	20.4	19.1	21.1	
	Richer	17.5	18.1	17.1	
	Richest	19.5	20.4	19.0	
Marital status	Married/cohabiting	61.1	55.9	63.8	<0.001
	Never married	1.2	1.0	1.3	
	Separated/divorced/widowed	37.7	43.0	34.9	
Unemployed	Yes	78.4	88.2	73.2	<0.001
Setting	Urban	50.7	52.8	49.6	0.15
Smoking	Yes	29.3	31.7	29.3	<0.001
Alcohol consumption	Yes	13.9	8.2	16.8	<0.001
Social cohesion index ^a		18.5 (23.9)	15.8 (24.0)	20.2 (23.0)	<0.001
Depression	Yes	6.5	7.9	5.8	0.01
Anxiety	Yes	9.8	12.7	8.2	<0.001
Obesity	Yes	10.4	11.8	9.8	0.08
Disability	Yes	12.0	20.9	7.3	<0.001
Mobility ^b		4.3 (4.9)	5.0 (5.5)	3.9 (4.5)	<0.001
Pain and discomfort ^b		3.6 (4.7)	4.0 (5.1)	3.4 (4.5)	<0.001
Sleep and energy ^b		3.3 (5.0)	3.7 (5.4)	3.1 (4.7)	<0.001
Cognition ^b		3.9 (4.9)	4.4 (5.2)	3.6 (4.7)	<0.001

Abbreviation: SD Standard deviation; PA Physical activity

^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 meeting physical activity guidelines and covariates with happiness estimated by multivariable ordinal logistic regression

Characteristic		Model 1		Model 2		Model 3	
		OR	95%CI	OR	95%CI	OR	95%CI
Meeting PA guidelines	Yes vs. No	1.50***	[1.26,1.78]	1.53***	[1.27,1.83]	1.27*	[1.04,1.54]
Age	per year increase	0.99*	[0.98,1.00]	1.00	[0.99,1.01]	1.02***	[1.01,1.04]
Sex	Male vs. Female	1.11	[0.96,1.30]	0.89	[0.74,1.06]	0.70**	[0.57,0.87]
Education	per year increase			1.04***	[1.02,1.06]	1.03**	[1.01,1.05]
Wealth	Poorest			1.00		1.00	
	Poorer			1.46***	[1.13,1.87]	1.25	
	Middle			1.79***	[1.38,2.32]	1.60***	[0.99,1.59]
	Richer			2.09***	[1.68,2.60]	1.81***	[1.24,2.06]
	Richest			3.53***	[2.70,4.61]	2.68***	[1.97,3.64]
Marital status	Married/cohabiting			1.00		1.00	
	Never married			0.80	[0.46,1.37]	0.63	[0.36,1.08]
	Separated/divorced/widowed			0.91	[0.77,1.09]	0.93	[0.78,1.10]
Unemployed	Yes vs. No			0.82*	[0.69,0.96]	1.14	[0.96,1.35]
Setting	Urban vs. Rural			1.16	[0.92,1.46]	1.03	[0.82,1.30]
Smoking	Yes vs. No					0.98	[0.83,1.16]
Alcohol consumption	Yes vs. No					1.17	[0.99,1.38]
Social cohesion index ^a	per one-unit increase					1.02***	[1.01,1.03]
Depression	Yes vs. No					0.46***	[0.34,0.64]
Anxiety	Yes vs. No					0.69*	[0.50,0.96]
Obesity	Yes vs. No					0.79	[0.58,1.07]
Disability	Yes vs. No					0.87	[0.64,1.19]
Mobility ^b	per one-unit increase					0.91***	[0.87,0.95]
Pain and discomfort ^b	per one-unit increase					0.94***	[0.90,0.97]
Sleep and energy ^b	per one-unit increase					0.90***	[0.87,0.93]
Cognition ^b	per one-unit increase					0.93***	[0.90,0.96]

Abbreviation: OR Odds ratio; CI Confidence interval; PA Physical activity

Models are adjusted for all variables in the respective columns and country.

^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.

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

Table 3 Mediators in the association between meeting physical activity guidelines and happiness

Mediator	Total effect		Direct effect		Indirect effect		Mediated % ^a
	OR [95%CI]	P-value	OR [95%CI]	P-value	OR [95%CI]	P-value	
Smoking	1.53 [1.27,1.84]	<0.001	1.53 [1.28,1.84]	<0.001	1.00 [0.99,1.01]	0.772	NA
Alcohol consumption	1.53 [1.27,1.83]	<0.001	1.51 [1.26,1.81]	<0.001	1.01 [1.00,1.02]	0.054	NA
Social cohesion	1.54 [1.27,1.86]	<0.001	1.41 [1.18,1.70]	<0.001	1.09 [1.05,1.13]	<0.001	20.0
Depression	1.55 [1.29,1.86]	<0.001	1.52 [1.26,1.82]	<0.001	1.02 [0.99,1.05]	0.153	NA
Anxiety	1.54 [1.28,1.85]	<0.001	1.49 [1.24,1.78]	<0.001	1.04 [1.00,1.07]	0.027	8.6
Obesity	1.55 [1.27,1.88]	<0.001	1.54 [1.27,1.87]	<0.001	1.00 [1.00,1.01]	0.275	NA
Disability	1.54 [1.29,1.85]	<0.001	1.39 [1.15,1.67]	0.001	1.11 [1.07,1.15]	<0.001	24.0
Mobility	1.57 [1.32,1.88]	<0.001	1.32 [1.09,1.59]	0.004	1.19 [1.13,1.25]	<0.001	38.8
Pain/discomfort	1.57 [1.32,1.86]	<0.001	1.44 [1.21,1.71]	<0.001	1.09 [1.05,1.13]	<0.001	18.9
Sleep/energy	1.56 [1.29,1.89]	<0.001	1.44 [1.19,1.75]	<0.001	1.08 [1.04,1.13]	<0.001	18.1
Cognition	1.56 [1.30,1.87]	<0.001	1.40 [1.16,1.68]	<0.001	1.12 [1.08,1.16]	<0.001	24.9

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 ($p < 0.05$).

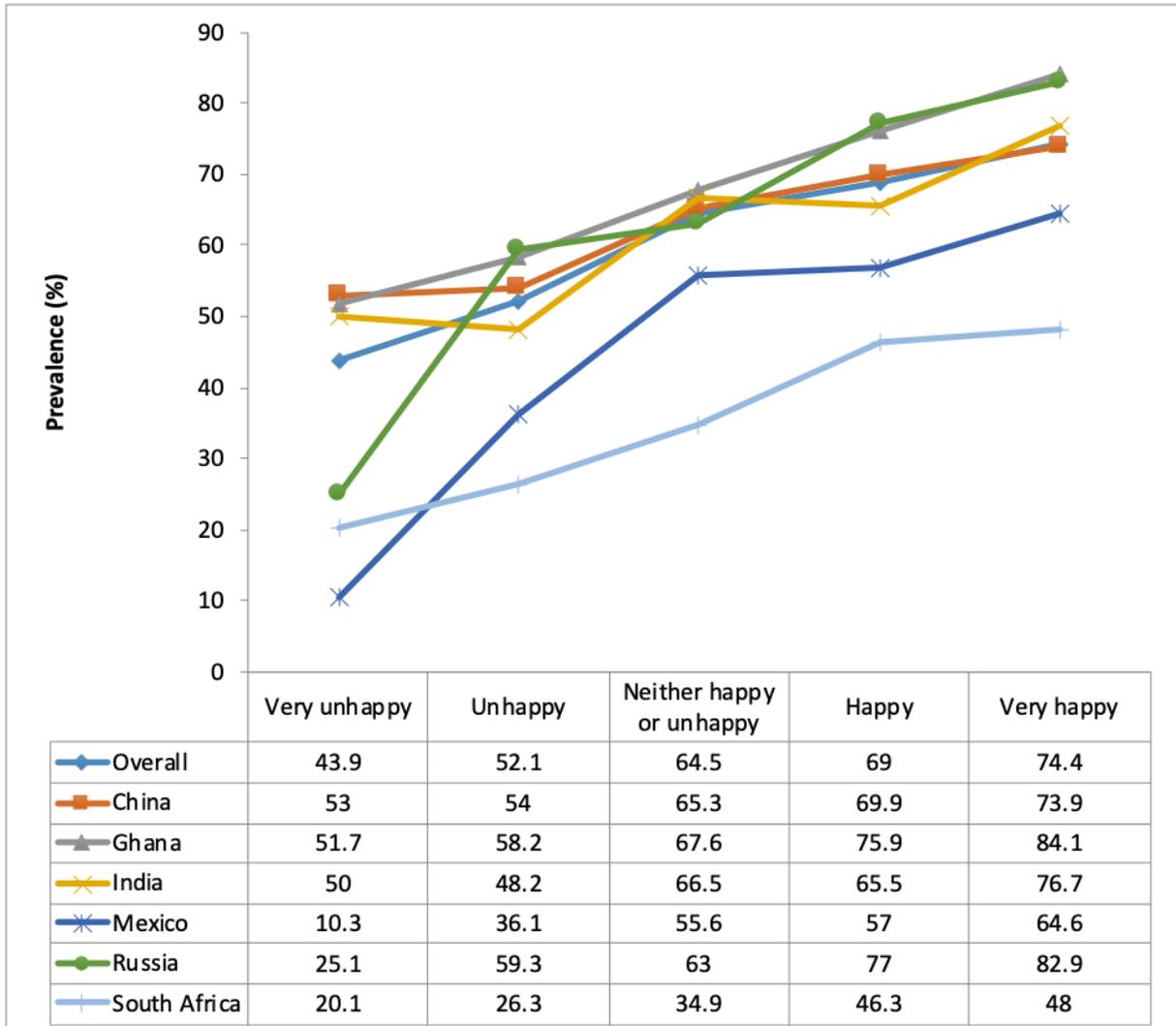


Figure 1 Prevalence of meeting physical activity guidelines by levels of happiness

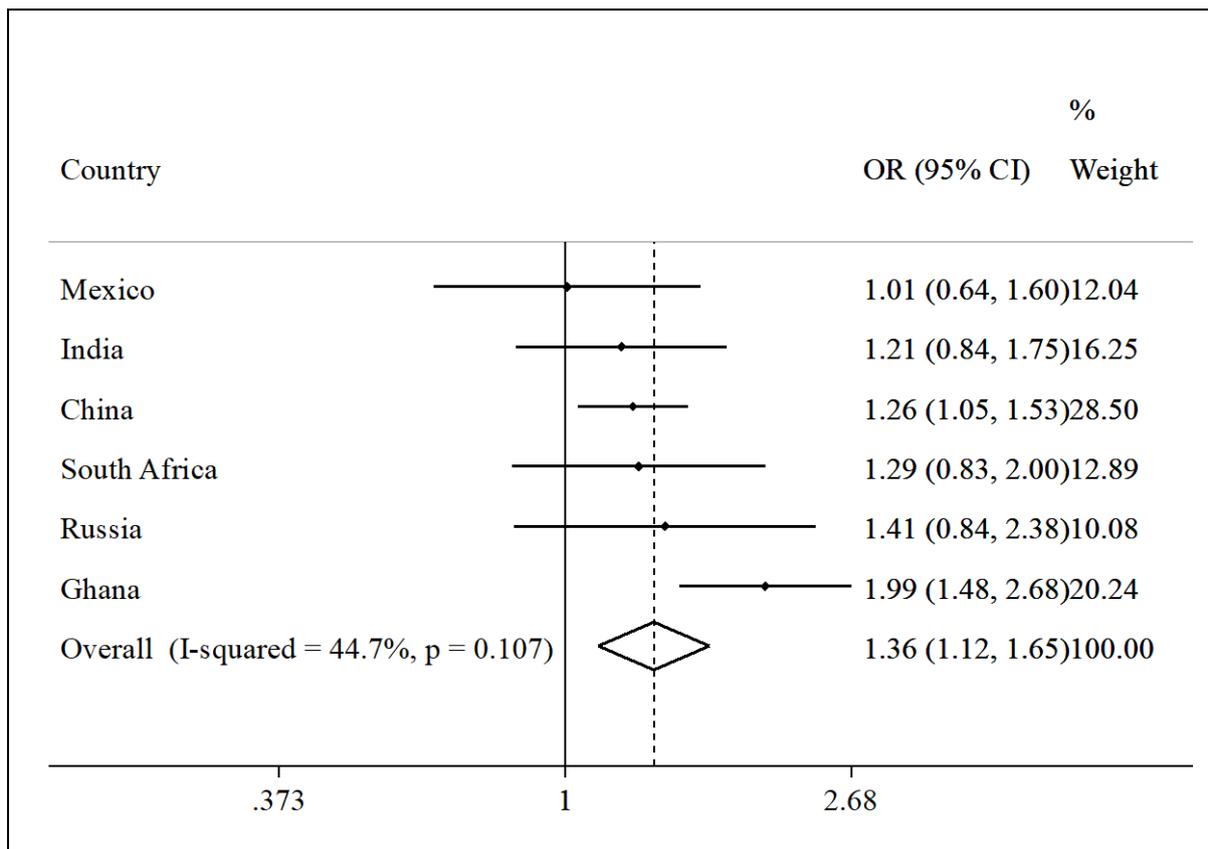


Figure 2 Association between meeting physical activity guidelines and happiness by country estimated by ordinal logistic regression

Abbreviation: OR Odds ratio; CI Confidence interval

Models are adjusted for age, sex, education, wealth, employment, setting, smoking, alcohol consumption, social cohesion, depression, anxiety, obesity, disability, mobility, pain/discomfort, sleep/energy, and cognition.

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

APPENDIX

Table S1 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)?

Table S2 Sample characteristics by country

Characteristic		China	Ghana	India	Mexico	Russia	South Africa	p value
Age (years)		72.3 (11.0)	74.1 (14.1)	71.6 (10.0)	74.7 (15.9)	74.2 (10.4)	72.8 (14.6)	<0.001
Sex	Female	53.4	48.0	48.0	54.9	68.2	60.6	<0.001
Education (years)		4.5 (9.2)	2.7 (8.7)	3.0 (0.2)	4.0 (9.0)	9.6 (6.2)	5.3 (10.5)	<0.001
Wealth	Poorest	23.2	19.4	20.5	23.1	21.1	21.2	0.03
	Poorer	19.9	20.8	20.5	26.5	24.3	18.8	
	Middle	20.3	21.1	18.0	16.5	24.6	16.4	
	Richer	19.5	19.3	17.0	17.0	14.3	19.2	
	Richest	17.1	19.4	24.0	16.8	15.7	24.3	
Marital status	Married/cohabiting	73.4	50.8	60.9	54.2	42.1	48.4	<0.001
	Never married	0.8	1.2	0.7	7.0	1.6	8.3	
	Separated/divorced/widowed	25.8	48.0	38.4	38.7	56.3	43.3	
Unemployed	Yes	76.2	46.9	72.9	81.4	91.4	87.9	<0.001
Setting	Urban	54.9	40.5	29.5	78.6	74.0	62.4	<0.001
Smoking	Yes	23.4	11.7	51.0	17.7	9.3	19.8	<0.001
Alcohol consumption	Yes	17.1	26.6	5.5	11.4	20.7	10.1	<0.001
Social cohesion index ^a		15.5 (20.1)	39.5 (38.1)	22.0 (21.8)	16.1 (30.4)	15.1 (16.9)	30.8 (34.9)	<0.001
Depression	Yes	1.0	9.0	14.5	6.6	4.3	2.3	<0.001
Anxiety	Yes	1.0	8.1	21.3	5.9	7.2	11.0	<0.001
Obesity	Yes	5.4	7.2	2.2	23.2	28.8	43.5	<0.001
Disability	Yes	3.2	11.7	19.0	11.2	15.9	15.2	<0.001
Mobility ^b		3.1 (4.5)	4.8 (4.6)	5.2 (4.3)	3.8 (6.8)	5.0 (4.0)	3.3 (6.2)	<0.001
Pain and discomfort ^b		2.5 (4.4)	4.5 (4.0)	4.5 (4.1)	2.7 (5.7)	4.0 (3.9)	3.8 (5.5)	<0.001
Sleep and energy ^b		2.1 (4.6)	3.6 (4.9)	4.0 (4.4)	2.5 (5.8)	4.3 (3.7)	3.1 (6.0)	<0.001
Cognition ^b		3.3 (4.7)	3.8 (4.8)	4.6 (4.5)	2.6 (5.5)	3.7 (4.2)	3.8 (6.0)	<0.001

Values are % for categorical variables and mean (standard deviation) for continuous variables.

^aThe social cohesion index ranged from 0-100 with higher scores representing higher levels of social cohesion.

^bScores ranged from 0-10 with higher scores representing worse health status.

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