Estimating the global economic benefits of physically active populations over 30 years (2020 to 2050)

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ABSTRACT

Objectives

We assess the potential benefits of increased physical activity on the global economy for 23 countries and the rest of the world over a 30-year time horizon (from 2020 to 2050). The main factors taken into account in the economic assessment are excess mortality and lower productivity.

Methods

This study links three methodologies. First, we estimate the association between physical inactivity and workplace productivity using multivariable regression models with proprietary data on 120,143 individuals in the UK and six Asian countries (Australia, Malaysia, Hong Kong, Thailand, Singapore and Sri Lanka). Second, we analyse the association between physical activity and mortality risk through a meta-regression analysis with data from 74 prior studies with global coverage. Finally, the estimated effects are combined in a computable general equilibrium (CGE) macroeconomic model to project the economic benefits of physical inactivity over time.

Results

Doing at least 150 minutes of moderate-intensity physical activity, as per lower limit of the range recommended by the 2020 World Health Organisation guidelines, would lead to an increase in global GDP of 0.16%-0.23% per year by 2050, worth up to US $314-$446 billion per year and $6.0-$8.6 trillion cumulatively over the 30-year projection horizon (in 2019 prices). The results vary by country due to differences in baseline levels of physical activity and GDP per capita.

Conclusions

Increasing physical activity in the population would lead to reduction in working-age mortality and morbidity and an increase in productivity, particularly through lower presenteeism, leading to substantial economic gains for the global economy.

What are the new findings

- A novel study assessing the economic benefits of increased physical activity on a global scale.
- If the entire adult population was doing at least 150 minutes of moderate-intensity physical activity per week, there would be an increase in global GDP in the order of $6.0-$8.6 trillion cumulatively over the 2020-2050 period (in 2019 prices).
- The results vary by country, with United States estimated to see the greatest economic benefits both per capita and in absolute terms.

How might it impact on clinical practice in the near future

- Our results should encourage organisations and policy makers to develop new programmes and promote physical activity at the population level particularly in high income countries.
- Such policies could contribute not only to better health and lower mortality, but also to substantial economic benefits associated with increased productivity and prosperity.

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Contributors

MH and EY were co-chief investigators. MS contributed to the economic modelling and helped to rewrite the original report into a journal article. WP, JP, AD, MW, FM, SS and CvS contributed to various parts of the report and made revisions. All authors read and approve the final manuscript.

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Patient involvement

No

INTRODUCTION

Insufficient physical activity is one of the leading risk factors for death, posing a global public health problem associated with up to 5 million premature deaths every year [1, 2]. Health benefits of increased physical activity include a lower risk a series of major of diseases, such as hypertension and diabetes, to improved mental health [3, 4] and overall quality of life. Despite these well-established health benefits, insufficient physical activity has become increasingly prevalent over the last decades. Globally, it is estimated that about 30 per cent of the population is physically inactive, but the prevalence rate varies across countries [5]; in high income countries, the share of physically inactive population has increased from 31.6% to 36.8% over the 2001-2016 period. Given finite financial resources and competing health priorities, including resources dedicated to tackling the COVID-19 pandemic, public health responses to address the problem have been inadequate. Economic analysis can help in this regard to quantify the scale of the problem, increase public, policy and industry engagement, and offer data for use in public health advocacy.

Existing studies that analyse the economic burden of insufficient physical activity (see e.g. [6, 7]) are typically conducted at the national level and apply the cost-of-illness (COI) approach, varying in costs (e.g. direct and indirect) and health conditions considered. Nevertheless, they all find substantial potential savings and health benefits from a more physically active population [8-11]. A relevant literature review is presented in [7].

As Keogh-Brown and colleagues explain in further detail, such cost-of-illness studies often disregard long-term and second-order effects, limiting the scope of the analysis and thus potentially underestimating the overall costs [12]. For instance, healthier individuals may live longer and may be more productive than non-healthy individuals, earning more income and consuming more over time. The benefits of being healthier then apply not only to the individual themselves, but further create positive external effects in the economy (e.g. on firms, the government) because they may consume more, save more and pay more taxes for longer.

This study addresses these shortcomings by comprehensively estimating the global macroeconomic cost of physical inactivity using a novel general equilibrium model that captures both long term and second-order effects, and highlighting the potential health and economic benefits associated with increased physical activity, complementing the recent Global Action Plan for Physical Activity 2018-30 [13].

METHODS

The model used in this study links physical inactivity with the labour supply through excess mortality and productivity, and estimates the potential economic benefits of increasing national physical activity levels to that recommended by the 2020 WHO guidelines [14]. Due to the extent of the analysis, the following text provides a summary of the three methodological approaches used and the corresponding main findings. Full details are available in a free-access technical report that we have recently published [15]. Throughout this study, physical activity is measured using minutes of metabolic equivalents of task (MET-minutes). One MET-minute is roughly equivalent to the energy expended when sitting quietly for a minute.

Macroeconomic simulation model

The overall economic impact of increased physical activity is assessed using a multi-country, dynamic, economy-wide Computable General Equilibrium (CGE) modelling framework, an approach that has recently gained ground in health economics [16-18]. Our model is broadly based on [19, 20] and calibrated using the Global Trade Analysis Project (GTAP) v10 data [21]. The applied model is implemented in the GAMS software [22].

The economy of each country is modelled separately, considering a variety of inputs (e.g. labour, capital) and outputs (goods and services). Individual countries are linked through international bilateral trade. In all scenarios, economies grow according to their long-term growth rate derived from the total factor productivity growth, which we calibrated using data from the Penn World Tables version 9.1 [23]. The model, furthermore, includes a demographic segment, which uses a cohort-component model that projects future country populations [24]. Input data for the cohort-component model on mortality, fertility and migration are provided by the UN Population Database, covering the 2020-2100 period [25]. The analysis is conducted for 23 countries and the rest of the world,[5] and projected forwards 30-years from 2020 to 2050 to capture the dynamic demographic effects beyond the productivity benefits of improved physical activity. Additional scenarios are available in [15].

The implications of improved physical activity are reflected by an increase in the effective labour supply through a combination of two elements: (i) Improved physical activity increases the size of the labour force through a lower mortality risk. (ii) Improved physical activity raises worker productivity levels by reducing sickness absence and presenteeism.

Two scenarios are considered in the macroeconomic analysis: First, a status quo scenario, where physical activity, mortality and productivity remain at their current real-world levels. Second, a counterfactual scenario, where all people globally achieve at least 150 minutes of moderate-intensity physical activity per week (equivalent to 600 MET-minutes), i.e. lower limit of the range recommended by the 2020 World Health Organisation guidelines [14]. In this scenario, all individuals below the recommended activity threshold improve their activity levels to the recommended amount. The baseline physical activity levels by country are obtained from [5].

The analysis relies on the following simplifying assumptions: all changes to physical activity levels in the population are permanent; individuals do not engage in additional physical activity at the cost of other health-enhancing activities such as sleep; and overall consumption patterns

5 Argentina, Australia, Austria, Canada, China, Ecuador, France, Germany, Hong Kong, Japan, Malaysia, Netherlands, New Zealand, Pakistan, Philippines, Singapore, South Africa, South Korea, Sri Lanka, Thailand, United Kingdom, United States, Vietnam. All other countries are combined into ‘Rest of the World’. The countries were chosen based on data availability and representativeness of the world as a whole.

remain unchanged. Physical activity levels in the population as well as the productivity and mortality impacts are assumed to take place in the first year of the model's projection.

The following two sections explain how we link improved physical activity with mortality risk and worker productivity, which together make up the effective labour supply in the CGE model.

Linking physical activity with mortality

We apply the meta-regression approach established by [26] and previously applied in health research e.g. by [27].[6] It consists of a systematic review of the relevant empirical literature and assessment of the link between physical activity and mortality. Estimates obtained from the literature are used in a range of statistical methods to synthesise and evaluate the findings, while considering potential publication selection and study design heterogeneity.

We performed a systematic literature search up to May 2019 by searching on PubMed, Embase, Scopus, Web of Science and PsycInfo. Keywords for the search of titles and abstracts included various combinations of:

- "physical activity" OR "lifestyle activity" OR "leisure time activity" OR "occupation* activity" OR "energy expenditure" OR "energy metabolism" OR exercise OR "active commute" OR sport OR walk* OR "metabolic equivalent" OR cycling OR "physical inactivity" OR sedentary*
- AND
- "all cause mortality" OR "all-cause mortality"
- AND
- "hazard ratio" OR "relative risk" OR "odds ratio"

To be included in the review, a study needed to contain a new empirical estimate of the relationship between physical activity and all-cause mortality, together with confidence intervals, standard errors, or *t* statistics. We discarded all summaries, systematic reviews, or meta-analyses for this analysis. Furthermore, to obtain comparable estimates, we considered only studies in which physical activity estimates can be transformed into MET-minutes, i.e. those that measure activity through a combination of intensity and duration, including, through the minutes of moderate- or vigorous-intensity activity, as well as directly provided MET-minutes. Finally, we focused only on studies that use inactivity or sedentary lifestyles as their baseline and compare the relative mortality risk of individuals who are active to those who are sedentary or less active. In line with physical activity guidelines, we defined a minimum activity threshold of 500 to 600 MET-minutes per week. No additional restrictions regarding the date of publication or peer-review status were imposed. Separate studies conducted on the same cohort were included.

[6] The meta-regression analysis follows the MAER-NET guidelines: www.maer-net.org.

This process initially identified 20,135 records, including 12,739 duplicates, which were removed. These were screened on the basis of title and abstract, with 7,256 studies excluded at this stage. Lastly, the remaining 380 articles were assessed for eligibility based on full-text review: 67 articles were excluded due to insufficient level of information to obtain the equivalent of MET-minute estimates, 191 articles due to focus on non-representative population segments, and 48 articles were excluded due to lack of relevant data analysis, with 74 relevant and comparable studies remaining for the analysis. The full list of studies is provided in Table 7. We test the extracted estimates for publication bias and obtain corrected results using the precision-effect estimate with standard error (PEESE) regression model [28]. To adjust for within-study dependence, random-effect (RE) and fixed-effect (FE) estimators are applied together with clustered standard errors at the study-level.

To reflect study heterogeneity, we include a range of moderator variables, such as type of physical activity (e.g. leisure-time vs occupational), publication year, country or region, sample size, cohort size, age range of study cohort (e.g. whole population vs elderly only) and whether the underlying estimates are unadjusted or adjusted for age, gender, income, alcohol consumption, smoking, BMI, chronic health conditions. Further information about that analytical process is provided in [15].

Linking physical activity with productivity at work

Links between physical activity and productivity at work are assumed to manifest through sickness absence and presenteeism, generally defined as showing up for work when one is ill [29]. We use proprietary data from employers and employees in the United Kingdom, Australia, Malaysia, Hong Kong, Thailand, Singapore and Sri Lanka collected through Vitality's Britain's Healthiest Workplace Survey[7] and AIA Vitality's Asian Healthiest Workplace Survey.[8] We include two annual survey waves (2017-2018) for the UK and three (2017-2019) for the Asian countries, covering a total of 120,143 individuals (UK: 58,410; Asia: 61,733). The surveys are open to all organisations with 20 or more employees from any sector in the economy. Participating organisations self-select to the survey and distribute the survey links to their employees. There is no fee for participation or a selection process for participants. All employees aged 18+ are allowed to complete the survey, yet their participation is voluntary, and results are anonymised. The surveys collect responses on a range of personal, workplace and broader organisational themes. A more comprehensive description of the survey data is provided in [15, 30, 31].

We analyse the data using a set of multivariable generalized linear regression models (GLMs) with Gaussian distribution and identity link. Technical details of the model specifications are provided in [15]. Physical activity is measured using the International Physical Activity Questionnaire (IPAQ) [32] and transformed into MET-minutes per week according to the

[7] See www.rand.org/randeurope/research/projects/britains-healthiest-workplace.html for more information.

[8] See www.rand.org/randeurope/research/projects/asia-s-healthiest-workplace.html for more information.

IPAQ guidelines, i.e. with moderate activity equivalent to 4 METs and vigorous activity equivalent to 8 METs. Absence and presenteeism are measured using the Work Productivity and Activity Impairment (WPAI) questionnaire [33] with a 7-day recall period. WPAI assesses the number of hours missed from work, the number of hours worked, and the degree to which respondents feel that a health problem affected their productivity while at work. WPAI outcomes are expressed as impairment percentages due to absence, presenteeism or both, where a higher percentage indicates greater work impairment and lower productivity. All information is self-reported.

All regression models were adjusted for sociodemographic, health and work-related factors. In order to account for heterogeneity in workplace environments, we included company identifier dummy variables in all GLMs and therefore only exploit variation across employees within the different organisations participating. Further included are dummy variables for the week, month and year of the survey response given. Standard errors are clustered at the organisational level and statistical significance was assessed at a significance level of 0.05. All statistical analyses were conducted in STATA 16 (StataCorp, College Station, TX).

RESULTS

Physical activity and mortality risk

The systematic literature review process identified 74 relevant and comparable studies, providing 1,124 estimates of relative all-cause mortality risk (RR) associated with insufficient physical activity. Descriptive statistics for the meta-sample is provided in Table 8. Table 1 summarises the meta-regression estimates by gender and geographical region. The presented meta-regression estimates for RRs compare individuals with moderate and high levels of physical activity to the baseline low-activity group and are based on estimates adjusted for age, underlying health conditions and lifestyle factors.

Physical activity is associated with lower all-cause mortality. Estimates suggest greater benefits for females than males, and residents of the USA and Europe than Asia. Note that the estimates are based on the information provided in the primary studies and do not indicate the underlying reasons for differences by gender or region. We use the relative mortality risk parameter estimates for the moderate activity group by gender and region for the counterfactual scenario in the economic model.[9] Applying our counterfactual scenario with increased levels of physical activity and reduced mortality will therefore have a positive effect on size of the labour force in the future.

[9] In the economic model we applied the mortality risk estimates for Asia to the rest of the world group as they tend to be more conservative (lower in magnitude) than the estimates for the United States and Europe.

Table 1: Physical activity and all-cause mortality risk

Gender	Region	Physical activity level: Moderate	High
Female	United States and Europe	0.72 (0.68 to 0.76)	0.66 (0.61 to 0.70)
	Asia	0.83 (0.79 to 0.88)	0.77 (0.72 to 0.82)
Male	United States and Europe	0.78 (0.74 to 0.82)	0.71 (0.67 to 0.76)
	Asia	0.89 (0.85 to 0.94)	0.83 (0.79 to 0.88)

Note: All-cause relative risk estimates are compared to physically inactive individuals (less than 500 to 600 MET-minutes per week, baseline RR = 1) which is taken as baseline. Moderate = 500-1,500 MET-minutes per week. High = more than 1,500 MET-minutes per week. 95% confidence intervals in parentheses.

Physical activity and productivity

The results of the regression analysis assessing the association between improved physical activity and productivity are presented in Table 2. It summarises the estimated associations across both gender and survey regions for different levels of physical activity, controlling for socio-economic, work-related, health and lifestyle factors. Additional results differentiated by gender, age and region are reported in [15].[10] The descriptive statistics for all variables used in the analysis are presented in Table 5. On average, the survey participants reported doing 975 MET-minutes of activity per week and lost 10% of their work time due to absence (2%) and presenteeism (8%).

As summarised in Table 2, physical activity is associated with higher levels of workplace productivity, with individuals doing 600-750 MET-minutes of physical activity per week reporting, on average, a 0.8-1.5 percentage point (pp) lower work impairment due to absence and presenteeism than inactive individuals (those performing less than the recommended 600 MET-minutes per week). The productivity loss reduction increases with the level of physical activity reported. The specific value estimate depends on the number of correlates considered in the analysis; models with fewer correlates assign higher importance to physical activity. Physical activity is assumed to affect productivity both directly and indirectly, through a range of mediation factors such as improved physical and mental health. More complex models, however, may unintentionally control for some of the indirect effects. As a result, two inputs are considered in the simulation model: a low estimate of 0.8 pp and a high estimate of 1.2 reduction in productivity loss, as per columns (2) and (3) in Table 2. These two parameter values are applied for all countries and regions analysed in the economic model.

[10] No statistically significant differences in the parameter estimates for the association between physical activity and productivity were found by (a) gender; (b) age; (c) or by region of the survey sample (e.g. UK vs. Asia).

Table 2: The association between physical activity and work impairment due to absence and presenteeism (% of work time lost)

		(1)	(2)	(3)
MET-minutes per week	600–750	**-0.015****	**-0.012****	**-0.008****
		(-0.011 to -0.019)	(-0.008 to -0.016)	(-0.004 to -0.012))
	750–900	**-0.022****	**-0.017****	**-0.011****
		(-0.016 to -0.028)	(- 0.013 to -0.021)	(-0.007 to -0.015)
	900–1,500	**-0.024****	**-0.018****	**-0.011****
		(-0.02 to -0.028)	(-0.14 to -0.22)	(-0.007 to -0.15)
	1,500–2,100	**-0.031****	**-0.024****	**-0.016****
		(-0.025 to -0.037)	(-0.02 to -0.28)	(-0.012 to -0.02)
	>2,100	**-0.033****	**-0.027****	**-0.018****
		(-0.029 to -0.032)	(-0.023 to -0.031)	(-0.014 to -0.022)
Controls	Socio-demographic	Yes	Yes	Yes
	Work-related	No	Yes	Yes
	Health and lifestyle	No	No	Yes

Notes: ** $p<0.01$, * $p<0.05$. n = 117,240. 95% confidence intervals in parentheses. Regression model in column (1) controls for age, gender, education, marital status, ethnicity, financial concerns, being a carer for a child or ill family member, engagement in voluntary or civic activities, and country- and time-fixed effects; column (2) additionally controls for work-related factors, including working irregular hours, total hours of work per week, job position, income and stress at work; column (3) additionally controls for lifestyle, physical and mental health variables, including excessive alcohol consumption, smoking, psychological distress, chronic illnesses, sleep length and BMI. All model specifications include organisational dummy variables, as well as dummy variables for the week, month and year of the survey response given. Estimates need to be multiplied by 100 to calculate the percentage point change in work impairment due to absenteeism and presenteeism. Results based on Table A.8 in [15].

Economic benefits of physical activity

The economic benefits from physical activity improvements are reported in Table 3. These are reported in the form of added gross domestic product (GDP) – a measure of the aggregate economic output of a country – in constant prices (i.e. disregarding inflation). The ‘low’ and ‘high’ scenarios correspond to the two distinct productivity parameters reported in the previous section. Table 6 provides a detailed breakdown by country, and further information on the sensitivity analysis is provided in [15].

As reported in Table 3, compared to the baseline (status quo) scenario, global GDP is estimated to be 0.15%-0.24% higher, on average, per year over the 30-year period. The immediate productivity gain is assumed to fully manifest in the first year and remain constant thereafter; further gains then accumulate over time through a comparatively larger labour force and the secondary and multiplicative effects in the economy. Therefore, the change (between adjacent time periods) in annual and cumulative benefits increases in later years. For example, Table 3 shows that the annual economic gain rises from US $138-$203 billion in 2025 to $314-$446 billion in 2050. Finally, the total cumulative difference in economic output over the 30-year period is US $6.0-$8.6 trillion, or approximately $3,060-$4,409 per adult who becomes more physically active.

Table 3: Estimated difference in annual global GDP relative to baseline scenario with current physical activity levels.

		Scenario	2025	2030	2035	2040	2045	2050
Aggregate	**Annual, %**	Low	0.15	0.15	0.16	0.16	0.16	0.17
		High	0.22	0.22	0.23	0.23	0.23	0.24
	Annual, US$ billion	Low	137.5	167.1	198.1	231.9	270.3	313.5
		High	203.3	243.1	285.6	332.4	385.7	446.3
	Cumulative, US$ trillion	Low	0.4	1.2	2.1	3.2	4.5	6.0
		High	0.6	1.7	3.1	4.7	6.5	8.6
Per more active adult	**Cumulative, US$**	Low	246.0	652.1	1,118.8	1,684.0	2,343.1	3,059.8
		High	363.6	958.0	1,632.6	2,446.1	3,388.3	4,408.5

Notes: All US$ values in 2019 prices.

Most of the gains are a result of an improvement in productivity (i.e. lower absence and presenteeism rates) as shown in Table 4.

Table 4: Estimated global GDP gain in US$ billion 2019 prices, by mechanism (mortality, absence, presenteeism), average over the assumed 30-year period.

	Total	Mortality	Absence	Presenteeism
Scenario 1 (Low)	219.7	33.2	28.7	157.8
Scenario 1 (High)	316.1	33.2	55.9	227.0

DISCUSSION

There are numerous benefits of improving physical activity, from better mental and physical health, lower all-cause mortality rates, and higher workplace productivity to improved life satisfaction. While the direct economic benefits associated with lower cost of healthcare have been thoroughly investigated in prior literature, the broader macroeconomic benefits presented in this study have been missing from the overall picture. The analysis suggests that improving physical activity in the population, even by making everyone adhere to the lower threshold of the 2020 WHO guidelines range [14] could be associated with economic benefits, potentially adding trillions of dollars in added economic output over a 30-year period and providing a range of other benefits to the people affected.

Critically, the threshold of 150 minutes of moderate-intensity physical activity (or its equivalents) can be achieved by fast-pace walking for e.g. 10-20 minutes after each lunch, cycling to work a couple times per week or by choosing to walk instead of using car or public transport more often. Indeed, the Global Action Plan for Physical Activity (GAPPA) 2018-30 suggests integrating physical activity into settings in which people live, work and play, as well as promoting sports and active recreation, which can in turn become key drivers of tourism, employment and infrastructure [13].

The reality is that the process of achieving such a change at the population or even global scale will be slow and difficult. GAPPA adopted a target of 15% relative reduction in the global prevalence of physical inactivity in adults and in adolescents by 2030, an extension of an earlier commitment by the WHO Member States of 10% by 2025. Although the current GAPPA target is significantly below the level of change assumed in this study, the associated benefits would remain substantial: using the methodology discussed above, we estimate that by achieving the GAPPA target, $25.0-$36.5 billion could be added to the global GPD annually by 2030.

To the best of our knowledge, only one study has assessed the macroeconomic benefits of getting people to be more physically active, looking specifically at the Canadian economy [34]. Considering reductions in premature mortality, sickness absence and disability, the study estimates that getting 10% of Canadians with suboptimal levels of physical activity to exercise more would increase Canada's GDP by CAN$7.5 billion cumulatively between 2015 and 2040. Our estimates for Canada are higher as they also consider the added benefits of lower presenteeism rates, which are estimated to contribute more than the reduction in mortality and sickness absence combined (see Table 6). A study by PJM Economics [35] estimates the potential benefit of improved productivity due to higher levels of physical activity to UK businesses at £6.6 billion per year, broadly in line with our findings for the UK.

Our analysis considers only the adult population, potentially underestimating the total effect if, for instance, children and adolescents benefit from better health and educational outcomes by becoming more physically active [36, 37]. It is also important to highlight that this study does not consider the direct healthcare cost associated with physical activity, estimated at additional $53.8 billion annually [6]. We also do not directly quantify the intangible effects from being more physically active, such as higher life satisfaction or happiness.

However, it is important to highlight that this analysis does not consider in detail the potential cost associated with getting people to be more active. Such costs could include the direct costs of interventions and the unobserved negative utility cost for people who dislike physical activity. Utility costs are difficult to measure and monetise but could in principle for some individuals be larger than the benefits of getting them to be more active.

LIMITATIONS

The presented statistical and economic analysis has several limitations related to the lack of more appropriate data and a number of simplifying assumptions that need to be considered.

First, the estimated associations between physical activity and productivity do not necessarily represent a causal relationship. While each multivariable regression model adjusts for a large set of covariates, reverse causality or omitting a relevant variable may cause a bias in the presented estimates.

Second, the survey data used to examine the association between physical activity and productivity is self-reported. This may lead to over-reporting of certain lifestyle factors, such as physical activity, or under-reporting negative habits, such as smoking or alcohol consumption. Even though we only examine individuals within the same organisation and adjust for a variety of different individual factors that could determine the likelihood of employees within an organisations participating in the survey (e.g. age, gender, health status), the data may also suffer from selection bias. Nevertheless, the employee-level data have been shown to be remarkably representative of the broader population across a number of characteristics including age, gender, ethnicity and broader health characteristics, as reported in [30].

Third, the input parameters for the economic model have been based on the best available evidence, including some additional statistical analysis presented in this study regarding the association between physical activity and mortality risk or productivity. However, some of the underlying data was not available for every country or region; in such cases, generalised estimates based on a limited number of countries have been applied.

Fourth, the economic model relies on the simplifying assumption that all additional physical activity happens during leisure time, not work time, and has no indirect negative effects on the aggregate economic output or labour supply. While there may be such effects, the opposite holds true as well: in some occasions more active individuals may require new exercise equipment and clothes, a bicycle, gym memberships or may start going out more often as an indirect long-term result of being more active. Unemployed workers may also enter the labour force. In reality, it is impossible to measure the extent to which such effects are offset. The model therefore does not consider such effects and assumes a fixed labour supply in each country.

Furthermore, the model only considers the benefits of physical activity through improved productivity and lower mortality risk but does not take into account the potential opportunity cost for the individual for getting more active. For instance, watching TV may increase individual's utility which would be lost if the individual is forced to do physical activity instead. As it is very difficult to assess such trade-offs, none of the associated implications are considered in this study. Arguably, as previously mentioned, the time-cost required to raise the minimum physical activity level is rather small and might simply be a matter of changing behaviour.

Finally, this study only examined the potential economic benefits of getting people to be more physically active, but it did not take into account the corresponding cost to achieve this outcome. Although many physical activity options involve no costs, we would like to emphasise that our work is therefore not a cost-benefit analysis of getting people more physically active.

CONCLUSION

Increasing physical activity levels of the world's population to at least the lower threshold of the 2020 WHO guidelines [14] range of 150 minutes of moderate-intensity physical activity per week (equivalent to 600 MET-minutes) is estimated to contribute up to US$8.6 trillion to the global economy cumulatively by 2050 (in 2019 prices), suggesting a potential economic benefit of policies promoting physical activity, particularly in high income countries with currently lower physical activity levels.

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