Mortality and economic expenses of cardiovascular diseases caused by physical inactivity in Spain

SÁNCHEZ-OLIVER, ANTONIO JESÚS1,2; GARCÍA, CHRISTIAN MARTÍN3; GÁLVEZ-RUIZ, PABLO4; GONZALEZ-JURADO, JOSÉ ANTONIO2

1 Area of Human Motricity and Sports Performance. Faculty of Education Sciences, Seville University, Seville, SPAIN.
2 Sport Departament. School of Sport Sciences, Pablo de Olavide University, Seville, SPAIN
3 Research Department Francisco Valsecchi, Pontificia Universidad Católica Argentina, ARGENTINA.
4 International University of La Rioja, SPAIN

Abstract:
Non-communicable diseases caused 16 million early deaths in 2016 according to the data published by the World Health Organization. Insufficient physical activity has become an international concern since several years ago and it is strongly related to these early deaths. The present study estimated the mortality and economic expenses of cardiovascular diseases caused by physical inactivity in Spain. Mortality attributable to physical inactivity (MA) was evaluated as the product between the population attributable fraction (PAF) and the number of deaths caused by associated cardiovascular diseases. The statistical value of life (SVL) was determined, following the human capital approach, from which SVL was estimated through the productivity lost by early death. The economic expenses were calculated using MA and SVL, classifying by gender, age group and level of physical activity. A sensitivity analysis was carried out to evaluate how the expenses vary in three possible scenarios. MA is very different regarding age and sex, with maximum levels in men between 35 and 69 years. The early death of younger individuals is more expensive, with a much lower SVL in old adults. The economic cost is much higher in the sample group with low physical activity, with an increase from 35 years and maximum values at 55-59 years. The economic costs varied, with 0.31% of the GDP for the minimum scenario, 0.09% for the medium scenario, and 0.03% for the maximum scenario. It is recommended to reinforce the development of public policies aimed at reducing sedentarism and physical inactivity in Spain.

Key words: physical activity; attitude; motivation; institutionalised elderly.

Introduction
Non-communicable diseases (NCD) cause 40 million deaths per year, which represent 70% of the deaths worldwide. These diseases are not transmitted among people, are of long-term duration, evolve slowly and generate high costs for healthcare systems. Every year, around 15 million people between 30 and 69 years of age die of NCD, prematurely. Cardiovascular diseases constitute most of the deaths by NCD (17.7 million per year), followed by cancer (8.8 million), respiratory diseases (3.9 million) and diabetes (1.6 million). These four groups of diseases account for over 80% of all the early deaths by NCD. Among the different types of NCD, the most important are cardiovascular diseases, diabetes and cancer (Molina, 2014). At the global level, of the 57 million people who died in 2008, 63% were due to NCD and over 80% of these deaths were caused by cardiovascular and respiratory diseases (World Health Organization, 2010). These diseases are favoured by factors such as quick and unplanned housing development, globalisation of unhealthy lifestyles and the aging of the population. Modifiable behaviours such as smoking, physical inactivity, unhealthy diets and the uncontrolled consumption of alcohol increase the risk of NCD (World Health Organization, 2009).

In Spain, as in other countries in the same socio-economic environment, most deaths are caused by NCD, with three fifths of the total mortality being a consequence of cardiovascular diseases and cancer. Cardiovascular diseases represent the first cause of death in the Spanish population, with 29% of the total mortality in 2015 (Ministry of Health, 2017).

Although sedentarism and physical inactivity have been used as synonyms, they are different. A sedentary lifestyle refers to a physiological (activities within the continuum of energy expenditure measured in metabolic equivalents <1.5 METs), postural (sitting or in a reclined position) and contextual question (in wakefulness). Currently we could define sedentary lifestyle as the absence of ambulatory movement in any position (Stamatakis et al., 2018). On the other hand, physical inactivity or being inactive refers to those people who do not perform moderate to vigorous physical activity (3-5.9 METs is considered moderate, ≥6 METs...
vigoroso) lo largo suficiente para que puedan recomendarse en los diferentes guías para ese fin (van der Ploeg & Hillsdon, 2017).

Según la Organización Mundial de la Salud (OMS), la inactividad física es el cuarto factor de riesgo de mortalidad más importante; ha sido atribuido el 5.5% de todas las muertes a nivel mundial y es responsable de 32 millones de muertes al año (OMS, 2009). Este factor de riesgo se extiende a otros países y tiene un gran impacto en la salud de la población del mundo como desencadenante de NCD.

Un análisis sistemático realizado por los colaboradores del GBD Risk Factors (2017), que proporciona una síntesis actualizada de la evidencia de la exposición a los factores de riesgo y la carga atribuible de la enfermedad en diferentes países en los últimos 25 años, concluyó que se podrían atribuir 1.6 millones de muertes al año a la inactividad física insuficiente.

Además de ser un factor de riesgo importante, la inactividad física genera un considerable costo económico para los sistemas de salud. En un análisis de la inactividad física y la obesidad en el sistema de salud pública de Ontário, Canadá, se estimó en 2009 que el costo económico era aproximadamente US$ 3.5 billones (US$ 1.2 billones en costos directos y US$ 2.34 billiones en costos indirectos) (Katzmarzyk, 2011). En Australia, modelos de simulación fueron desarrollados para calcular cuánto sería el incremento económico generado de una reducción del 10% de la inactividad física. Los resultados indicaron que esta reducción habría traducido en 6,000 casos menos de enfermedades, 2,000 menos muertes, 114,000 trabajos menos en casa y 180,000 días laborales en la producción doméstica, con un ahorro total de 96 millones de dólares australianos para el sistema de salud (Cadilhac et al., 2011). En los Estados Unidos, se estimaron los costos económicos relacionados con los recursos médicos utilizados para atender casos de sarcopenia (pérdida de masa muscular) con una población de personas mayores de 60 años de edad. En el año 2000, los costos directos derivados del tratamiento atribuible a sarcopenia fueron US$ 18.5 billones (US$ 10.8 billón para hombres y US$ 7.7 billón para mujeres), que representan alrededor del 1.5% de los costos totales de ese año (Janssen, Shepard, Katzmarzyk, & Roubenoff, 2004). Además, hay evidencia científica sólida para afirmar que los costos directos atribuibles a la inactividad física son superiores a 1% y 4% de los costos totales en la salud y los indirectos son dos veces más (Janssen, 2012). Asimismo, varios estudios muestran que las intervenciones de actividad física son cost-efectivas (Muller-Riemenschneider, Reinhold, & Willich, 2009; Wu, Cohen, Shi, Pearson, & Sturm, 2011).

Por lo tanto, la inactividad física puede generar factores de riesgo metabólicos, que son los principales factores de riesgo de las enfermedades por enfermedades crónicas no transmisibles. Los factores de riesgo metabólicos contribuyen a cuatro cambios metabólicos fundamentales que aumentan el riesgo de NCD: el aumento de la presión arterial, el sobrepeso y la obesidad, la hiperglucemia (niveles altos de azúcar en la sangre), y la hiperlipidemia (niveles altos de lípidos en la sangre) (GBD, 2017; Suárez Carmona, Sánchez Oliver, & González Jurado, 2017).

En vista de lo anterior, el objetivo del presente estudio fue estimar la mortalidad y los costos económicos causados por las enfermedades cardiovasculares atribuibles a la inactividad física en España.

**Metodología**

*Calculation of the population attributable fraction (PAF) link to physical inactivity.*

El riesgo relativo (RR) estimado en un metaanálisis (García, 2014) se usó como entrada, junto con la proporción de prevalencia del factor de riesgo obtenida de los microdatos del Encuesta Nacional de Salud 2011-2012 (Ministerio de Salud y Consumo, 2013). El PAF se puede expresar matemáticamente como:

\[
P_{AF} = \frac{P(D) - \sum_i P(D|\bar{E},i)P(i)}{P(D)}
\]

Donde \(P(D)\) es la probabilidad media de la enfermedad en una población con expuestos e inmunizados, y \(\sum_i P(D|\bar{E},i)P(i)\) representa la probabilidad marginal condicional de la enfermedad en ausencia de la exposición media en las estratificaciones de otros factores de riesgo (Rockhill, Newman, & Weinberg, 1998). Para estimar los PAFs, se han usado varias fórmulas, y en este caso, la siguiente ecuación fue aplicada para diferentes categorías de exposición como un enfoque empírico a la expresión previa:

\[
P_{AF} = 1 - \frac{\sum_{i=0}^{1} p_iRR_i}{\sum_{i=0}^{1} p_iRR_i}
\]

Donde \(p_i\) es la proporción de la población que pertenece a la categoría de exposición \(i\), y \(RR_i\) es la razón de riesgo en la categoría de exposición \(i\). Las categorías de exposición se categorizaron en METs según el metaanálisis utilizado, estableciendo tres escenarios: baja actividad física (600-3999 min/semana), media actividad física (4000-7999 min/semana), y alta actividad física (>7999 min/semana).
Estimation of mortality attributable to cardiovascular diseases associated with physical inactivity.

This was calculated using equation 3, as the product between the PAFs and the number of deaths caused by associated cardiovascular diseases:

$$MA_{e,s,n,af} = Deaths_{e,s} \cdot PAF_{e,s,n,af}$$  \[3\]

, where MA to the risk factor is the product of the number of deaths stratified by age (e) and sex (s) groups, times the PAFs stratified by groups of age, sex and level of exposure to the risk factor (level of physical activity). Given the fact that the meta-analysis does not separate the causes of death beyond cardiovascular diseases or cerebrovascular accidents (Garcia, 2014), it is not possible to separate the estimations of the economic costs by disease. Therefore, hypertensive diseases (I10-I15), heart ischemic diseases (I20-I25), other forms of heart disease (I30-I52), and cerebrovascular diseases (I60-I69) were considered, according to the International Classification of Diseases, 10th edition (Panamerican Health Organization, 2003), and based on the deaths by disease published by the National Institute of Statistics (NIS) (National Institute of Statistics, 2015).

Valuation: productivity lost by cardiovascular deaths attributable to low physical activity.

The statistical value of life (SVL) was determined by following the human capital approach, by which statistical life is estimated by the productivity lost by early death:

$$PVFI_i = \sum_{j=1}^{99} p(\text{alive})_{i}^{j} \cdot Income_{j} \cdot (1 + g)^{i-j} \cdot \left(\frac{1}{1+r}\right)^{j-i}$$  \[4\]

The SVL can be determined by using the actuarial formula proposed in equation 4, where the productivity lost by early death is estimated with the labour income that an individual receives, deducing this to obtain the present value of the future income (PVFI). In this equation, \(p(\text{alive})\) is the probability of the person with age \(i\) to be alive at age \(j\), \(Income_{j}\) is the average labour income of the people of age \(j\), \(g\) is the growth rate of the average income, and \(r\) is the deduction rate. The growth rate of the average labour income was calculated as the average growth value of the GDP per capita in the period of 2000-2016 (Aguirre Botello, 2014; Escaño-Marín et al., 2017). An average deduction rate of 5% was selected for being moderate. The probability of survival was estimated by using the mortality tables of the NIS. To calculate the probability of survival of an individual of age \(i\) at age \(i+n\), the following formula was used:

$$p(\text{alive})_{i}^{j} = \frac{k(i+n)}{i(i)}$$  \[5\]

The total average income by age is the income that the individual would have perceived if he/she would have survived. To calculate this, the microdata from the Life Conditions Survey (LCS) of 2016 were used, of which the authors only employed the labour income for all the clusters weighted by their expansion factor. However, the income by gender was not differentiated since, otherwise, there would be a marked difference between the salaries for not considering the implicit household production, along with a lower participation of women in the job market and lower average salaries.

Then, a sensitivity was conducted proposing different scenarios, with the aim of evaluating how the outputs are modified (SVL or PVFI) when the inputs (growth rate of the average product, reduction rate) vary between age groups. To carry out this analysis, a simulation of Montecarlo was performed with 20,000 iterations. In this simulation, a triangular distribution was used, which allowed reflecting different scenarios with respect to the variability of the values selected. Regarding the inputs, a minimum limit of 1% and a maximum limit of 7% were established for the product growth rate. With respect to the reduction rate, a minimum limit of 3% and a maximum limit of 7% were established, as recommended by Harrison for sensitivity analyses in this type of studies (Harrison, 2010).

Economic costs associated with cardiovascular diseases attributable to physical inactivity.

The economic costs of early death associated with the loss of productivity attributable to physical inactivity can be calculated by using the following equation:

$$CMA_{e,s,n,af} = MA_{e,s,n,af} \cdot PVFI_{e}$$  \[6\]

, where \(CMA_{e,s,n,af}\) is the economic cost by early death associated with the loss of productivity attributable to scarce physical activity, stratified by groups of age (e), sex (s) and level of exposure to the risk factor, and \(PVFI_{e}\) is the present value of the future income or SVL by age group.
Results

Figure 1 shows the mortality calculated for individuals with a low level of physical activity and stratified by sex and age. As can be observed, after the groups of 35-39 years of age, a gap begins to grow between the two curves (men and women), which reaches a maximum point in the group of 65-69 years, as a consequence of the large number of deaths in men.

![Figure 1. Mortality, number of deaths, attributable by sex and age in Spain. Source: compiled by author.](image1)

Figure 2 shows the SVL over the average growth of the GDP per capita in the period of 2000-2016, for which an average reduction rate of 5% was selected for being moderate. As can be observed, the early death of the younger individuals is the most costly. By stratifying this group, it is shown that the largest cost by early death corresponds to male individuals between 15 and 19 years of age. On the other hand, in mature adults the SVLs are lower, since this group have less years of life ahead and also because their probability of survival decreases along with their expected income.

![Figure 2. Statistical value of a life, expressed in thousands of euros, by groups of age and sex in Spain. Source: compiled by author.](image2)

Figure 3 shows the economic costs by early death associated with the loss of productivity attributable to cardiovascular diseases caused by physical inactivity, distributed in 3 levels of physical activity (according to METs) and age groups. The variation of the curves is caused by the interaction between the values of the RR, the prevalence proportion of the risk factor and the SVLs, which vary between younger individuals (who have a very high SVL and a low RR, even when they do not carry out any physical activity) and older adults. However, this graph only shows the variations of the SVL values at different ages, which does not occur with the RR (beyond the differences by level of physical activity), since these were not stratified by age. In the low level of physical activity (600-3999 METs), it can be observed that the economic cost is higher even at younger ages (18-24 years), with the curve increasing much more from 35 years and reaching a maximum value in the age group of 55-59 years. After reaching this maximum point, the SVL of the following age group (60-64 years) decreases considerably with respect to the previous group, and this decrease continues in the following groups. Although the difference between the group of low physical activity and the other two groups analysed (medium and high) is very high, the difference between the latter two is low. From all these findings, it was determined that the
economic losses varied 0.31% of the GDP for the minimum scenario, 0.09% for the medium scenario, and 0.03% for the maximum scenario.

Fig. 3. Economic costs, expressed in millions of euros, by early death associated with the loss of productivity attributable to cardiovascular diseases linked to physical inactivity, by groups of age and level of physical activity in Spain. Source: compiled by author.

Discussion

Every year, non-communicable diseases cause 16 million early deaths. Thereby, the WHO urges to double the efforts (Chan, 2016). Since several years ago, insufficient physical activity has become an international concern. In 2014, around 23% of adults and 81% of teenagers (11 to 17 years of age) were not sufficiently active (World Health Organization, 2014).

The results obtained can be compared with those of other studies carried out in other countries that used the same method with other risk factors. Thus, in 2016 the economic impact of smoking on the healthcare systems of South America was estimated (Pichon-Riviere et al., 2016). Likewise, the Argentinian Drug Observatory calculated the economic cost of the abuse of psychoactive substances, establishing this at 0.91% of the GDP for smoking, 1.07% for the consumption of alcohol, and 2.93% for the consumption of legal and illegal drugs (Argentinian Drug Observatory, 2007). Following this line, with communicable diseases, the cost of the productivity loss due to deaths associated with aids in Argentina was estimated in 2011, which was 0.40% of the GDP (Avendaño, 2011). In the same manner, with similar numbers, there are Spanish studies that estimated the mortality attributable to the consumption of illegal drugs (Teresa Brugal et al., 2004).

According to the results obtained in the present study, MA to low and moderate physical activity varied between age groups and genders. The SVL was similar to that found in other studies (García & González-Jurado, 2017). The evaluation of the total costs indicates a great economic loss in both genders, and even in early ages when the level of physical activity is low. The results indicate an important load of mortality and costs attributable to cardiovascular diseases associated with physical inactivity in Spain; thus, it is recommended to reinforce the development of public policies targeted to reduce sedentarism and physical inactivity in Spain. To this end, it is essential to know how long it would take for a state intervention to generate positive results. In this sense, it is important to mention that there is substantial scientific evidence of a causal relationship between improvements in the cardiovascular profiles of individuals and the implementation of short-term programs of physical activity (Giada, Biffi, Agostoni, Anedda, Belardinelli, Carlon, Carù, et al., 2008; Giada, Biffi, Agostoni, Anedda, Belardinelli, Carlon, Carù, et al., 2008; Pedersen & Saltin, 2015). Physical inactivity and sedentarism, with sitting time being one of the key components, have been related to a higher prevalence of diseases and higher risk of mortality from any cause (Endorsed by The Obesity Society et al., 2016). Thus, in this way, we find the paradox that there are people who practice some sport but that the time dedicated and the intensity of this activity are not adequate to assume a protection factor (Ekelund et al., 2016), or on the other hand, finding individuals who can be considered physically active despite being sedentary (Cristi-Montero & Rodríguez, 2014). It would be convenient to determine whether sedentarism influences inactive people to estimate higher costs than more active people, making them fall into a vicious circle that is difficult to leave. Thus, some researchers analysed the influence of previous experiences with physical activities on the cost-profit calculation conducted by individuals. The costs of exercising were significantly higher for individuals with less experience in exercising than for those with more experience, since the former might have had a less positive experience with exercise and more positive with the inactive leisure activities (Hagberg & Lindholm, 2010).

The importance of the present work lies in the estimation of mortality and the costs of cardiovascular deaths attributable to physical inactivity in Spain. In this sense, it is necessary to expand the research about the analysis of cost-profit in these diseases or other diseases related to physical inactivity and sedentarism, and carry out subsequent evaluations to determine whether the different strategies and policies established are improving...
the current framework. Regarding limitations, this study did not consider the costs generated from exercising, the direct costs generated from medical care, or the economic loss generated by the individuals who are excluded from the job market due to disabilities derived from cardiovascular diseases.

Conclusions

The results of this study suggest that physical inactivity poses an important economic and mortality load for the population of Spain and, as a consequence, it is recommended to develop research lines that explore the factors that affect the practice of physical activity, and to adopt efficient measures targeted to decrease this risk factor through better policies designed to reduce sedentarism and physical inactivity.

References


---