Volume 22 Issue 8 August 2022 ISSN 1746-1391

European Journal of Sport Science

The Official Journal of the European College of Sport Science

Routledge Taylor & Francis Group

European Journal of Sport Science

Routledge

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tejs20

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To cite this article: Pablo Castellanos-García, Fernando Lera-López & José Manuel Sánchez-Santos (2022): Light, moderate and vigorous physical activities: New insights into a virtuous circle with happiness, European Journal of Sport Science, DOI: 10.1080/17461391.2022.2089053

To link to this article: https://doi.org/10.1080/17461391.2022.2089053

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Published online: 26 Jun 2022.

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EUROPEAN JOURNAL OF SPORT SCIENCE
https://doi.org/10.1080/17461391.2022.2089053

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Light, moderate and vigorous physical activities: New insights into a virtuous circle with happiness

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ABSTRACT

The study of the physical activity engagement (PA) has given rise to a relevant research agenda in a wide range of fields, such as its close relationship with subjective well-being, self-perceived health and social capital. Previous evidence has identified interrelationships among these variables, but without considering different levels of physical activity. We have thus considered three levels of activity: light (walking), moderate and vigorous. Structural Equation Modelling (SEM) is undertaken on data from Spain's National Health Survey in 2011–2012 to analyse these interrelationships. The SEM shows a simultaneous and bidirectional relationship between different levels of PA (moderate and vigorous activities) and happiness, with a more robust association stemming from happiness to PA than vice versa. This relationship is mediated through health. From a policy perspective, this implies a virtuous circle: involvement in different levels of PA increases happiness and self-perceived health, while happiness involves higher PA and subsequent positive increases in health and happiness. Nevertheless, this virtuous circle does not always run successfully when social capital is considered to mediate the relationship between PA and happiness, which might explain why it has proven to be very difficult for health policymakers to fight against inactivity and a sedentary lifestyle within a great part of the population.

Highlights:

- We investigate bidirectional interrelationships between different levels of physical activity (PA) and happiness.
- We consider the mediation role played by self-perceived health (SPH) and social capital.
- Our results highlight a network of association between different levels of PA, SPH, social capital and happiness.
- SPH positively mediates this relationship for any type of PA level, whereas social capital only mediates positively when vigorous PA is developed.
- From a health policy perspective, the simultaneity between PA levels and happiness implies a virtuous circle.

KEYWORDS

Physical activity; self-perceived health; happiness; well-being; social capital; structural equation modelling

1. Introduction

International evidence shows that PA levels are falling in many countries and inactivity is increasing, with at least $67.5 billion of economic burden annually derived from the negative effects of this inactivity on health (Ding et al., 2020). At the same time, happiness inequality has increased worldwide and only 31.9% of people consider themselves very happy, according to the last World Values Survey (2020). Within this context, the global need to reduce sedentary behaviour and identify and promote any factors that contribute to heightening individuals' well-being emerges as two relevant related issues.

There is a general consensus that PA engagement is closely related to subjective well-being (SWB) and happiness (Zhang & Chen, 2019). However, there are less studies and consensus regarding the different levels of intensity in PA. Downward and Dawson (2016) and Wicker and Frick (2015) showed that moderate-intensity activity has a positive impact on SWB, while vigorous being negatively linked to SWB. These authors argue that moderate activities seem to be more likely related

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to a casual recreation nature, generating the highest SWB to the individual, while vigorous is more associated to health benefits. Nevertheless, more recent evidence (Silva, Monteiro, & Sobreiro, 2020; Wicker & Frick, 2017; Zhang, He, & Chen, 2022) have obtained a positive impact of vigorous PA on SWB and happiness.

Moreover, different levels of intensity in PA could indirectly impact happiness through two mediated variables: health and social capital. There is a general consensus about PA as a key factor in improving physical and mental health (World Health Organization, WHO, 2019), affecting positively to individual self-perceived health (SPH) (e.g. Badr, Rao, & Manee, 2021). Different studies have shown that vigorous PA has greater health benefits than moderate-intensive PA (Rosen & Hagströmer, 2019).

In turn, there is widespread agreement on the positive relationship between health status and happiness (Ngamaba, Panagioti, & Armitage, 2017). Along this same line, some studies have considered the indirect and mediated effects of SPH on the relationship between PA and happiness (Downward, Hallmann, & Rasciute, 2018; Ross, Cloutier, & Searle, 2019).

At the same time, the effects of PA intensities might go beyond its beneficial impacts on physical and mental health and have a positive effect on social interaction (Becchetti, Ricca, & Pelloni, 2012). In this regard, PA is considered a platform for meeting people and creating social networks, contributing to an increase in social capital (Pawlowski & Schüttoff, 2019). Although the concept of social capital could apparently be ambiguous, taking as a reference the common elements of the definitions by authors such us Bourdieu (1986), Coleman (1988) and Lin (2001), we assume that social capital refers to both social support and the type and number of individuals' social interactions.

When analysing the relationship between the four considered variables, the possibility of reverse causality cannot be ignored. For instance, the reciprocal influence of PA and happiness has also been widely investigated (van Woudenberg, Bevelander, Burk, & Buijzen, 2020). Moreover, Downward et al. (2018) have shown that this simultaneous relationship is more robust stemming from happiness to PA, although there is no evidence by PA intensities.

The hypothesis that happiness influences SPH and vice versa is well documented in literature (Kushlev et al., 2020). Similarly, the link between health and PA may also be bidirectional (Paggi, Jopp, & Hertzog, 2016), arguing that health status conditions PA intensities. Regarding the possible causation of happiness to social capital, studies highlight that happier people have more prosocial behaviour (Jasielska & Rajchert, 2020). Finally, empirical evidence has shown that social support and social networks have a significant and positive effect on PA (e.g. Chen et al., 2019).

Considering this evidence, we identify a significant research gap. Previous studies only analyse the direct effects between PA and happiness, and just a few researchers consider the role of health (e.g. Ross et al., 2019; Zhang, Chen, & Chen, 2021) and social capital (Downward et al., 2018) as mediators of this relationship. Also, to our best knowledge, no previous study has considered different PA intensities in these relationships. Consequently, the main objective of this paper is to explore the mutual interactions between different levels of PA (total, vigorous, moderate and walk), happiness, SPH and social capital. We hypothesise that the relationships between the variables involved in our analysis are bidirectional. In order to verify this hypothesis, we test bidirectional models between PA and

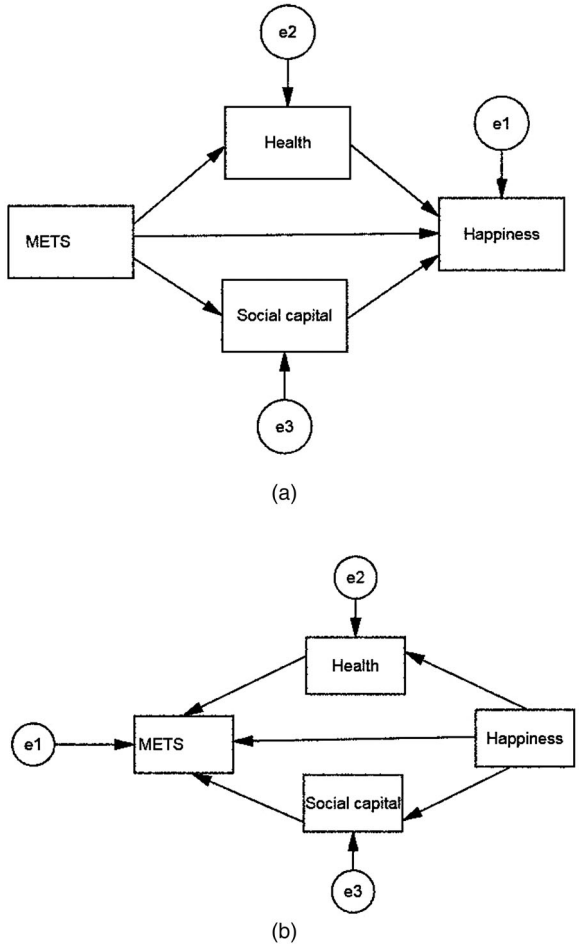

Figure 1. Research models. (a) Model with Happiness as dependent variable. (b) Model with METs as dependent variable.

Note: METS means "Metabolic Energy Expenditure of Tasks" and ei stands for error variables, i.e. disturbances.

happiness mediated by SPH and social capital in an attempt to elucidate whether the association is more robust stemming from PA to happiness or vice versa, taking into account the total effects (i.e. both direct and indirect). This is developed by means of a SEM (Structural Equation Modelling) analysis, which is a powerful multivariate approach that allows these mutual relationships to be tested. Research models are shown in Figure 1.

2. Material and methods

2.1. Data

Our database comes from the Spanish National Health Survey (ENSE) 2011–2012 (Spanish Ministry of Health, 2014). This national survey has been conducted periodically every five years by the Spanish Ministry of Health and follows the general guidelines established by the European Health Interview Survey (EHIS). ENSE, like EHIS, consists of different modules on health status, health care use and health determinants for populations of 15 years of age and older and living in private households. The ENSE 2011–2012, for the first time, applies the short version of the International Physical Activity Questionnaire (IPAQ) and the EuroQol instrument with five dimensions (EQ-5D-5L) to measure PA and SPH, respectively. These two reasons justify the use of this dataset since, unfortunately, the last ENSE from 2017 does not follow this approach.

ENSE 2011–2012 data were collected from June 2011 to June 2012 by computer-assisted personal interviews (CAPI) and face-to-face interviews among adults. The initial sample consisted of 21,007 people aged 15 years and older and the estimated response rate was 89.6%. The final sample decreased to 6,000 individuals because of missing values in the key variables and because the IPAQ questionnaire was only applied to people between 18 and 69 years of age. Consequently, our final sample included 15,370 individuals and was representative of the national distribution of the Spanish population in terms of gender and age (Spanish Ministry of Health, 2014). According to the European legislation (i.e. Regulation EU N° 2016/679 of the European Parliament and the Council of 27 April 2016, European Union, 2016) and since the data are anonymized, their use for research purposes does not require the approval of an accredited ethics committee (Spanish National Statistics Institute, INE, 2017).

PA is measured through the short version of the IPAQ developed by Craig et al. (2003) and adapted to the Spanish language by Román Viñas, Ribas Barba, Ngo, and Serra Majem (2013). This methodology has been applied by the WHO and the European Commission to measure the amount of PA in populations between 18 and 69 years of age in more than 75 countries. According to WHO (2019), PA includes any physical activity that lasts at least ten minutes during work (PA performed in the job when not sitting), active commuting or travel (e.g. walking or cycling for going to work, shopping, etc.), in leisure time (including sporting activities, training and other recreational pursuits, such as going for a walk, dancing or gardening) or through housework (e.g. cleaning the house, taking care of elderly people or children, etc.). Following previous empirical evidence (Castellanos-García, Lera-López, & Sánchez-Santos, 2021; Wicker & Frick, 2017) and the European Commission (2018) guidelines (i.e. all continuous walks of at least ten minutes without stopping with the purpose of increasing the physical condition), walking is considered to be light intensity activity.

Therefore, with the information provided regarding time spent (minutes) and frequency (days per week) in light (walk), moderate and vigorous PA, we calculated the Metabolic Energy Expenditure of Tasks (METs) during a week as a continuous variable for vigorous PA (*METs vigorous*), moderate PA (*METs moderate*), light PA (walk) (*METs walk*) and for total PA (sum of vigorous, moderate and light; *METs total*). Following the approach developed by Ainsworth et al. (2011), we assigned an intensity unit of 3.3, 4.0 and 8.0 METs to light (walk), moderate and vigorous activities, respectively, in order to quantify the energy cost of weekly PA. Values are expressed in METs·minutes per week^{-1}.

Health identifies the self-assessed health status on a visual analogue scale (EQ-VAS) that is obtained by applying the EuroQol EQ-5D-5L as a measure of health. This is a standardised health-related quality of life questionnaire in which the current health status of individuals is described through five dimensions (mobility, self-care, usual activities, pain/discomfort and anxiety/depression). The EQ-VAS was self-reported by respondents and provided data on individuals' subjective perceptions of some relevant aspects of their health. It assesses the subjective health status on a scale ranging from 0 (worst imaginable health state) to 100 (best imaginable health state). This evaluation has been widely applied and it is the most recommended instrument throughout many countries (Feng, Kohlmann, Janssen, & Buchholz, 2020).

Happiness denotes the level of happiness following the methodological approach adopted in international statistics such as the European Values Survey and the World Values Survey. It is a well-known survey first developed in 1981 and currently used in more than 100 countries due to internal consistency, validity, reliability

and a high degree of stability over time (Frey & Stutzer, 2002). Happiness is addressed with the following statement: "Taking all things together, would you say that you are … ". The level of happiness is then measured on a scale ranging from 1 (not at all happy) to 4 (very happy).

Social capital is measured through the Abbreviated Duke Social Support Index (DUKE-UNC-11). The DUKE-UNC-11 was designed by Broadhead, Gehlbach, Degruy, and Kaplan (1998) to measure perceived social support. It consists of 11 items measuring both a subjective evaluation of the adequacy of support received as well as a more objective evaluation of the type and number of social interactions. The item's response options are on a 5-point scale ranging from 1 (much less than I would like) to 5 (as much as I would like). All the scores are summed and an average is calculated, meaning that a higher score implies a greater level of social support. The instrument has been applied in many studies, particularly in primary care settings, for measuring social. In Spain, it has been included in the ENSE since 2006.

2.2. Statistical analysis

To analyse the mutual interactions between PA, SPH, social capital and happiness, we applied the Structural Equation Modelling (SEM) analysis, a powerful multivariate approach that tests causal relationships by simultaneously estimating direct and indirect or mediating effects among the variables of interest. Mediation analysis helps to identify intermediate variables that lie in the causal pathway between the exposure and the outcome. Bearing in mind Figure 1 and considering that PA intensity was included in separate models (one for each of the four measures) as outcome or exposure variables rather than including all intensity PA in a model, we posed eight different SEM models. These models were standardised in order to calculate standardised estimates.

One of the most common approaches in the software used to estimate structural models (in our study, IBM SPSS AMOS) is maximum likelihood (ML), which is efficient and unbiased when the assumptions of multivariate normality are fulfilled. The sensitivity of this estimation method to non-normality generates the need of alternative estimation techniques. In our case, where non-normal variables (either ordinal or continuous) are present and we have a great sample, we used the asymptotically distribution-free ADF procedure. To do so, we opted to obtain bias-corrected estimates using 1,000 bootstrap samples.

Regarding the goodness-of-fit statistics, a combination of different fit indices should be used. Although, *a priori*, a statistically significant chi-square would indicate a poor fit, we have to consider the fact that this indicator is generally weak for big sample sizes like ours (Hu & Bentler, 1999). Therefore, we consider other alternatives, such as the CFI (Comparative Fit Index) or the RMSEA (Root Mean Square Error of Approximation). CFI values close to 1 indicate a very good fit. In relation to the RMSEA, a value of about 0.05 or less would indicate a close fit of the model, and a value of about 0.08 or less would imply a reasonable error of approximation; we should not employ a model with a RMSE greater than 0.1.

As this study is not a randomised controlled trial (our current sample was selected from a population), the presence of confounding variables could lead to biased results. Unfortunately, according to literature, there are many factors that might influence our variables of interest. Particularly, demographic variables (i.e. gender and age) and socioeconomic status are traditionally considered (i.e. Cabane & Lechner, 2015; Zhang & Chen, 2019).

Considering these studies and confounders in the previous evidence (i.e. Downward et al., 2018) and limited to the data available in our study, we selected three potential confounding variables: *Age* [with three groups: 18–34 years (4,070 people), 35–64 years (9,933) and more than 64 years (1,367) individuals]; *Gender* [two groups: males (7,391 people) and females (7,979)]; and *Socioeconomic status*, proxied by the social class based on occupation status [three groups: skilled workers (8,144 people), skilled agricultural workers and semiskilled workers (4,747) and non-skilled workers (2,479)].

The methodology we use in our estimations requires the variables to be continuous, and obviously this condition is not met for two of our confounding variables: *Gender* and *Socioeconomic status*. On the other hand, regarding our unique continuous confounding variable, *Age*, there is wide evidence (e.g. Cabane & Lechner, 2015) that its impact is non-linear, so this confounder does not fit to the features of our modelling, which is based on linear relationships. Thus, it is unfeasible to include our confounding variables as control variables in our SEM models. Therefore, to test the influence of the confounders, we performed multi-group analyses.

3. Results

Table 1 shows the descriptive statistics on participants' socioeconomic characteristics, as well as the variables included in the structural equation modelling.

Regarding the SEM models, first, we considered the models for the different levels of PA, taking *Happiness*

Table 1. Main descriptive statistics of variables included in SEM models and potential confounders.

	N (*)	Mean	Median	Mode	Standard Deviation	Minimum	Maximum
METs vigorous	2,931	594.189	0	0	1,717.499	0	10,080
METs moderate	4,294	427.661	0	0	1,007.359	0	5,040
METs light	1,1261	1,160.279	693	0	1,249.691	−594	4,158
METs total	13,055	2,182.130	1386	0	2,129.195	0	11,040
Health	15,309	0.938	1	1	0.149	−1	1
Social capital	15,370	47.958	50	55	7.345	11	55
Happiness	15,176	1.967	2	2	0.436	0	3
Gender (1)	15,370		2	2		1	2
• Male	7,391						
• Female	7,979						
Age	15,370	44.364	44	37	14.151	15	69
• 18–34 years	4,070						
• 35–64 years	9,933						
• > 64 years	1,367						
Marital status (2)	15,370		2	2		1	9
• Single	5,089						
• Married/Living in common	8,481						
• Widowed	648						
• Separated	418						
• Divorced	719						
• No reply	15						
Social class based on occupation status (3)	15,370		4	5		1	9
• 1st class	1,742						
• 2nd class	1,269						
• 3rd class	2,918						
• 4th class	2,215						
• 5th class	4,747						
• 6th class	2,090						
• No reply	389						

Notes: (*) Sample size, non-zero responses. (1) 1 = male, 2 = female. (2) 1 = single, 2 = married/living in common, 3 = widowed, 4 = separated, 5 = divorced, 9 = I don't answer. (3) 1 = Managers, chief executives in firms with 10 or more employees, professionals with university degree; 2 = Managers, chief executives in firms with less than 10 employees, professionals with bachelor degree; 3 = Technicians and self-employment workers; 4 = Intermediate managers and skilled workers; 5 = Skilled agricultural workers and semiskilled workers; 6 = Non-skilled workers; 9 = Non-answer.

Table 2. SEM estimates for the models with Happiness as dependent variable.

	Models with Happiness as dependent variable		
	MODEL 1a: METs total		
	Total effect	Direct effect	Indirect effect
METs total → Health	0.128****	0.128	–
METs total → Social capital	(−0.007)^{ns}	(−0.007)	–
METs total → Happiness	0.047***	0.020	0.027
Health → Happiness	0.216****	0.216	–
Social capital → Happiness	0.102****	0.102	–
	Chi sq. (d.f.); *p*-value	CFI	RMSEA (90% CI); PCLOSE
	121.689 (1); < 0.001	0.781	0.089 (0.076–0.102); < 0.001
	MODEL 1b: METs vigorous		
	Total effect	Direct effect	Indirect effect
METs vigorous → Health	0.080****	0.080	–
METs vigorous → Social capital	0.027****	0.027	–
METs vigorous → Happiness	0.045***	0.025	0.0201
Health → Happiness	0.217****	0.217	–
Social capital → Happiness	0.102****	0.102	–
	Chi sq. (d.f.); *p*-value	CFI	RMSEA (90% CI); PCLOSE
	114.700 (1); < 0.001	0.776	0.086 (0.073–0.100); < 0.001
	MODEL 1c: METs moderate		
	Total effect	Direct effect	Indirect effect
METs moderate → Health	0.042****	0.042	–
METs moderate → Social capital	(−0.039)****	(−0.039)	–
METs moderate → Happiness	0.024**	0.019	0.005
Health → Happiness	0.217****	0.217	–
Social capital → Happiness	0.102****	0.102	–
	Chi sq. (d.f.); *p*-value	CFI	RMSEA (90% CI); PCLOSE
	122.205 (1); < 0.001	0.719	0.089 (0.076–0.102); < 0.001
	MODEL 1d: METs light		
	Total effect	Direct effect	Indirect effect
METs light → Health	0.074****	0.074	–
METs light → Social capital	(−0.018)**	(−0.018)	–
METs light → Happiness	(−0.001)**	(−0.015)	0.014
Health → Happiness	0.219****	0.219	–
Social capital → Happiness	0.101****	0.101	–
	Chi sq. (d.f.); *p*-value	CFI	RMSEA (90% CI); PCLOSE
	121.789 (1); < 0.001	0.726	0.089 (0.076–0.102): < 0.001

Notes: Bias-corrected estimates using 1,000 bootstrap samples.
****p-value < 0.001; ***p-value < 0.01; **p-value < 0.05; *p-value < 0.10; ns Not significant at the 10% level.
90% CI = "Confidence Interval at the 90% level".
PCLOSE = p-value for testing the null hypothesis that the population RMSEA is no greater than 0.05.

as the dependent variable (Figure 1(a), where METs means "Metabolic Energy Expenditure of Tasks" and e_i stand for error variables, i.e. disturbances). The corresponding results are shown in Table 2 with the goodness-of-fit measures.

From Table 2, we can see that absolutely all the *METs variables* are very highly correlated with *Health* with a positive association. However, the relationship between *METs indicators* and *Social capital* is completely mixed: *METs total* has no significant relationship, whereas *METs vigorous* has a positive and noticeable effect. This is in contrast with *METs moderate* and *METs light (walk)*, which shows a negative effect. Most of the different measures of METs show a positive and very significant effect on *Happiness*, with the only exception being *METs light* with a negative association. Additionally, both *Health* and *Social capital* exert a positive and very important influence on *Happiness*. Finally, METs indicators were indirectly associated with *Happiness* both through *Health* for any type of PA level and for *METs vigorous* in the case of *Social capital*.

In these models, the chi-square is statistically significant due to the big sample size, and the CFIs are below 0.95, which indicates a poor fit. We could also say that RMSE is on the edge.

In order to obtain evidence about the existence of a simultaneous and bidirectional relationship between different levels of PA and happiness, we decided to try a different model, taking the METs measures as dependent variables (Figure 1(b), Table 3). According to the results shown in Table 3, it is not surprising that *Health* has a highly significant (p-value < 0.0001) positive association in all the cases. The interrelationship of *Social capital* is relevant (although as a whole, it is less so than in the case of the former variable) and its sign is mixed: while it is positive for *METs vigorous*, the opposite occurs for both *METs moderate* and *METs light*. Regarding *METs total*, the influence of *Social capital* is negative. Finally, *Happiness* has a significant positive relationship with all types of METs and with relation to *Health* and *Social capital*. *Happiness* is indirectly and positively associated with *PA levels* through *Health* for

Table 3. SEM estimates for the models with METs as dependent variable.

	Models with METs as dependent variable		
	MODEL 2a: METs total		
	Total effect	Direct effect	Indirect effect
Health → METs total	0.128****	0.128	–
Social capital → METs total	(−0.016)**	(−0.016)	–
Happiness → METs total	0.053***	0.023	0.030
Happiness → Health	0.253****	0.253	–
Happiness → Social capital	0.141****	0.141	–
	Chi sq. (d.f.); *p*-value	CFI	RMSEA (90% CI); PCLOSE
	63.446 (1); < 0.001	0.887	0.064 (0.051–0.077); 0.039
	MODEL 2b: METs vigorous		
	Total effect	Direct effect	Indirect effect
Health → METs vigorous	0.073****	0.073	–
Social capital → METs vigorous	0.019**	0.019	–
Happiness → METs vigorous	0.047****	0.026	0.021
Happiness → Health	0.253****	0.253	–
Happiness → Social capital	0.141****	0.141	–
	Chi sq. (d.f.); *p*-value	CFI	RMSEA (90% CI); PCLOSE
	63.446 (1); < 0.001	0.877	0,064 (0.051–0.077); 0,039
	MODEL 2c: METs moderate		
	Total effect	Direct effect	Indirect effect
Health → METs moderate	0.041****	0.041	–
Social capital → METs moderate	(−0.043)****	(−0.043)	–
Happiness → METs moderate	0.027***	0,022	0.005
Happiness → Health	0.253****	0.253	–
Happiness → Social capital	0.141****	0.141	–
	Chi sq. (d.f.); *p*-value	CFI	RMSEA (90% CI); PCLOSE
	63.446 (1); < 0.001	0.855	0.064 (0.051–0.077); 0.039
	MODEL 2d: METs light		
	Total effect	Direct effect	Indirect effect
Health → METs light	0.084****	0.084	–
Social capital → METs light	(−0.019)**	(−0.019)	–
Happiness → METs light	0.003*	(−0.016)	0.019
Happiness → Health	0.253****	0.253	–
Happiness → Social capital	0.141****	0.141	–
	Chi sq. (d.f.); *p*-value	CFI	RMSEA (90% CI); PCLOSE
	63.446 (1); < 0.001	0.858	0.064 (0.051–0.077); 0.039

Notes: Bias-corrected estimates using 1,000 bootstrap samples.
****p-value < 0.001; ***p-value < 0.01; **p-value < 0.05; *p-value < 0.10; ns Not significant at the 10% level.
90% CI = "Confidence Interval at the 90% level".
PCLOSE = p-value for testing the null hypothesis that the population RMSEA is no greater than 0.05.

any type of PA level and for *METs vigorous* in the case of *Social capital*.

In relation to the goodness-of-fit statistics, the chi-square is, again, statistically significant for the same reason as seen in the former model. CFI values are below 0.95, which would mean a poor fit, but they are higher than they were in the first model. The RMSEA results imply a reasonable error of approximation that is better than that of the other model and very close to the value of 0.06, which is the "ceiling" established by some authors (Hu & Bentler, 1999) in order to consider the RMSEA to be "acceptable".

In summary, the second model behaves better than the previous one and is considered to be reasonably adequate for the analysis posed in this research, especially if we keep in mind the size of our sample, which is much higher than the average in any standard SEM study and makes model fit difficult.

A possible concern about our structural equation models is that they did not consider any confounding individual variables. The poor goodness-of-fit might be because these confounding variables were not taking into account in the models. For this reason, we carried out multiple-group analyses for our three potential confounding variables to check if the structural relations among our variables of interest can be considered invariant across the different groups considered. In all these cases, we developed nested model comparisons to test an unconstrained model for all the corresponding groups combined (where structural coefficients can be different for each group) against a constrained model (where structural coefficients are supposed to be equal between groups). If the chi-square difference statistic is significant between the unconstrained and constrained models, then we conclude that the confounding variable in question should be included in the model, significantly changing the results previously obtained in Tables 2 and 3. In addition, we made pairwise parameters comparisons by means of critical ratios for searching significant differences between parameters across groups in the unconstrained models.

The statistically significant results of this robustness check show that when we control for age, gender or socioeconomic status, goodness-of-fit is slightly better in general, and the sign of the coefficients are always exactly the same as in the previously estimated models. Therefore, considering this information, it can be confirmed that the results presented in Tables 2 and 3 are very robust. However, we found some changes regarding the size of the impacts and/or statistical significance that are summarised as follows.

On the one hand, for the models where *Happiness* is the dependent variable, the most outstanding cases were: (i) in Model 1c, where the relationships of *METs moderate–Health* and *METs moderate–Social capital* are non-significant for groups 1 (18–34 years) of *Age* and 3 (Non-skilled workers) of *Socieconomic status*, respectively; and (ii) in Model 1d, where the link between *METs light* and *Health* is non-significant for Group 1 (18–34 years) of *Age*. On the other hand, for the models where *METs* is the dependent variable, there are also two relevant cases: (i) in Model 2b, the link between *Happiness* and *METs vigorous* is non-significant for Group 2 (Females) of *Gender*; and (ii) in Model 2c, the relationships between *Health-METs moderate* and *Social capital-METs moderate* are non-significant for groups 1 (18–34 years) and 3 (More than 64 years) of *Age*, whereas the link between *Social capital* and *METs moderate* is non-significant for group 3 (Non-skilled workers) of *Socioeconomic status*. The full results are available for any researcher in the following link: https://drive.google.com/file/d/1vjiWdV6yqEHJdXuT1Pr0NQetLvU05fnf/view?usp=sharing

4. Discussion

Our results highlight a network of association between different levels of PA, SPH, social capital and happiness. Also, it seems that there is a more robust association stemming from happiness to PA than vice versa, confirming the empirical evidence shown by Downward et al. (2018). In particular, the direct relationship between PA and happiness depends on the level of participation intensity, with moderate and vigorous activities yielding a positive increase in happiness, while light has a negative impact, partially confirming previous empirical evidence (Downward & Dawson, 2016; Silva et al., 2020; Zhang et al., 2022). It could be suggested that PA requires a minimum of intensity to have a direct influence on happiness. In addition, this result could be associated with the fact that in Spain many adults are encouraged by doctors to practice light intensive activity such as walking regularly, which could be associated to health purposes more so than to social and recreational reasons. Nevertheless, feeling happier leads to more PA at any level. The exception is for women for whom happiness does not an impact on practicing more vigorous PA, revealing the differences between males and females in happiness and PA levels (Badr et al., 2021; Zhang & Chen, 2019).

We also found that the pathways between PA intensities and happiness are closely tied to mediating effects through SPH and social capital. A clear mediating or indirect effect of SPH on the relationship between PA intensities and happiness is shown, as noted in the literature about PA for the general population (Downward et al., 2018; Ross et al., 2019; Zhang et al., 2021), meaning that PA may contribute to individuals' happiness directly and as a function of perception of health-related quality of life. The mediating effect of SPH could be explained by the health benefits of PA and the positive association between SPH and happiness as described in the first section. Only in the case of people less than 35 years old is this mediated effect of SPH not confirmed for moderate and light PA, showing that young people are less worried about health than other age groups and that vigorous PA is more associated with SPH than moderate-light PA due to its direct effects on health status (Rosen & Hagströmer, 2019; WHO, 2019).

The mediating influence of social capital on the relationship between PA intensities and happiness is weaker but still significant, as noted in the literature (Downward et al., 2018; Kim, Ryu, Lee, Kim, & Heo, 2020), and it cannot be confirmed for some age groups, emphasising some age differences previously shown (Pawlowski, Downward, & Rasciute, 2011). A distinctive result is that the mediation in this case is closely determined by the intensity of the PA developed by the individual. In other words, the mediating role played by social capital depends on the intensity of PA. When vigorous PA is developed, the mediating influence of social capital is positive, whereas if the PA is moderate or light, the mediating influence is negative. In this way, it is shown that vigorous PA promotes the formation of social capital, and at the same time, people with a relatively higher stock of social capital have a higher probability of participating in PA, particularly at the vigorous level (Chen et al., 2019).

From a health policy perspective, our results suggest that practically any type of PA (in terms of intensity) can be used as a policy tool to directly encourage the SPH of individuals. Also, SPH mediates the association between PA and happiness, particularly for vigorous PA. As a consequence of the simultaneity, involvement in PA not only increases SPH and mediates happiness, but happiness also signifies better health and higher PA,

subsequently leading to positive increases in both health and happiness and multiplying the effects of these interrelationships. Nevertheless, as explained below, this virtuous circle or causal spiral does not always run successfully when social capital is considered to mediate the relationship between PA and happiness. In fact, this might explain why it has proven to be very difficult for health policymakers to fight against inactivity and a sedentary lifestyle within a large part of the population.

Traditionally, PA has been seen as a healthy instrument to improve health (WHO, 2019) and consequently happiness (Ross et al., 2019; Zhang et al., 2021). At the same time, much PA could be enjoyable and the social activities in which it occurs could promote networks and social relationships, which subsequently increase happiness. In this vein, previous evidence has shown that this mediating role played by social capital is more remote than the health mediating role (Downward et al., 2018). Confirming this evidence and according to our findings, social capital mediates between PA and happiness when social networks are developed among participants, and these networks seem to be more associated to vigorous PA than moderate and light PA. More specifically, our results suggest that the mediating role of social capital depends on the intensity of PA, with some differences in terms of individual's age for moderate PA. In terms of opportunity costs, this might explain why any policy measures to raise vigorous PA could have a closer relationship with happiness through the mediating role of social capital than moderate and light PA. A closer relationship with happiness would subsequently imply closer ties with health outcomes and more involvement in PA. This implies that PA-based social capital intervention can add significant value to the general population's happiness, and such value subsequently improves the population's self-perceived health levels. Only when people participate in vigorous PA does the virtuous circle run successfully, multiplying the positive effects of these networks.

5. Strenghts and limitations

The primary strength of this study was the use of different PA intensities to analyse the relationships between PA and happiness and the mediator roles played by health and social capital. To our best knowledge, no previous study has considered different PA intensities in these relationships. We obtain that these relationships depend on the level of participation intensity (moderate and vigorous activities), suggesting that PA requires a minimum of intensity to have a direct influence on happiness. Additionally, from a conceptual framework, we consider that the relationships between these variables are bidirectional. A novel finding of this research is that there is a more robust association stemming from happiness to PA than vice versa. Also, the use of the SEM approach give us the possibility to estimate direct and indirect causal effects among our variables. Finally, a main strength of the study lays on the large number of individuals from a representative sample, allowing for the adjustment in terms of age, gender and socio-economic status.

However, this study is not without limitations. The use of a very large sample size implies that some of the goodness-of-fit statistics could show poor fit. A second limitation is related to the utilisation of subjective measures of health status, happiness, social capital and PA levels. Although all these variables have been validated in many previous studies, they might be susceptible to socially acceptable answers. Another potential limitation has to do with the nature of the data. The cross-sectional nature of the survey precludes us from establishing causal chains among the variables. Additionally, the application of the long version of the IPAQ would give us the possibility to separately analyse the PA levels in four different domains: work, displacement, leisure time and home. Last, but not least, given the timing of data collection (between 2011 and 2012), our results might be not reflective of the current situation.

6. Conclusions

This paper offers new insights about the interrelationships among key variables of public and health policy, including PA, SPH, happiness and social capital. For the first time, this paper analyses these interrelationships, making distinctions between different PA levels. Our research shows that PA and happiness are simultaneously related and mediated through SPH and social capital. SPH positively mediates this relationship independently of the PA levels, whereas social capital positively mediates the relationship only when vigorous activity is developed but is negative when PA is moderate and light in intensity. This suggests that policymakers could encourage any PA to improve health and happiness, but at the same time, the development of social networks through vigorous PA could attract new participants or increase the intensity level of actual participants.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Ministry of Economy and Competitiveness [grant number: Project CSO2017-86178-R]; Spanish Ministry of Science and Innovation [grant number: Project PID2020-115018RB-C32 (MCIN/AEI/10.13039/50)] Open access funding provided by Universidad Pública de Navarra.

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