An insight into physical activity across domains: implications for depression and perceived health

ABSTRACT

Research question: The main purpose of this paper is to gain a better understanding of the potential beneficial effects of leisure time, travel and work-related physical activity on diagnosed depression and perceived health. The effects of smoking and drinking lifestyles are accounted for as well. Previous economics research has primarily focused on examining the effects of leisure - time physical activity on physical health outcomes. However, non-recreational physical activity domains as well as their effects on mental conditions have received less attention.

Research methods: A multivariate probit model of diagnosed depression, self-assessed health, regular recreational physical activity, active travel, physical activity during principal daily activities, regular drinking and current smoking behaviour was applied using a sample of 16,121 adults from the 2014 European Health Survey in Spain.

Results and Findings: There is evidence that the physical activity domain is relevant to health outcomes but the results are heterogeneous. While both work-related and travel-related domains reduce the likelihood of depression and contribute to better self-perceived health, the recreational domain has no direct influence on health. Moreover, unobservable effects suggest a positive correlation between the physical activity domains. The same applies to health outcomes as depression and poor subjective health are positively correlated.

Implications: This research contributes to the literature by demonstrating that there are heterogeneous effects of physical activity on health. Findings support actions that prioritise physical activity in the non-recreational domains. Bringing physical activity into the daily routine would mitigate the burden of physical and mental conditions in healthcare systems.

Keywords: Physical activity domains; lifestyles; depression; self-assessed health; multivariate probit regression

Introduction

More than 70% of the Spanish population reports good health (OECD, 2017). However, the globalization of unhealthy lifestyles along with an increased life expectancy have resulted in an escalation of non-communicable diseases (NCDs) worldwide. Specifically, in Spain, 45% of people aged 16 or over suffer from at least one NCD (INE, 2013), with depression becoming a major mental disorder. Depression is linked to a greater medical comorbidity, high dependency and substantial costs for healthcare systems (Arias-de la Torre et al., 2018; Schuch et al., 2018). This has resulted in its prevention being included for the first time in the United Nations' Sustainable Development Goals (World Health Organization, 2017).

The main objective of this paper is to explore the association between domain-related physical activity, drinking and smoking, and distinct health outcomes. Lifestyles -in particular smoking, drinking, and physical activity- have been associated with health status, and it is also recognized that many health-risk behaviours emerge in combination and consequently it is relevant to discuss the link between them (Poortinga, 2007). Smoking is especially relevant in Spain because its prevalence in adults is higher than in most EU countries (OECD, 2019). Regarding physical activity (PA), which is the lifestyle in which we focus our work, individuals can engage in PA in different domains of everyday life: leisure time, commuting, or daily chores including housework and work-related tasks. Spain has the second-lowest figures in terms of moderate weekly PA in the EU (OECD, 2017). In terms of recreational sports,[1] there has also been a slight decline in the proportion of Spaniards who play sport with some regularity, and the proportion of those who never engage in sports is

[1] Physical activity and sport are differently conceptualized, but it can be argued that sport is embedded in the physical activity notion (see e.g., Muñiz & Downward, 2019).

increasing (European Commission, 2018). Regarding active travel, whilst the proportion of individuals walking regularly is among the highest across the EU, Spain exhibits the lowest percentage of daily cycling in urban areas across EU (European Commission, 2013, 2018). Moreover, work and home as domains for PA are also very unusual in Spain, particularly the work domain (European Commission, 2018).

The benefits of regular recreational PA on health have been broadly analysed in the economics literature whereas the effect of PA done during commuting or principal daily activities has been less studied. However, there is extensive research on the effect of different domains of PA in health sciences. Saunders et al. (2013) review the literature on the health benefits of active travel, whereas Honda et al. (2015), Kuwahara et al. (2016), and White et al. (2017) study domain-specific effects for physical or mental health indicators. Modern life brings less physical effort in household chores, in the workplace and travel. However, non-leisure PA domains may lead to better health outcomes because they can be undertaken more regularly and for longer periods than leisure-time PA. Additionally, the intensity of PA during active travel or at the workplace may be higher than in some leisure physical activities.

More specifically, Teychenne et al. (2020) suggest that the PA domain plays an important role in the prevention of mental illness. In line with this, Jurakic´ et al. (2010) note that it is relevant to account not just for overall PA but for the specific domain in which it takes place, as leisure time, transportation, domestic and occupational domains have different effects on health-related quality of life indicators. Consequently, a holistic approach of the different domains of PA might be crucial to plan strategies and policies to promote PA and ultimately health. For instance, the provision of bicycle lanes or PA and sports facilities around workplaces could be beneficial as the strategic location of PA and sport facilities is central to promoting the participation of individuals (Hallmann et al., 2012).

Theoretical framework and literature overview

There is a vast literature on the effects of PA on various health outcomes in health-related sciences and, to a lesser extent, in economics. In this section, we briefly describe the dominant theoretical framework in economics research to explain the relationship between PA and health. Then, we summarise the empirical literature on the subject.

Theoretical framework

Most of the economics literature on health and PA follows the theoretical neoclassical approach, which assumes that individuals are rational and make decisions about consumption and time allocation with the goal of maximizing their welfare subject to monetary and time constraints. Within this framework, Becker (1964) developed the human capital theory and suggested health as a type of human capital. Subsequently, he constructed a formal model of households as producers of commodities using time, goods and services purchased in markets (Becker, 1965). Such a model is underpinning Grossman's health demand model (1972, 2000). Grossman suggests that health differs from other types of human capital in that it does not directly affect productivity, but it increases the time available for working or producing commodities at home. Moreover, it is argued that health has a direct effect on utility as well as an indirect effect through the time constraint. In addition, individuals inherit a health stock that depreciates over time but can be improved by using inputs such as time, medical care, diet, exercise, recreation and so on.

Subsequently, Cawley (2004) presented a theoretical economic framework to understand PA and nutrition, known as the SLOTH model, which has been widely recognized in sports economics analysis. According to Cawley, an individual’s utility depends on time spent sleeping (*S*), at leisure (*L*), at occupation (*O*), in transportation (*T*), in home production (*H*) as well as on weight, health, food and other goods. Individuals face budget, time and biological constraints to maximize the utility. Under these assumptions, PA for recreational purposes is part of '*L*', PA for travel purposes is part of '*T*' and PA during principal daily activities is part of '*O*' and '*H*'. Consequently, PA has a direct positive effect on an individual's welfare, but it also has an indirect impact through its effect on health and weight. Cawley's model is especially relevant to our approach because it highlights the different areas in which PA can take place.

Literature overview

There is ample empirical evidence in health sciences about the positive effects of regular PA on different health outcomes (Pedersen & Saltin, 2015; Warburton & Bredin, 2016; Warburton et al., 2006). Regarding studies distinguishing among the domains in which PA can be done, Honda et al. (2015) concluded that vigorous exercise had an effect on diabetes while occupational PA and walking to work were not associated with this disease. Kuwahara et al. (2016) found however that moderate or vigorous recreational PA as well as high occupational PA had an effect on the risk of metabolic syndrome unlike commuting PA. In terms of commuting PA, Celis-Morales et al. (2017) reported that cycling reduces the risk of a wide array of health issues, while commuting on foot was only associated with a lower risk of cardiovascular disease in a sample of workers. Finally, Saunders et al. (2013) made a review of the empirical health studies about the benefits of active travel and they stated that the evidence is not conclusive, although positive effects tend to be found when travelling long periods.

Regarding the effects of PA on mental health, recent meta-analyses reported positive effects on the symptoms of anxiety and the physical and psychological quality of life of individuals with depression (Schuch et al., 2016; Stubbs et al., 2017). High levels of PA have also been shown to have a more powerful impact on depression than low levels of activity (Schuch et al., 2018). White et al. (2017) have conducted a meta-analysis exploring different domains of PA and concluded that PA at home and work worsened mental health as opposed to the positive effects from PA in the domains of leisure and transport. Morres et al. (2019) found that moderate PA reduces depression and suggested that this might be related to the PA domain. They concluded that more research was required on the relationship of the different domains of PA to diagnosed depression. Chalder et al. (2012) also reported that PA had no effect on self-reported depression for adults.

There is therefore evidence of different effects of the domains as well as different implications for physical and mental health. For instance, regarding non-recreational domains, positive associations with physical health but mixed associations with mental health have been recognized for active travel. In terms of occupational PA, mixed associations with physical health have been found, with some studies indicating a beneficial association with depression (see Mason et al., 2016).

With regard to health indicators, although they are frequently analysed in isolation, it is now recognized that there is an association between mental and physical health, but little is known about the pathway between them (Ohrnberger et al., 2017). The World Health Organization also recognizes that severe mental disorders including depression are associated with poorer health, e.g., cardiovascular disease or diabetes mellitus (WHO, 2018a). Finally, Collins et al. (2012) summarise the contemporary health science focusing on severe physical illnesses affecting people with major mental disorders.

In terms of the sports economics literature, Cabane and Lechner (2015) reviewed the correlates and determinants of PA, as well as its effects on associated outcomes, including health. They concluded that there was an overall positive impact of PA on health outcomes such as self-reported health status and different NCDs. Importantly, this survey did not address the effects of PA on mental health. On the other hand, the economics literature on the impact of active travel and work-related PA is still scarce.

Therefore, the literature has shown that PA and health are generally correlated but causality is difficult to identify because there may be potential unobserved variables, such as time preferences, psychological or sociological factors that affect both of them, which may lead to inconsistent estimates (Wooldridge, 2010). Some studies try to control for this endogeneity problem. In particular, Colman and Dave (2013), Lechner (2009), Sari and Lechner (2015), Brechot et al. (2017), and Sarma et al. (2014) provided estimates about the influence of PA on various objective health measures as well as subjective health, trying to identify causality by means of the research method and the panel structure of the data. Other authors analysed the potential causal effect of PA on health with cross-sectional data applying bivariate or multivariate probit (MVP) models, which allow for correlation between unobservable factors that influence both PA and health outcomes. Specifically, Humphreys et al. (2014) estimated recursive bivariate probits of participation in leisure-time PA and several objective health outcomes and obtained a clear impact. Sarma et al. (2015) used both bivariate recursive probit models and linear instrumental variable models of recreational PA and several objective health outcomes and health risk factors, and including work-related PA as an additional explanatory variable. They found that leisure-time exercise reduced the probability of obesity but did not affect other health indicators. However, PA at work not only reduced the probability of obesity but also the probability of NCDs. The first findings are in line with Brechot et al. (2017) which suggested that sport did not have an effect on an array of health outcomes though it played a role in overweight and sleeping problems. Rashad (2007) focused on the effects of cycling on different health indicators, using longitudinal data and propensity score methods. The results showed positive effects of cycling on mental health and, in the case of men, on diabetes. However, most of the results suggested a non-significant effect on high cholesterol.

Finally, Contoyannis and Jones (2004) and Balia and Jones (2008) applied MVP models to examine the relationship between several lifestyles (exercise, diet, smoking, drinking alcohol, sleep, weight and stress) and different health indicators. Both studies concluded that exercise had important effects on the likelihood of reporting good or excellent self-assessed health, although Balia and Jones (2008) found that exercise was not significant in the mortality equation.

In summary, the empirical literature about the impact of PA and sports on health that controls for possible endogeneity problems has produced mixed results. Previous studies have suggested either a positive or a non-significant relationship depending on the data and the type of health indicator considered.

Data

In the empirical analysis, we used micro-level data from the European Health Survey in Spain (EHSS -2014) conducted in 2014 by the INE (INE, 2015). EHSS is a large cross-sectional survey carried out every five years in Spain and is designed to collect information about individual health status, use of health care services and potential health determinants. The questionnaire is filled in by an individual aged 15 or over who is randomly selected among the household members. The survey is harmonized and comparable at European level. We limit our study to the adult population who provide information on all variables used in our empirical specifications and who are not severely limited in their daily activities due to long-standing health problems (these individuals are excluded because they cannot freely decide on certain lifestyles).

Self-assessed health ('SAH') is one of the measures used to capture health status. The question regarding SAH is the following: 'In the last twelve months, would you say your health has been very good, good, fair, bad or very bad?'. From this, we generate a binary variable equals to one for bad or very bad perceived health.[2] Analogously, a binary variable ('Depression') is defined as taking value one if the individual has been diagnosed with depression and has been suffering from it during the past 12 months. Table 1 reports the definition and main summary statistics of all variables. According to the figures, 7% of the adult population was diagnosed with depression and 6% reported poor or very poor SAH in the sample.

<<INSERT TABLE 1 APPROXIMATELY HERE>>

There are several questions in the survey about time spent on PA in different domains of daily life in a typical week. In terms of recreational PA, the individual was asked: '(…) how many days do you participate in sport, gymnastics, cycling, brisk walking, etc., for at least 10 minutes in a row?'. From here, we defined a binary Leisure Time Physical Activity ('LTPA') variable equals to 1 when the frequency is three days or more.[3] Analogous to LTPA, regular Active Travel ('AT') is a binary indicator equal to 1 if the individual walks and/or uses the bike to make trips at least three days a week.

[2] Because our specification is a MVP model, the dependent variables are binary, despite the survey records some of them in greater detail. This is the case of SAH, which is recorded as an ordered variable with five categories. Though it is likely that merging categories results in loss of information, the aggregation also overcomes the problem of having very few observations in some categories.

[3] There is evidence to support beneficial effects of continuous exercise versus high-intensity exercise on health-related outcomes and that a frequency of at least 3 times of PA a week is required as well (Keating et al., 2014; Wenger & Bell, 1986). Harvey et al. (2018) also suggest that regular recreational PA of any intensity prevents depression.

In addition to LTPA and AT, there is a third domain that should be investigated, that is, PA in everyday activities (household chores, work, etc.). We defined a binary dependent variable ('WRPA') that is equal to one if the individual is physically active in the main daily activity, be it study, work or home tasks, and zero when the individual is sitting most of the day (see detailed description in Table 1).

Though our main purpose is to break down PA into three domains, our research accounts for other important health-risk factors: drinking and smoking, which may have the same endogeneity problems as the PA variables. 'Drinking' is a binary variable equal to one when the individual drinks alcohol at least 5 days a week. 'Smoking' is a binary indicator that captures whether the individual is a current smoker.

Methodology

A MVP to address the simultaneous determination of health indicators, PA in different domains and smoking and drinking behaviours was implemented. Consequently, we estimated the following seven-equation system allowing correlation among the unobservable factors that affect these variables:

$$Depression = f\ (LTPA\ , AT\ , WRPA, Smoking, Drinking, Z\ ) \qquad 1.\text{a}$$

$$SAH = f\ (LTPA\ , AT\ , WRPA, Smoking, Drinking, Z\ ) \qquad 1.\text{b}$$

$$LTPA = f\ (I, Z) \qquad 1.\text{c}$$

$$AT = f\ (I, Z) \qquad 1.\text{d}$$

$$WRPA = f\ (I,\ Z) \qquad 1.\text{e}$$

$$Drinking = f\ (I, Z) \qquad 1.\text{f}$$

$$Smoking = f\ (I, Z) \quad 1.\text{g}$$

In the previous equations, we omitted the individual subscripts for notational convenience. We specified the health equations (1.a-1.b) including PA in the different domains, smoking and drinking as explanatory variables, as well as a vector of covariates (Z). Z includes those variables that may determine preferences or the amount of goods and time allocated to improve health (sex, income, age, marital status, or labour status); the efficiency in health production (e.g. educational level) or differences in healthcare services and environmental factors (regional dummies). All these factors are usually considered in the economics literature on health-related outcomes.

Although theoretically the model could be identified by its functional form (Wilde, 2000), it is difficult to achieve convergence without exclusion restrictions. Therefore, the lifestyle equations (1.c -1.g) were estimated including the same covariates as the health equations (Z) plus a set of variables (I) to facilitate parameter identification: urbanization level, activity sector, number of children in the household, number of adults in the household and nationality. We exclude the variables related to household composition from the health equations because they are expected to play an indirect role in individual preferences and decisions about health through their effect on lifestyles (Di Novi, 2010, 2013). For the same reason, we believe that nationality does not have a direct impact on health (Haan & Myck, 2009). Population size variables are also excluded from the health equations because different locations may indirectly affect health through actions that promote healthy lifestyles like PA (Stevenson et al., 2016). Additionally, we have used the activity sector to facilitate the identification of lifestyle equations, since PA in the different domains is related to the activity sector (see e.g., Jans et al., 2007). We checked these exclusion restrictions on a statistical basis. First, we estimated a MVP model similar to our main specification, but without exclusion restrictions. Then, we re-estimated the MVP progressively dropping from the health equations: urbanization variables, activity sector, number of adults and children in the household, and nationality. Both the Akaike Information Criterion and the Bayesian Information Criterion were smaller and smaller as those variables were gradually excluded. Similar variables have also been excluded in related literature (Balia & Jones, 2008; Contoyannis & Jones, 2004).

The system of equations was estimated by maximum simulated likelihood, assuming that the error terms of the latent equations follow a multivariate normal distribution, with zero means and unit variances. More specifically, the Geweke-Hajivassiliou-Keane (GHK) simulation method, which relies on a Cholesky factorization was applied. The GHK method is consistent 'as the number of draws and the number of observations tend to infinity' (Cappellari & Jenkins, 2003, p. 282). In the next section, we focus on the results corresponding to 220 draws although, according to Cappellari and Jenkins (2003), it would be sufficient to set a number of pseudo-random draws equal to the square root of the sample size.

Results and discussion

Prior to discussing the primary results of the regression, we present a descriptive analysis of the sample. Table 2 provides information about the subsample of individuals who are physically active in leisure, transport and work-related domains on a weekly basis. This information is categorized in terms of the individual's physical and mental condition. 77% of the sample walked and/or cycled at least 3 days a week on trips, which shows the preponderance of regular walking in Spain. Similarly, 66% did not exhibit a sedentary pattern in their daily routines. However, under a third of the sample took part in LTPA. Looking at the health status of individuals who were regularly active in leisure, travel and work-related domains, most of them reported good or very good health as well as no depression diagnosis.

For each specific domain, the rates of physical health problems are slightly below those for depression disorders when the individual is physically active.

<<INSERT TABLE 2 APPROXIMATELY HERE>>

Though the primary aim of our research is to explore the effects of each specific PA domain on SAH and diagnosed depression, we have previously estimated a MVP without distinction of PA domains. Therefore, this model consists of five equations and there is only one PA variable, which is equal to one if the individual is physically active in any of the three domains previously defined (LTPA, AT or WRPA).[4] Our main variable of interest - overall PA - is significant and has the expected effect on health outcomes: it decreases the probability of self-reporting a bad health status, as well as the probability of suffering from depression.

Next, we present the results of our main estimates, in which we distinguish three domains of PA, so that we estimate a seven-equation system of two health outcomes and five lifestyle equations. Table 3 shows the coefficients and t-statistics of the MVP model.

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Interestingly, we find different impacts of the PA domains on health. Looking at the equations of depression and SAH, there is no significant effect of regular LTPA on health outcomes. This is in line with Brechot et al. (2017), who examine two measures of perceived overall health and conclude that there are no health impacts from sports activity, using an instrumental variables approach. Sari and Lechner (2015) demonstrate positive effects of PA on self-rated health for men. However, they note that this beneficial impact is only reached with a moderate level of PA. Consequently, it may be that the intensity of practice or the type

[4] Further information is included in a supplementary file. Table A1 in the Appendix shows the coefficients and t-statistics of this MVP model. Table A2 shows the correlation matrix.

of exercise are relevant in explaining health outcomes, but we cannot check this with our data. Another plausible reason is some kind of compensatory behaviour, in the sense that some people who do LTPA may also have other behaviours that counteract the benefits of PA for health, such as more calorie intake than recommended.[5] However, regular AT reduces the probability of reporting a poor SAH or depression. PA during transport has also been linked to improvements in chronic diseases such as cardiovascular disease but not with an amelioration in other diseases, including diabetes or risk of metabolic syndrome (Celis-Morales et al., 2017; Honda et al., 2015; Kuwahara et al., 2016). In terms of mental health, White et al. (2017) suggest positive effects from transport domain. Rasciute and Downward (2010) also obtain positive effects of walking and cycling. Regarding WRPA, according to our results, it improves SAH and mental health. Kuwahara et al. (2016) and Sarma et al. (2015) also report positive health effects of high levels of occupational PA. Conversely, a recent meta-analysis suggests that PA at work and home worsens mental health (White et al., 2017).

In addition to the effects of the PA domains, other covariates are also associated with SAH and diagnosed depression. '*Drinking*' is associated with a lower probability of reporting bad or very bad health and to be diagnosed with depression. The reason could be that '*Drinking*' measures regular consumption but not intensity. This may corroborate a beneficial effect of moderate use of alcohol on health (Kenkel, 1995; Sayed & French, 2016). However, being a current smoker is positively associated with depression but not with SAH. In terms of the rest of the covariates, most of the results are consistent with previous findings in which the socioeconomic status plays a fundamental role in explaining health outcomes. It is also worth noticing that some sociodemographic covariates have a different effect on SAH and

[5] Courtemanche et al. (2020) suggest compensatory behaviour as an explanation for the small effect of PA on body mass that they find.

depression. In particular, males and married people are less likely to suffer from depression but these variables are not significant in the case of SAH. Turning now to the determinants of PA (*eq. 3-5*), although there are some discrepancies between domains, the results are in line with the general findings in previous literature (see Cabane & Lechner, 2015, for a survey).

The estimated correlation coefficients between the different equations are presented in Table 4. A likelihood-ratio test leads us to reject the null hypothesis of no correlation among the seven equations. The coefficients reveal that there is a negative correlation between LTPA and bad health outcomes. Thus, we do not find a significant direct effect of LTPA on our health indicators, but we do find that there are unobserved factors that increase both the probability of LTPA and the probability of having good self-reported and mental health. A relationship of complementarity is also suggested between LTPA, AT and WRPA in the sense that the correlation coefficients between domains are all positive and statistically significant, so that individuals who are prone to being physically active in one context are also more likely to be active in other domains. Finally, there are unobservable effects that lead to a very significant connection between depression and poor SAH. This reinforces the evidence that people with major mental disorders are also more likely to suffer from serious physical diseases (Collins et al., 2012).

<<INSERT TABLE 4 APPROXIMATELY HERE>>

We have conducted additional estimates to check the sensitivity of our results to the specification assumptions. Firstly, we have performed falsification tests that may be useful to ascertain whether our exclusion restrictions are valid. We follow Humphreys et al. (2014), who estimated two bivariate probits of PA and particular chronic conditions, assuming that PA was not related to these diseases. In our case, two MVP models including a health equation and three equations for each of the PA domains were estimated. [6] In one of them, the health variable captures whether the individual has suffered from allergy during the previous 12 months and, in the other one, the health indicator is equal to one if the individual has suffered from haemorrhoids in the previous 12 months. Our hypothesis is that allergies and haemorrhoids are not associated with PA and the estimates confirm it.

Secondly, we have specified a MVP model that differs from our primary estimates in the definition of the recreational PA variable, which is defined in a more restrictive way: it is equal to one if the individual has done PA 3 or more days and at least 150 minutes in a typical week. This specification underpins our results regarding the sign and the significance of PA domains.

Thirdly, we estimated univariate probit models for each health variable and the results show that the three PA domains reduce the likelihood of suffering from depression or reporting a bad health status. [7] Therefore, comparing these estimates with our main specification, we may conclude that the impact of LTPA on health is not direct but through the correlation between unobserved factors that affect PA and health, so that when this correlation is not controlled for, LTPA becomes significant.

Nevertheless, the fact that many people do PA in more than one domain might difficult the identification of the effects of these variables and might explain the lack of significance of LTPA. That is why we have estimated a MVP model taking into account just one PA domain (LTPA) –i.e. the model consists of five equations for Depression, SAH, LTPA, Smoking and Drinking- and constraining the sample to those individuals who either do LTPA or are not physically active at all. In this case, LTPA is significant and has the expected negative

[6] We did not include the equations for smoking and drinking in the falsification tests because the correlation coefficients between these lifestyles and health outcomes were not significant at 5% level in our main specification, but we keep these two variables as explanatory covariates in the health equations.
[7] The results of the robustness checks are available upon request.

coefficient. Therefore, when LTPA is analysed in isolation and the control group consists of individuals who do not do any type of PA, the results reveal that LTPA has beneficial effects for both SAH and depression.[8]

Conclusion

There is a widespread belief in economics and health sciences that regular PA has positive effects on health outcomes. Moreover, the analysis of specific domains of PA is important as social changes and technical progress may lead to insufficient levels of PA during domestic and occupational activities and the use of non-active modes of transport. Consequently, this could have a detrimental impact on health. However, there is scarce economic literature that discriminates the specific health impacts of the PA domains. Empirical research focuses primarily on the recreational domain and it usually analyses the effects of this specific domain on several health indicators separately. What is more, the effects of PA on objective mental diseases have been rarely analysed in the economics literature.

This research explores the effect of PA done at different domains of life on health outcomes, although the specification also accounts for smoking and drinking lifestyles. There are several contributions to the literature. Firstly, two different measures of health -SAH and diagnosed depression- are jointly examined. Secondly, PA is segregated in three different types: LTPA, AT and WRPA, which is informative for governments to promote PA and public health by prioritising the domains that are the best drivers of health. Thirdly, we assume that lifestyles and health outcomes may be simultaneously affected by unobserved factors, so that a MVP model is estimated. As far as we know, this is the first study to apply

[8] The results of this estimation are included in Tables A3 and A4 in the Appendix.

this methodology to the simultaneous analysis of SAH and mental conditions along with potential determinants of health.

Policy implications

The empirical analysis carried out can be helpful in designing public policies to foster PA. Our results suggest that PA improves mental and SAH but, when we separate the three domains in which it is performed - daily tasks, leisure and travel - we observe some interesting differences. Regular walking and/or cycling for travel purposes and daily activities such as household chores contribute to better SAH and lower the probability of diagnosed depression. These results are consequently informative for governments in prioritising the incorporation of PA into daily routines of individuals to promote more active lifestyles. This is especially relevant in the scenario of the COVID-19 pandemic, given the increase in teleworking, which has caused a decrease in mobility that can remain in the long term if there is a permanent shift in companies' work patterns. Therefore, governments should make the population aware of the benefits of being physically active. Moreover, PA in daily activities would be more accessible to the general population and probably more sustainable in the long term. In terms of costs, there is evidence that active travel brings significant savings to health systems by causing benefits on the physical health and depression of individuals in addition to other indirect effects that are beneficial to public health such as reducing pollution (Jarrett et al., 2012). Our results support European and national actions that recognize the potential of PA domains for the purpose of travel and in the principal daily activities for enhancing the promotion of PA (WHO, 2018b).

Other conclusions may also be drawn from the residual correlation coefficients. There is a significant positive association between depression and poor perceived health. This could have implications for a more holistic approach to health systems that comprehensively address physical and mental disorders. Moreover, the positive correlations between PA domains seem to indicate that they are not mutually exclusive activities. On the contrary, people who are active in one PA domain are also more likely to be active in other PA domains. Therefore, policies targeted at promoting PA in a specific domain could enhance overall PA leading to further health benefits and the subsequent cost savings to health systems.

Limitations and future research

This study has some limitations. The lack of significance of LTPA in our main specification could be due to the difficulty of identifying the effect of each PA-related domain when they are simultaneously analysed. In fact, LTPA becomes significant when we study it in isolation and change the control group as well. This problem could be better solved if we had panel data to control for unobserved individual heterogeneity. Moreover, cross-sectional data do not allow the analysis of longitudinal effects. Consequently, we cannot check whether previous PA is most relevant for explaining health than current PA.

Another issue to consider is that PA data are self-reported, and some studies suggest that more objective measures would be appropriate (e.g., using accelerometers) since there is evidence that individuals are likely to underestimate the smoking status and overestimate PA as well (Ainsworth et al., 2006; Gorber et al., 2009). It would also be interesting to have data on the intensity or the type of practice to ascertain the effect of other PA dimensions apart from frequency. Finally, a future avenue of research might be to identify the mechanisms underlying the different impacts of the PA domains.

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Table 1

Descriptive statistics

Variable	Description	Mean	SD	Min	Max
Depression	'1' if diagnosed depression	0.07	0.26	0.00	1.00
SAH	'1' if bad or very bad self-assessed health	0.06	0.24	0.00	1.00
LTPA	'1' if doing leisure-time physical activity ≥3 days (for at least 10 minutes at a time) in a typical week	0.31	0.46	0.00	1.00
AT	'1' if walking and/or using the bike ≥3 days to make trips in a typical week	0.77	0.42	0.00	1.00
WRPA	'1' if standing most of the day; walking, carrying some weight or making frequent trips; or performing tasks that require great physical effort	0.66	0.47	0.00	1.00
Drinking	'1' if having alcoholic drinks (wine, beer, etc.) at least 5 days in a typical week	0.19	0.39	0.00	1.00
Smoking	'1' if current smoker	0.25	0.43	0.00	1.00
Sex	'1' if male	0.47	0.50	0.00	1.00
Age	Age in years	52.06	17.54	18.00	98.00
Educ1	'1' if primary education	0.41	0.49	0.00	1.00
Educ2	'1' if secondary education	0.27	0.44	0.00	1.00
Educ3	'1' if degree from university or equivalent	0.20	0.40	0.00	1.00
Income1	'1' if the household's total net monthly income between 970 and 1,400 €	0.23	0.42	0.00	1.00
Income2	'1' if the household's total net monthly income between 1,400 and 2,040 €	0.25	0.43	0.00	1.00
Income3	'1' if the household's total net monthly income between 2,040 and 3,280 €	0.16	0.37	0.00	1.00
Income4	'1' if the household's total net monthly income above 3,280 €	0.07	0.25	0.00	1.00
Working	'1' if working	0.47	0.50	0.00	1.00
Unemployed	'1' if unemployed	0.13	0.34	0.00	1.00
Married	'1' if married	0.56	0.50	0.00	1.00
#Child	Number of children in the household	0.41	0.75	0.00	6.00
#Adults	Number of adults in the household	2.05	0.90	1.00	9.00
Native	'1' if Spaniard	0.95	0.23	0.00	1.00
Municip2	'1' if the degree of urbanization between 20,000 and 100,000 inhabitants	0.24	0.43	0.00	1.00
Municip3	'1' if the degree of urbanization above 100,000 inhabitants or provincial capital	0.41	0.49	0.00	1.00
Agriculture	'1' if working in the agricultural sector	0.02	0.15	0.00	1.00
Industry	'1' if working in the industrial sector	0.07	0.25	0.00	1.00
Construction[1]	'1' if working in the construction sector	0.02	0.16	0.00	1.00
N		16,121			

[1]*The reference category for the three variables above is individuals working in the service sector and non-workers.*

Table 2

LTPA, AT, WRPA and health

	LTPA ≥ 3 days/week		AT ≥ 3 days/week		Daily WRPA	
Health Status	*Freq.*	*Percent.*	*Freq.*	*Percent.*	*Freq.*	*Percent.*
Mental Condition						
No diagnosed depression	4,687	95.23	11,638	93.60	10,016	93.68
Diagnosed depression	235	4.77	796	6.40	676	6.32
SAH						
Fair, good or very good SAH	4,764	96.79	11,806	94.95	10,231	95.69
Poor or very poor SAH	158	3.21	628	5.05	461	4.31
Total	4,922	30.53	12,434	77.13	10,692	66.32

Table 3

Multivariate probit model: depression and SAH

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Health equations		Lifestyle equations				
			PA-related domains			Other lifestyles	
	Depression	SAH	LTPA	AT	WRPA	Drinking	Smoking
LTPA	0.276	0.283					
	(1.55)	(1.57)					
AT	-0.665***	-0.875***					
	(-3.33)	(-4.72)					
WRPA	-0.352**	-0.749***					
	(-1.96)	(-3.56)					
Drinking	-0.484**	-0.378**					
	(-2.70)	(-2.04)					
Smoking	0.455*	0.071					
	(1.85)	(0.44)					
Sex	-0.429***	-0.082	0.228***	0.096***	-0.138***	0.887***	0.254***
	(-6.15)	(-1.29)	(10.31)	(4.09)	(-6.24)	(33.02)	(10.79)
Age	0.100***	0.082***	0.001	0.027***	0.064***	0.105***	0.060***
	(11.50)	(9.30)	(0.21)	(6.54)	(16.20)	(18.39)	(12.22)
$Age^2/100$	-0.083***	-0.066***	-0.010***	-0.032***	-0.065***	-0.074***	-0.076***
	(-10.25)	(-8.19)	(-2.56)	(-7.96)	(-17.09)	(-14.69)	(-15.16)
Educ1	-0.093*	-0.141**	0.263***	0.230***	0.268***	0.089**	0.095*
	(-1.70)	(-2.51)	(6.25)	(5.81)	(6.95)	(2.02)	(2.00)
Educ2	-0.237***	-0.250***	0.431***	0.268***	-0.039	0.096*	0.003
	(-3.52)	(-3.71)	(9.07)	(5.73)	(-0.87)	(1.84)	(0.07)
Educ3	-0.340***	-0.369***	0.442***	0.315***	-0.433***	0.119**	-0.298***
	(-4.04)	(-4.37)	(8.59)	(6.07)	(-8.90)	(2.07)	(-5.16)
Income1	-0.078*	-0.141***	0.141***	0.016	0.052	0.105***	0.026
	(-1.80)	(-3.09)	(4.40)	(0.47)	(1.62)	(2.78)	(0.77)
Income2	-0.130**	-0.216***	0.218***	-0.026	0.081**	0.173***	-0.026
	(-2.66)	(-4.19)	(6.39)	(-0.71)	(2.35)	(4.30)	(-0.73)
Income3	-0.224***	-0.331***	0.277***	-0.080*	-0.134***	0.186***	-0.061
	(-3.53)	(-5.00)	(6.74)	(-1.84)	(-3.25)	(3.79)	(-1.41)
Income4	-0.369***	-0.646***	0.362***	-0.116**	-0.350***	0.228***	-0.100*
	(-3.66)	(-5.70)	(6.72)	(-2.00)	(-6.49)	(3.51)	(-1.70)
Working	-0.429***	-0.469***	-0.216***	-0.372***	-0.052	-0.030	0.177***
	(-7.89)	(-8.13)	(-6.32)	(-9.99)	(-1.50)	(-0.71)	(4.78)
Unemployed	-0.104*	-0.079	-0.080**	-0.071	0.138***	0.065	0.274***
	(-1.67)	(-1.26)	(-1.98)	(-1.57)	(3.27)	(1.25)	(6.49)
Married	-0.142***	0.054	-0.033	-0.058**	0.101***	0.042	-0.223***
	(-3.57)	(1.35)	(-1.23)	(-2.05)	(3.77)	(1.29)	(-7.92)
#Child			-0.137***	-0.042**	0.024	-0.063***	-0.081***
			(-8.26)	(-2.47)	(1.43)	(-2.93)	(-4.76)
#Adults			-0.066***	-0.031**	0.026*	-0.051***	-0.006
			(-4.75)	(-2.07)	(1.84)	(-2.84)	(-0.44)
Native			0.145**	-0.050	-0.424***	0.076	0.142***
			(2.92)	(-0.95)	(-7.94)	(1.15)	(2.88)
Municip2			0.066**	0.111***	-0.078**	-0.121***	-0.016
			(2.25)	(3.68)	(-2.63)	(-3.49)	(-0.51)
Municip3			0.102***	0.253***	-0.065**	-0.137***	-0.006
			(3.82)	(9.13)	(-2.45)	(-4.43)	(-0.21)
Agriculture			-0.499***	0.074	0.808***	-0.015	-0.037
			(-5.90)	(0.98)	(7.93)	(-0.18)	(-0.51)
Industry			-0.099**	-0.212***	0.128**	-0.022	0.080*
			(-2.22)	(-4.74)	(2.83)	(-0.42)	(1.82)
Construction			-0.273***	-0.215***	0.354***	0.132*	-0.136**
			(-3.84)	(-3.07)	(4.67)	(1.76)	(-1.96)
Constant	-2.880***	-2.208***	-0.532***	0.123	-0.507***	-4.761***	-1.687***
	(-10.84)	(-8.15)	(-4.43)	(0.98)	(-4.22)	(-26.44)	(-12.99)
N				16,121			
Log L				-47,908.20			

Notes: *t* statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; the vector of covariates also includes regional variables.

Table 4

Correlation coefficients from the MVP - main model

Equation	Depression	SAH	LTPA	AT	WRPA	Drinking	Smoking
Depression	1.000						
SAH	0.455^{***}	1.000					
LTPA	-0.185^{*}	-0.238^{**}	1.000				
AT	0.283^{***}	0.352^{***}	0.164^{***}	1.000			
WRPA	0.095	0.219^{*}	0.167^{***}	0.268^{***}	1.000		
Drinking	0.198^{*}	0.120	-0.009	-0.033^{*}	0.064^{***}	1.000	
Smoking	-0.161	0.032	-0.170^{***}	-0.061^{***}	-0.016	0.190^{***}	1.000
LR test χ_2 (21)			1,110.71				

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.