

Income-based inequalities in self-reported moderate-to-vigorous physical activity among adolescents in England and the United States: comparisons from two cross-sectional surveys

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Abstract

Background: Inequalities in moderate-to-vigorous intensity physical activity (MVPA) may reflect differences in the propensity to do any, the amount of time spent active, or both. Using self-reported data from 4019 adolescents aged 11-15 years in England (Health Survey for England 2008, 2012, 2015) and 4312 aged 12-17 years in the US (National Health and Nutrition Examination Survey 2007-16) we examined inequalities in MVPA.

Methods: Hurdle models estimated inequalities by household income in three aspects: (1) doing any, (2) average minutes/day (MVPA: including those who did none), and (3) average minutes/day conditional on participation (MVPA-active). Inequalities after confounder adjustment (average marginal effects: AMEs) were quantified by computing the absolute difference in marginal means (low-income households as reference).

Results: In England, adolescents in high-income households were more likely than those in low-income households to have done any formal sports/exercise in the last seven days (AMEs boys: 11%; 95% CI: 4, 17; girls: 13%; 6, 20); girls in high-income households spent more time being active than their low-income counterparts (AME formal MVPA: 6 minutes/day, 95% CI: 2, 9). Girls in low-income households spent more time in informal activities than girls in high-income households did (AME informal MVPA: 21 minutes/day; 95% CI: 10, 33), whilst boys in low-income versus high-income households spent longer in active travel (AME active travel MVPA: 21 minutes/week; 95% CI: 8, 34). In the US, in a typical week, recreational activity was greater among high-income versus low-income households (AMEs recreational boys: 15 minutes/day; 95% CI: 6, 24; girls: 19 minutes/day; 95% CI: 12, 27). In contrast, adolescents in low-income versus high-income households were more likely to travel actively (AMEs boys: 11%; 95% CI: 3, 19; girls: 10%; 95% CI: 3, 17) and spend more time engaged.

Conclusions: Policy actions and interventions are required to increase levels of MVPA across all income groups in England and the US. Differences in formal sports/exercise (England) and recreational (US) activities suggest that additional efforts are required to move adolescents in low-income households from inactivity to activity, and to enable those already active to do more.

Introduction

Being physically active benefits mental, physical and social health in a dose-response manner [1], and is beneficial for higher academic achievement [2], yet global data for 2016 show that more than 80% of school-going adolescents aged 11–17 years did not meet the World Health Organization's (WHO) daily minimum recommendation of one hour of physical activity (PA) [3]. Socioeconomic inequalities in adolescent PA is an additional national and international concern [4]: evidence suggests these are domain-specific, with levels of activity in sports especially higher among the most advantaged [5].

Whilst enabling assessment against PA recommendations, categorising a continuous variable such as the minutes-per-day that adolescents typically spend engaged in moderate-to-vigorous intensity PA (MVPA) into a binary or ordinal variable loses information and statistical power [6]. Yet analysing the continuous variable is also problematic as MVPA distributions are not typically normally distributed but contain a stack of zeros (adolescents not doing any) and are positively skewed (high values for a small number who are highly active) [7]. Such data can be transformed to meet normality assumptions [7] but findings based on a single regression equation cannot identify potentially different determinants for participation and duration [8].

Hurdle models [9] can handle continuous MVPA data that contains a stack of zeros and positively skewness, as they treat participation and the amount of time spent active (conditional on overcoming the "hurdle" of participation)

separately. Although popular in the economics literature [10], no epidemiological studies to date have used hurdle models to quantify inequalities in adolescent MVPA. Yet such models could indicate, for example, whether adolescents living in high-income households are more likely to do any MVPA but, conditional on doing any, spend less time on average in MVPA than their counterparts in low-income households [10].

Using nationally-representative cross-sectional data for adolescents in England and the United States (US), we applied hurdle models to quantify and compare income-based inequalities in self-reported total and domain-specific MVPA. We hypothesised that adolescents in high-income versus low-income households have a higher propensity to do any, and that conditional on taking part, spend more time on average being active.

Methods

Data sources and study populations

England

The Health Survey for England (HSE) is used to monitor progress on numerous national health objectives, including PA for younger (aged 2–4 years) and older (5–15 years) children [11–13]. Details of sample design and data collection are described elsewhere [14]. Briefly, new, nationally-representative samples of people living in private households are drawn annually using multistage stratified probability sampling. We used the most recent surveys (2008, 2012, 2015) that included children's PA [11–13]. Up to two children aged 0–15 years were selected at each household in 2008 and 2012; a limit of four was used in 2015 (maximum two aged 13–15 years, interviewed directly, and maximum two aged 0–12 years, where a parent/guardian provided the information). Interviewers measured participants' height and weight and assessed demographics and health behaviours including PA. The household response rate ranged from 64% in 2008 to 60% in 2015.

We restricted the analytical population in this study to adolescents aged 11–15 years; participants aged 16 years or older are treated as adults, and so responded to a different PA questionnaire. Participants gave verbal consent for interview. Relevant national committees granted research ethics approval prior to the surveys. Overall, 4897 adolescents aged 11–15 years participated in one of the three surveys, of whom 4874 had valid PA data. Of these, 855 had missing income data, leaving an analytical sample of 4019 adolescents.

United States

The National Health and Nutrition Examination Survey (NHANES) uses a complex, stratified, multistage probability cluster sampling design. Details on sample design and data collection are described elsewhere [15]. Data collection is based on a nationally-representative sample covering all ages of the civilian noninstitutionalised population. During 2011–14, non-Hispanic Black, non-Hispanic Asian, and Hispanic persons, among other groups, were oversampled. NHANES protocols were approved by the National Center for Health Statistics Ethics Review Board. Written informed consent was obtained from all participants before participation.

To allow broad comparisons with the HSE and WHO data [3], we restricted the analytical population for this study to adolescents aged 12–17 years (less detailed questions are asked of 2–11 year-olds via a parental proxy). As the same PA questionnaire was used, we pooled five two-year cycles (2007-08, 2009-10, 2011-12, 2013-14, 2015-16). Overall, 4705 adolescents aged 12–17 had valid PA data. Of these, 393 had missing income data, leaving an analytical sample of 4312 adolescents.

Data collection and derivation of PA outcomes

Health Survey for England

Formal and informal activities

Adolescents (or their parents/guardians: hereafter referred to as participants) were asked questions about PA conducted outside school hours in the seven days prior to the day of interview. Participants were presented with two lists of physical activities: (i) formal activities: ten specific (e.g. individual and team sports/exercise such as football, workout with gym machines) plus up to five 'other' activities; and (ii) informal activities: nine specific activities (e.g. cycling excluding to/from school; walking excluding to/from school; active play). For each activity identified, participants were asked to recall on which days they took part; and on each day, how long they spent engaged in that activity (with no specified minimum duration). Each activity was assumed to be at least moderately-intensive.

Active travel

Participants who had been to school on at least one day in the seven days prior to interview were asked whether they had walked or cycled all or part of the way to or from school on any of those days (positive responses: walking, cycling, or both). If the participants had walked, they were asked: (i) the number of days they walked to school, (ii) the number of days they walked from school, and (iii) how long it usually takes to walk to school (an average was given if the journeys to and from school differed). These questions were repeated for cycling. Each activity was assumed to be at least moderately-intensive.

Derivation of outcomes

Outcomes were domain-specific: formal activities; informal activities; and active travel. Due to the difference in questionnaire format (daily assessment for formal- and informal-activities; weekly for active travel), total MVPA was calculated as the sum of formal and informal activities only. Time spent being active was calculated by the product of frequency and duration, truncated at 40 hours/week to minimise unrealistic values. Weekly totals (expressed in minutes) were divided by seven to calculate minutes-per-day (min/day). Time spent in active travel was obtained by multiplying the number of journeys (to and/or from school) by the usual time spent travelling (expressed as min/week). Those who had not attended school were included in all analyses but were allocated zero time for active travel [16].

Socioeconomic position and confounders

Household income was our chosen marker of socioeconomic position (SEP). The household reference person reports annual gross household income via a showcard (31 bands ranging from 'less than £520' to '£150 000+'). Household income is equivalised (McClements scale [17]), and grouped into tertiles (lowest, middle, highest). Body mass index (BMI) was calculated from valid weight and height measurements as weight in kilogrammes divided by height in metres squared. Three weight status categories were derived based on age (categorised in six-month bands) and the gender-specific UK National BMI centiles classification [18]: healthy weight (a BMI-for-age below the 85th percentile), overweight (85th to below the 95th percentile), and obese (\geq 95th percentile).

National Health And Nutrition Examination Survey

Global Physical Activity Questionnaire

An adapted version of the Global Physical Activity Questionnaire (GPAQ), developed by the WHO [19], was administered directly to 12–15 year-olds at the Mobile Examination Center (MEC), and during in-home interviews to 16–17 year-olds [20]. The GPAQ captures aerobic PA in three domains: recreational, active transportation, and work (e.g. paid or unpaid work, household chores, yard work). For the recreational- and work-domains, participants are asked whether they do

any vigorous-intensity activities (VPA) that “cause large increases in breathing or heart rate for at least 10 minutes continuously” in a typical week; those answering positively, are asked on how many days in a typical week they do VPA, and for how much time they spend doing VPA on a typical day. Similar questions were asked for moderate-intensity activities: those that “cause a small increase in breathing or heart rate”. For active transportation, participants are asked whether they walk or use a bicycle for at least 10 minutes continuously to get to and from places; those answering positively, are asked on how many days in a typical week they engage in such travel, and for how much time they spend travelling actively on a typical day (walking and bicycling are not assessed separately).

Outcomes were truncated at 40 hours/week to minimise unrealistic values. Total MVPA was calculated as the sum across the three domains. Frequency (number of days/week) and duration (average min/day) were multiplied and then divided by seven to calculate min/day MVPA for total and domain-specific MVPA [7].

Socioeconomic position and confounders

Household income was reported by the household reference person. The inflation-adjusted family income-to-poverty ratio (FIPR) is calculated by dividing family income by a poverty measure specific for family size. Larger FIPRs indicate higher income and was categorized as in other studies [21] [22] as low (< 1.3), middle (> 1.3 to 3.5), and high (> 3.5) (high-income). Race/ethnicity was categorised as non-Hispanic White, non-Hispanic Black, Mexican-American, and other. Three weight status categories were based on the Center for Disease Control and Prevention’s (CDC) gender-specific 2000 BMI-for-age growth charts for the US [22]: healthy weight, overweight, and obese were defined analogously to that described above for the HSE.

Statistical analysis

Sample characteristics

Data was pooled over the survey years to increase precision. Differences in age, race/ethnicity (US), and weight status were estimated by income, using Rao-Scott tests for independence [23]. HSE analyses were weighted using the appropriate selection and non-response weight; NHANES analyses used the combined two-year MEC sample weights.

Hurdle models

To handle continuous MVPA data that contains a stack of zeros and positive skew, we used the Cragg hurdle model [9], which comprises two parts: a selection/participation model and a latent model. The former is used to examine differences in the propensity for the continuous outcome to take positive values versus zero, whilst the latter examines differences in the positive, non-zero part of the distribution among those with non-zero values. Reflecting the difference in questionnaires, the lowest (observed) value for positive MVPA was five minutes (i.e. 0.071 min/day) in HSE and ten minutes (i.e. 1.43 min/day) in NHANES. In our analyses, the selection model assessed the influence of household income status on the binary outcome of participation (any versus none), whilst the latent model assessed its influence on the amount of time spent active, conditional on doing any MVPA (hereafter referred to as MVPA-active). We specified a probit model for the former and an exponential form for the latter. Each model contained income (as a three-category variable) and the confounders listed above.

Based on the model estimates, three sets of marginal means by income were calculated, evaluated at fixed values of the confounders. These sets correspond to different definitions of the expected value of MVPA [23]: (i) the probability of doing any, (ii) the average min/day MVPA for all participants (the unconditional mean), including those who did none; and (iii) the average min/day MVPA conditional on participation (MVPA-active). Average marginal effects (AMEs), representing inequalities after confounder adjustment, were quantified by computing the absolute difference in the marginal means (low-income households as reference).

We decided, a-priori, to conduct gender-stratified analyses due to expected differences in MVPA levels and inequalities in these as reported in the literature [20, 24]. All analyses accounted for the complex survey designs, including the geographical clustering of participants in primary sampling units. Two-sided P-values < 0.05 were considered statistically significant. Dataset preparation and analysis was performed in SPSS V22.0 (SPSS IBM Inc., Chicago, Illinois, USA) and Stata V15.0 (College Station, Texas, USA) for the HSE; datasets are available via the UK Data Service (<http://www.ukdataservice.ac.uk>) [25–27]. Stata was used to prepare and analyse NHANES; datasets are available via the CDC website (<https://www.cdc.gov/nchs/nhanes>).

Results

Sample characteristics

Information on key demographics by household income status is presented in **Table 1**. Adolescents in high-income households in the US were predominantly non-Hispanic White, whilst the proportions with healthy weight were highest in high-income households among both genders in both countries.

MVPA distributions

Boys and girls in England spent 96 and 70 min/day on average in total MVPA in the last seven days, respectively; equivalent figures for total MVPA in the US were 100 and 67 min/day. However, each distribution showed a stack of zeros (highest among girls in the US) and was positively skewed (**Figure 1-2**).

Hurdle models

Table 2 (England) and **Table 3** (US) show the average marginal effects (AMEs) from the estimated hurdle models corresponding to the absolute difference in the income-specific marginal means for the binary outcome of participation (doing any versus none), and the continuous outcomes of MVPA (including those who did none) and MVPA-active (conditional on those who did any). AMEs are shown graphically in **Figure 3** (England) and **Figure 4** (US).

Inequalities in MVPA in England

Among both genders, each of the three outcomes for total (i.e. formal and informal) MVPA showed similarities by income after confounder adjustment. However, this finding masked differences by gender, domain and outcome.

First, adolescents in high-income versus low-income households were more likely to have done any formal sports/exercise activity (AMEs boys: 11%; 95% CI: 4, 17; girls: 13%; 95% CI: 6, 20); whilst girls in low-income households spent more time on average being active than girls in high-income households did (AME formal MVPA: 6 min/day, 95% CI: 2, 9). Secondly, girls in low-income households spent more time in informal activities than their counterparts in high-income households (informal MVPA: 21 min/day; 95% CI: 10, 33; informal MVPA-active: 21 min/day; 95% CI: 9, 33), whilst the differences in informal activities among boys were attenuated to the null. Thirdly, higher levels of active travel among boys in low-income versus high-income households were found for each of the three outcomes. The difference between boys in low-income versus high-income households in the probability of having done any active travel in the last seven days was 8% (95% CI: 1, 15). Among those who did any, boys in low-income versus high-income households spent 20 min/week more on average travelling actively (95% CI: 2, 38).

Inequalities in MVPA in the US

Among both genders, adolescents in high-income versus low-income households were more likely to do any (total) MVPA in a typical week (AMEs boys: 3%; 95% CI: 0, 6; girls: 4%; 95% CI: 0, 7); whilst girls in high-income versus low-

income households spent more time being active (AMEs total MVPA: 16 min/day, 95% CI: 5, 26; total MVPA-active: 14 min/day, 95% CI: 3, 25). As in England, the findings for total MVPA masked differences by gender, domain and outcome.

First, higher levels of recreational MVPA in high-income versus low-income households were evident among both genders and each outcome. For example, differences between adolescents in high-income versus low-income households in recreational MVPA were 15 min/day in a typical week (95% CI: 6, 24) among boys and 19 min/day (95% CI: 12, 27) among girls; differences in recreational MVPA-active were 12 min/day (95% CI: 2, 21) and 16 min/day (95% CI: 8, 24) for boys and girls, respectively.

Secondly, boys in high-income households were more likely to do any work-based MVPA than their counterparts in low-income households (AME 9%; 95% CI: 2, 16), yet the continuous outcomes of work-based MVPA and MVPA-active showed similar levels by income. Thirdly, adolescents in low-income versus high-income households were more likely to have taken part in active transportation (AMEs boys: 11%; 95% CI: 3, 19; girls: 10%; 95% CI: 3, 17). Among all participants (including those who did none), those in the lowest-income versus highest-income households spent 7 min/day more in active travel (AMEs travel MVPA boys: 95% CI: 3, 12; girls: 95% CI: 4, 9). Among those who did any, boys and girls in low-income versus high-income households spent 8 min/day (95% CI: 1, 14) and 11 min/day (95% CI: 7, 16) longer on average travelling actively in a typical week, respectively.

Discussion

Using nationally-representative data from adolescents in England and the US, hurdle models were applied to compare levels and inequalities in total and domain-specific MVPA. We hypothesised that adolescents in high-income households were more likely both to participate in MVPA and, conditional on doing any, to spend more time on average being active than their counterparts in low-income households. Our analyses revealed a more complex picture: differences by household income status varied by gender, domain, and outcome. Levels of formal sports/exercise and recreational MVPA were higher among adolescents in high-income households in England and the US, respectively. In contrast, levels of active travel, among boys in England and both genders in the US, were higher in low-income households.

Comparisons with previous studies

Comparisons with previous studies are difficult due to differences in study characteristics (e.g. age range, or use of objective, device-based measurement) and analytical strategy. Bearing in mind this caveat, the low levels of MVPA across all income groups presented here agree with other English and US studies. In England, data from the HSE 2015 showed that 21% and 16% of boys and girls aged 5–15 years respectively achieved the WHO recommendation of at least 60 minutes of MVPA per day [13]; US data from the 2016 National Survey on Children's Health (NSCH) showed an equivalent figure of 24% among participants aged 6–17 years [28]. Likewise, the evidence of inequalities presented here broadly agree with systematic reviews [29], findings for vigorous-intensity activity among children in the UK [30], and US findings for physical activity [31], inactivity [21], recreational activity [20], active transportation [28] and cardiorespiratory fitness [32]. Our findings also agree with worldwide studies for levels of activity outside-of-school [24] and for activity frequency [33].

Our findings relating to the domain-specific nature of inequalities are also in agreement with previous studies. The lower involvement of adolescents in low-income households in formal, structured sports/exercise activities corresponds with empirical studies in England [34] and Australia [5]. Our findings of divergent patterns in the recreational and active transportation domains in the US correspond with similar patterns found among adults using

the same datasets as the present study [35]. Likewise, the higher levels of active travel for boys in low-income households in England agrees with findings of a greater likelihood of active travel among adults in more deprived areas in Scotland [36]. UK studies of younger children (7–8 year-olds) using accelerometry suggest no clear socioeconomic gradients in the time spent in MVPA [37]; however, activity monitors do not currently capture data on activity domain.

Our novel use of hurdle models adds to recent literature by showing the domain- and outcome-specific nature of inequalities in adolescent MVPA. For example, boys in England in high-income households were more likely to do any formal sports/exercise MVPA than their counterparts in low-income households; whilst the amount of time spent doing sports/exercise showed no difference by income amongst those who did any. In contrast, inequalities in recreational activity in the US exist in both the propensity to do any and in the amount of time spent active. Such findings illustrate the limitations of using single equation regression models when the determinants for participation and duration may differ. Decomposing the single continuous MVPA variable via hurdle modelling can therefore potentially shed light on the determinants of inequalities in the lower-tail of the distribution (drivers of inactivity) and those impacting the positive, non-zero, part of the distribution, implying potentially different solutions to reduce inequalities [38].

Mechanisms and implications for policy

There are numerous pathways through which markers of SEP such as household income impact on physical activity. Differences in financial/wealth resources and the built environment, including those driving inequalities in opportunity and access to affordable facilities and safe public outdoor spaces [39] are likely key modifiable determinants of inequalities in formal (England) and recreational (US) activities. Higher levels of active travel in low-income households likely reflect lower levels of car ownership [40]. Improving overall levels of physical activity and reducing inequalities requires policy actions and interventions to ensure low barriers of entry and adequate support to enable adolescents to “move more and sit less” [41]. Tackling income-based inequalities would also require tackling disparities in PA by the correlated dimension of race/ethnicity [42]. Analyses of NHANES 2011-12 data show lower levels of adolescent MVPA among non-Hispanic Blacks, Hispanics and Asians compared with non-Hispanic White populations [43].

According to the WHO [44], reducing inequalities requires both population-based policy actions to tackle the “upstream” determinants that shape the equity of opportunities for participation and support for “downstream” individually-focused (educational and informational) interventions, with both implemented according to the principle of proportional universality. Examples of the former include encouraging non-motorised modes of travel (through better road connectivity and improved provision of cycling and walking infrastructure such as segregated cycle lanes and improved road safety through traffic free routes [45]), and creating more opportunities for PA in public open spaces and local community settings [3]. In the UK, large PA interventions focusing on knowledge and motivation among children in primary schools have yielded null findings, highlighting the importance of more upstream societal and environmental approaches [46].

Strengths and limitations

Strengths of our study include the use of nationally-representative data across PA domains. Although it is well-known that MVPA distributions typically contain excess zeros and positive skewness, no epidemiological studies to date have applied hurdle models to assess the different aspects of adolescent MVPA (participation and duration) and estimate inequalities in these. Hurdle models avoid the loss of information and statistical power that occurs when time spent in MVPA is collapsed into a binary variable, transformed to meet the assumption of normality [7], or when separate single-equation models for participation and duration are estimated [20].

Caution is required, however, when interpreting our findings. First, self-reported PA data has well-known limitations such as recall and reporting (social desirability) bias [47]; this may be socially patterned, thereby potentially upwardly or

downwardly biasing our estimates of inequalities. Secondly, the analytical sample sizes (reduced further by missing income data) means our findings will be statistically underpowered to some extent despite the pooling of data across survey years. Thirdly, the analytical samples (aged 11–15 and 12–17 in England and the US, respectively) and PA outcomes were different. However, our aim was to compare inequalities rather than levels of MVPA. Fourthly, the choice of potential confounders was limited by data availability. We were unable to provide separate estimates by race/ethnicity using NHANES data or examine any potential moderation of income inequalities. Fifthly, our findings are contingent upon HSE and NHANES data collection methods, including the exclusion of in-school MVPA and the assumption that all activities were of at least moderate-intensity (HSE), the minimum duration of 10 minutes in NHANES (in accord with the contemporaneous US guidance [48] but differing from recent guidelines which acknowledge that PA of any duration enhances health [49]), and the inability to specifically focus on activities that require financial resources (both datasets). We acknowledge that different definitions may have led to different conclusions. Finally, we cannot draw causal inferences, as this was a descriptive study based on cross-sectional data.

Conclusions

Participation in formal sports/exercise and recreational MVPA was higher among adolescents in high-income households in England and the US, respectively. Our findings may assist policy-makers to identify and commission tailored policy actions and interventions to reduce inequalities in participation and duration, and our methods could be used by practitioners to monitor and evaluate their impact.

Declarations

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Authors contributions

SS conceptualised the study. SS was responsible for conducting the analyses, interpreting the results and drafting the manuscript. SS and JSM critically revised the manuscript. Both authors have read and approved the final manuscript.

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Availability of data and materials

The Health Survey for England 2008 dataset supporting the conclusions of this article is available from the UK Data Service, 10.5255/UKDA-SN-6397-2 (<https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=6397>). The Health Survey for England 2012 dataset supporting the conclusions of this article is available from the UK Data Service, 10.5255/UKDA-SN-7480-1 (<https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=7480>). The Health Survey for England 2015 dataset supporting the conclusions of this article is available from the UK Data Service, 10.5255/UKDA-SN-8280-2 (<https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=8280>). The NHANES datasets analysed during the current study are available at the Centers for Disease Control and Prevention

webpages: <https://wwwn.cdc.gov/nchs/nhanes/Search/DataPage.aspx?Component=Questionnaire&CycleBeginYear=2007;>
<https://wwwn.cdc.gov/nchs/nhanes/ContinuousNhanes/Default.aspx?BeginYear=2009;>
<https://wwwn.cdc.gov/nchs/nhanes/ContinuousNhanes/Default.aspx?BeginYear=2011;>
<https://wwwn.cdc.gov/nchs/nhanes/ContinuousNhanes/Default.aspx?BeginYear=2013;>
[https://wwwn.cdc.gov/nchs/nhanes/ContinuousNhanes/Default.aspx?BeginYear=2015](https://wwwn.cdc.gov/nchs/nhanes/ContinuousNhanes/Default.aspx?BeginYear=2015;)

Ethics approval and consent to participate

Each sampled address for the HSE is sent an advance letter which introduces the survey and states that an interviewer would be calling to seek permission to interview. A leaflet is also enclosed providing general information about the survey and some of the findings from previous surveys. The named interviewer calls, provides a more detailed leaflet, answers questions, and invites the household residents to take part in the survey. Individual interviews are conducted with adults who give verbal informed consent. At the end of individual interviews, participants are asked for agreement to a follow-up visit by a trained nurse. Written consent is obtained for collection of biological samples. It is made clear in the advance letters and information leaflets that participation in the survey is entirely voluntary, and that participants may decline to answer individual questions, withdraw or stop at any time, or refuse any particular measurement if they wish to do so. Interviewers and nurses will often repeat this information in their introductions and when they are setting up appointments, and throughout the interview as necessary. Indeed, many individuals do refuse to participate in the survey; others may refuse individual questions, decline to continue part way through an interview, or refuse physical or biological measurements. It is also standard practice to conduct interviews and nurse visits some time after an appointment has been made so that individuals have a chance to reflect on their agreement before the appointment takes place. The procedures used in the HSE to obtain informed consent are very closely scrutinised by a National Health Service (NHS) Research Ethics Committee each year. Information leaflets and both the content and wording of questionnaires are also carefully reviewed by the ethics committees. Research ethics approval for the HSE 2008 and HSE 2012 was obtained from the Oxford A Research Ethics Committee (reference number 07/H0604/102 and 10/H0604/56, respectively); ethical approval for the HSE 2015 was obtained from the West London Research Ethics Committee (reference number 14/LO/0862).

NHANES protocols were approved by the National Center for Health Statistics Ethics Review Board. Written informed consent was obtained from all participants before participation.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Abbreviations

AME: average marginal effects; BMI: body mass index; CDC: Center for Disease Control and Prevention; FPIR: family poverty-income ratio; GPAQ: Global Physical Activity Questionnaire; HSE: Health Survey for England; MEC: mobile examination centre; MPA: moderate-intensity physical activity; MVPA: moderate-to-vigorous physical activity; NHANES: National Health and Nutrition Examination Survey; PA: physical activity; US: United States; VPA: vigorous-intensity physical activity; WHO: World Health Organization

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Tables

Table 1: Key variables by income tertile and gender, Health Survey for England (HSE: 2008, 2012, 2015) and National Health and Nutrition Examination Survey (NHANES 2007-2016)

	Boys					Girls				
	Income				P-value ^a	Income				P-value ^a
	All	Lowest	Middle	Highest		All	Lowest	Middle	Highest	
N (%)	N (%)	N (%)	N (%)		N (%)	N (%)	N (%)	N (%)		
England:										
All	2387 (100)	714 (100)	725 (100)	529 (100)	-	2487 (100)	759 (100)	701 (100)	591 (100)	-
Age-group:										
11-12	988 (41)	303 (42)	311 (42)	217 (39)	0.506	1040 (41)	308 (40)	309 (42)	259 (44)	0.915
13-15	1399 (59)	411 (58)	414 (58)	312 (61)		1447 (59)	451 (60)	392 (58)	332 (56)	
Weight status:										
Healthy weight	1346 (57)	373 (53)	418 (58)	335 (65)	0.033	1417 (58)	401 (54)	390 (57)	385 (66)	<0.001
Overweight	340 (14)	103 (14)	105 (14)	82 (15)		357 (14)	97 (12)	116 (16)	86 (15)	
Obese	415 (17)	138 (19)	122 (17)	75 (13)		378 (15)	137 (18)	114 (16)	64 (10)	
Missing	286 (12)	100 (14)	80 (12)	37 (7)		335 (14)	124 (16)	81 (11)	56 (9)	
United States:										
All	2431 (100)	917 (100)	796 (100)	509 (100)	-	2274 (100)	862 (100)	775 (100)	453 (100)	-
Age-group:										
12-15	1595 (67)	619 (67)	519 (66)	334 (68)	0.738	1470 (65)	560 (64)	508 (67)	291 (63)	0.381
16-17	836 (33)	298 (33)	277 (34)	175 (32)		804 (35)	302 (36)	267 (33)	162 (37)	
Race/ethnicity:										
Non-Hispanic White	689 (57)	192 (34)	223 (56)	246 (78)	<0.001	617 (59)	178 (38)	217 (61)	201 (77)	<0.001
Non-Hispanic Black	618 (14)	263 (22)	219 (15)	87 (6)		553 (14)	224 (20)	192 (14)	88 (8)	
Mexican-American	536 (13)	250 (24)	177 (14)	45 (4)		535 (13)	264 (24)	173 (12)	38 (4)	
Other	588 (15)	212 (20)	177 (15)	131 (12)		569 (14)	196 (19)	193 (14)	126 (11)	
Weight status:										
Healthy weight	1422 (63)	515 (58)	461 (62)	327 (67)	0.033	1306 (63)	455 (54)	427 (59)	320 (75)	<0.001
Overweight	388 (16)	142 (16)	128 (17)	72 (15)		409 (17)	165 (19)	148 (18)	64 (14)	
Obese	518 (21)	219 (26)	176 (20)	84 (18)		486 (20)	212 (27)	177 (23)	56 (11)	

Figures are column percentages. Sample sizes are unweighted; percentages are weighted (not age-standardised).

^a P-values obtained using Rao-Scott tests for independence in two-way tables; P values for weight-status obtained excluding missing category.

Table 2. Parameter estimates from multivariable hurdle models (any participation and amount of time spent active), Health Survey for England 2008, 2012 and 2015

	Any (%)		Unconditional: Mean MVPA min/day		Conditional: Mean MVPA-active min/day	
	AME (95% CI) ^a	P-value	AME (95% CI) ^a	P-value	AME (95% CI) ^a	P-value
Boys						
Total:						
Middle vs lowest	3 (0, 5)	0.022	6.3 (-10.2, 22.8)	0.454	3.0 (-14.1, 20.1)	0.731
Highest vs lowest	-1 (-4, 2)	0.592	0.9 (-14.0, 15.7)	0.910	2.0 (-13.1, 17.2)	0.792
Formal activities:						
Middle vs lowest	7 (1, 13)	0.030	2.2 (-1.8, 6.3)	0.284	-0.3 (-6.0, 5.3)	0.910
Highest vs lowest	11 (4, 17)	0.001	2.3 (-1.7, 6.2)	0.258	-2.4 (-7.7, 2.9)	0.367
Informal activities:						
Middle vs lowest	4 (1, 8)	0.004	-0.8 (-16.6, 15.0)	0.919	-5.8 (-22.6, 11.0)	0.501
Highest vs lowest	-3 (-7, 1)	0.207	-8.4 (-22.7, 6.0)	0.252	-6.4 (-21.7, 8.9)	0.410
Active travel:						
Middle vs lowest	1 (-6, 7) ^b	0.854	2.2 (-10.4, 14.7) ^b	0.732	2.4 (-13.5, 18.3) ^b	0.766
Highest vs lowest	-8 (-15, -1) ^b	0.022	-20.6 (-33.5, -7.7) ^b	0.002	-20.3 (-38.4, -2.2) ^b	0.028
Girls						
Total:						
Middle vs lowest	-2 (-5, 0)	0.084	-5.4 (-19.6, 8.8)	0.454	-3.1 (-17.7, 11.6)	0.682
Highest vs lowest	0 (-2, 3)	0.958	-5.1 (-18.5, 8.3)	0.454	-5.4 (-19.1, 8.2)	0.437
Formal activities:						
Middle vs lowest	4 (-2, 10)	0.218	1.5 (-1.3, 4.4)	0.293	1.1 (-3.7, 5.9)	0.658
Highest vs lowest	13 (6, 20)	<0.001	5.5 (2.2, 8.8)	0.001	3.8 (-1.3, 8.9)	0.141
Informal activities:						
Middle vs lowest	-3 (-6, 1)	0.147	-11.6 (-24.4, 1.1)	0.074	-10.3 (-23.7, 3.1)	0.132
Highest vs lowest	-2 (-6, 1)	0.198	-21.4 (-32.9, -9.8)	<0.001	-21.3 (-33.4, -9.2)	0.001
Active travel:						
Middle vs lowest	4 (-2, 10) ^b	0.225	13.5 (-0.1, 27.2) ^b	0.052	15.0 (-3.4, 33.3) ^b	0.110
Highest vs lowest	0 (-7, 7) ^b	0.969	-3.0 (-15.4, 9.5) ^b	0.637	-5.9 (-22.9, 11.2) ^b	0.501

^a Adjusting for age and weight status. Missing weight status as additional category. AMEs evaluated at fixed values of the confounders: for adolescents aged 11-12 years and having a healthy weight (a BMI-for-age below the 85th percentile).

^b Estimates for active travel are min/week.

AME: average marginal effect.

Table 3. Parameter estimates from multivariable hurdle models (any participation and amount of time spent active), NHANES 2007-2016

	Any (%)		Unconditional: Mean MVPA min/day		Conditional: Mean MVPA-active min/day	
	AME (95% CI) ^a	P-value	AME (95% CI) ^a	P-value	AME (95% CI) ^a	P-value
Boys						
Total:						
Middle vs lowest	1 (-2, 3)	0.474	3.6 (-10.2, 17.4)	0.606	2.7 (-10.9, 16.4)	0.693
Highest vs lowest	3 (0, 6)	0.023	9.8 (-7.2, 26.8)	0.254	6.4 (-10.3, 23.2)	0.449
Recreational:						
Middle vs lowest	3 (-1, 7)	0.148	10.2 (2.8, 17.6)	0.007	9.1 (1.2, 17.0)	0.024
Highest vs lowest	6 (2, 10)	0.005	15.1 (5.8, 24.3)	0.002	11.8 (2.2, 21.4)	0.016
Work:						
Middle vs lowest	3 (-3, 9)	0.304	-1.7 (-9.2, 5.9)	0.657	-6.5 (-19.8, 6.9)	0.339
Highest vs lowest	9 (2, 16)	0.012	-1.1 (-10.1, 7.9)	0.808	-10.7 (-25.4, 3.9)	0.149
Active transport:						
Middle vs lowest	-9 (-14, -5)	<0.001	-5.3 (-9.1, -1.5)	0.007	-4.5 (-10.1, 1.0)	0.108
Highest vs lowest	-11 (-19, -3)	0.005	-7.1 (-11.6, -2.7)	0.002	-7.7 (-14.3, -1.1)	0.024
Girls						
Total:						
Middle vs lowest	2 (0, 5)	0.061	11.3 (1.6, 21.0)	0.022	10.0 (-0.1, 20.1)	0.052
Highest vs lowest	4 (0, 7)	0.034	15.8 (5.1, 26.4)	0.004	13.7 (2.7, 24.7)	0.015
Recreational:						
Middle vs lowest	6 (2, 10)	0.005	11.4 (3.9, 18.9)	0.003	9.6 (1.1, 18.1)	0.027
Highest vs lowest	10 (5, 16)	<0.001	19.5 (11.8, 27.1)	<0.001	15.7 (7.7, 23.6)	<0.001
Work:						
Middle vs lowest	3 (-3, 8)	0.351	1.6 (-3.0, 6.2)	0.499	1.4 (-8.4, 11.1)	0.778
Highest vs lowest	6 (-1, 13)	0.077	0.9 (-3.8, 5.7)	0.700	-3.4 (-13.1, 6.2)	0.478
Active transport:						
Middle vs lowest	-2 (-8, 5)	0.624	-2.4 (-5.3, 0.5)	0.102	-4.6 (-9.9, 0.7)	0.085
Highest vs lowest	-10 (-17, -3)	0.007	-6.7 (-9.5, -3.9)	<0.001	-11.4 (-16.3, -6.6)	<0.001

^a Adjusting for age, race/ethnicity and weight status. AMEs evaluated at fixed values of the confounders: for adolescents aged 12-15 years, non-Hispanic White, and having a healthy weight (a BMI-for-age below the 85th percentile).

AME: average marginal effect.

Figures

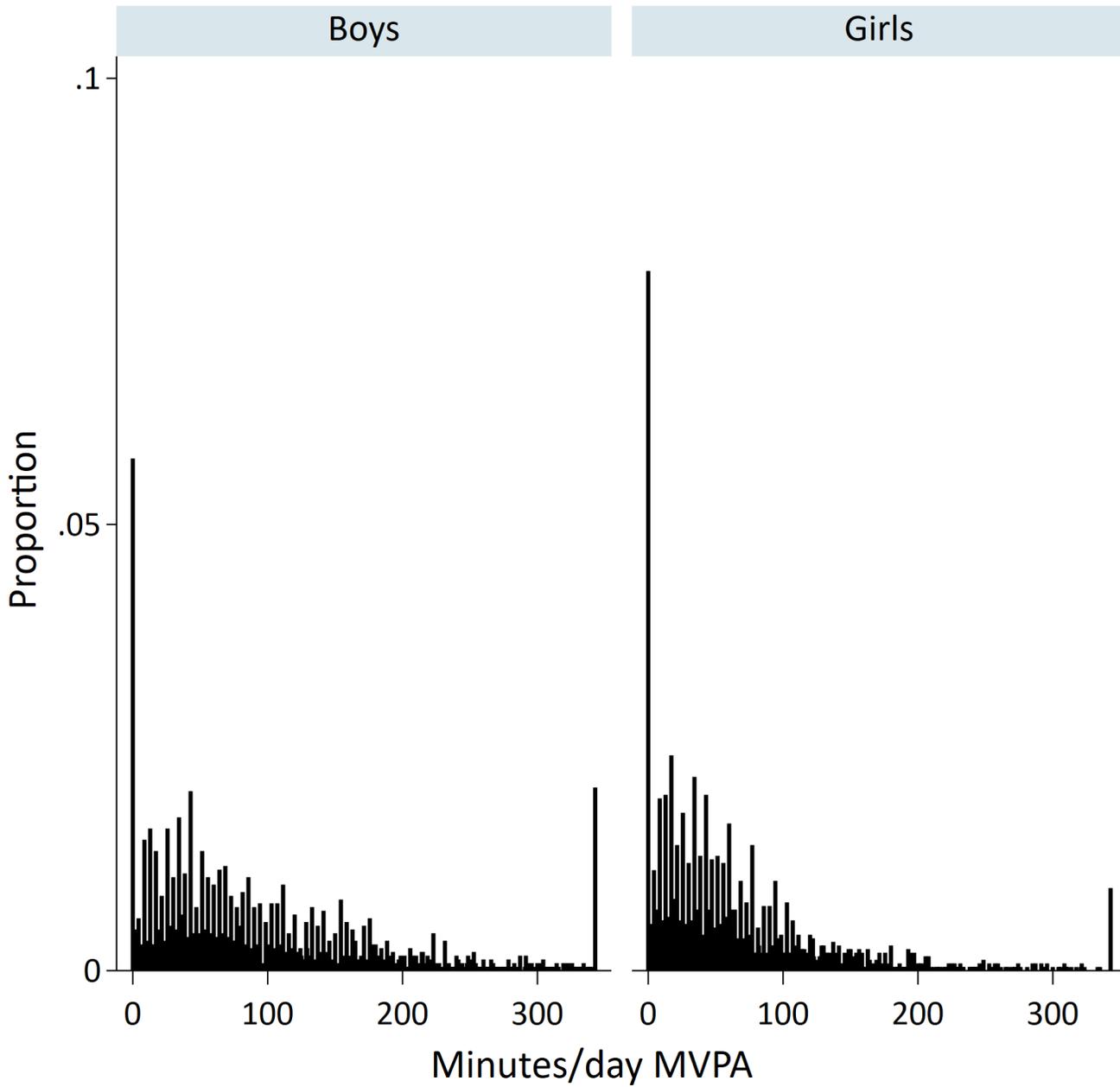


Figure 1

Distribution of minutes/day MVPA by gender in England

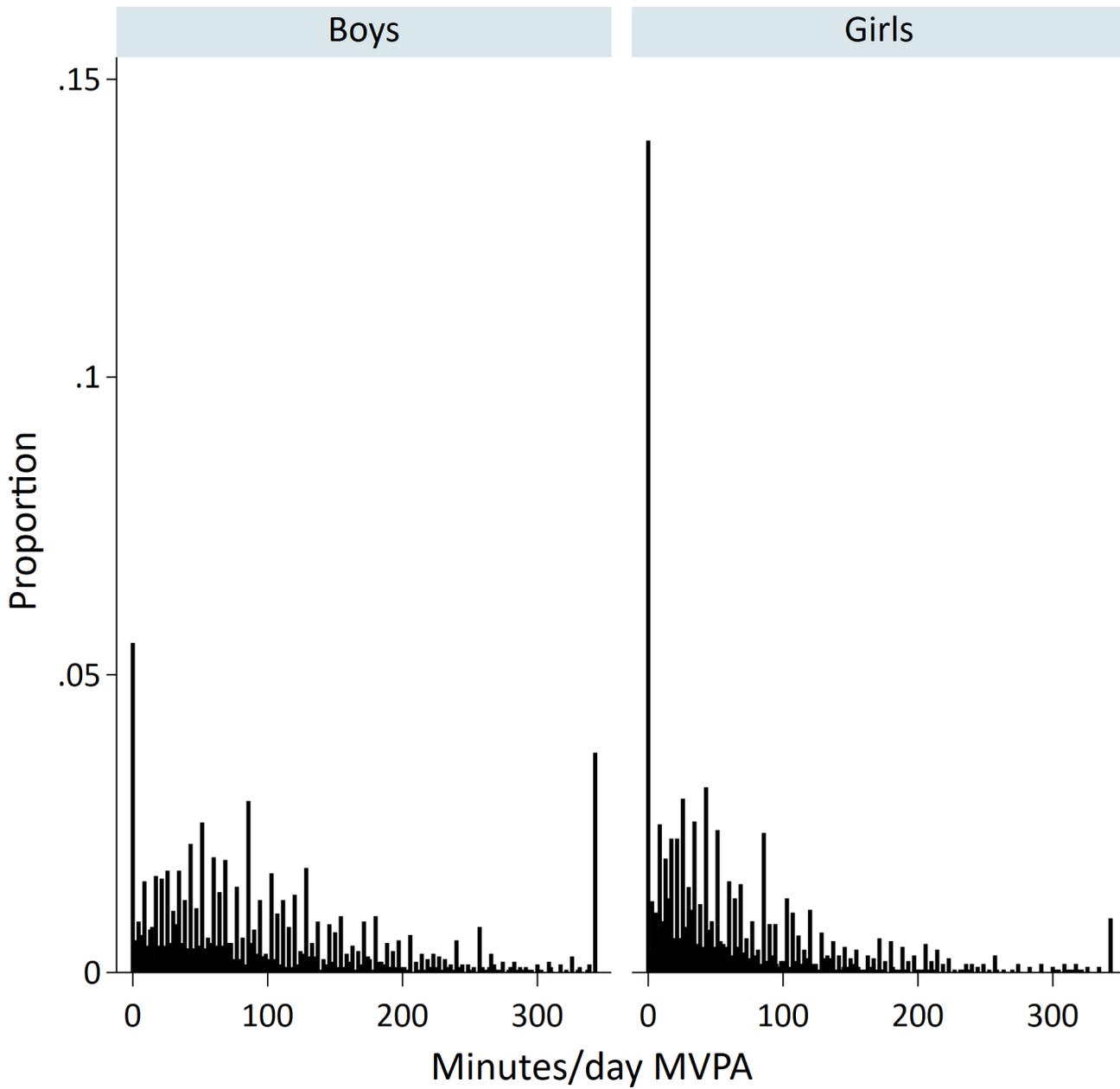


Figure 2

Distribution of minutes/day MVPA by gender in the United States

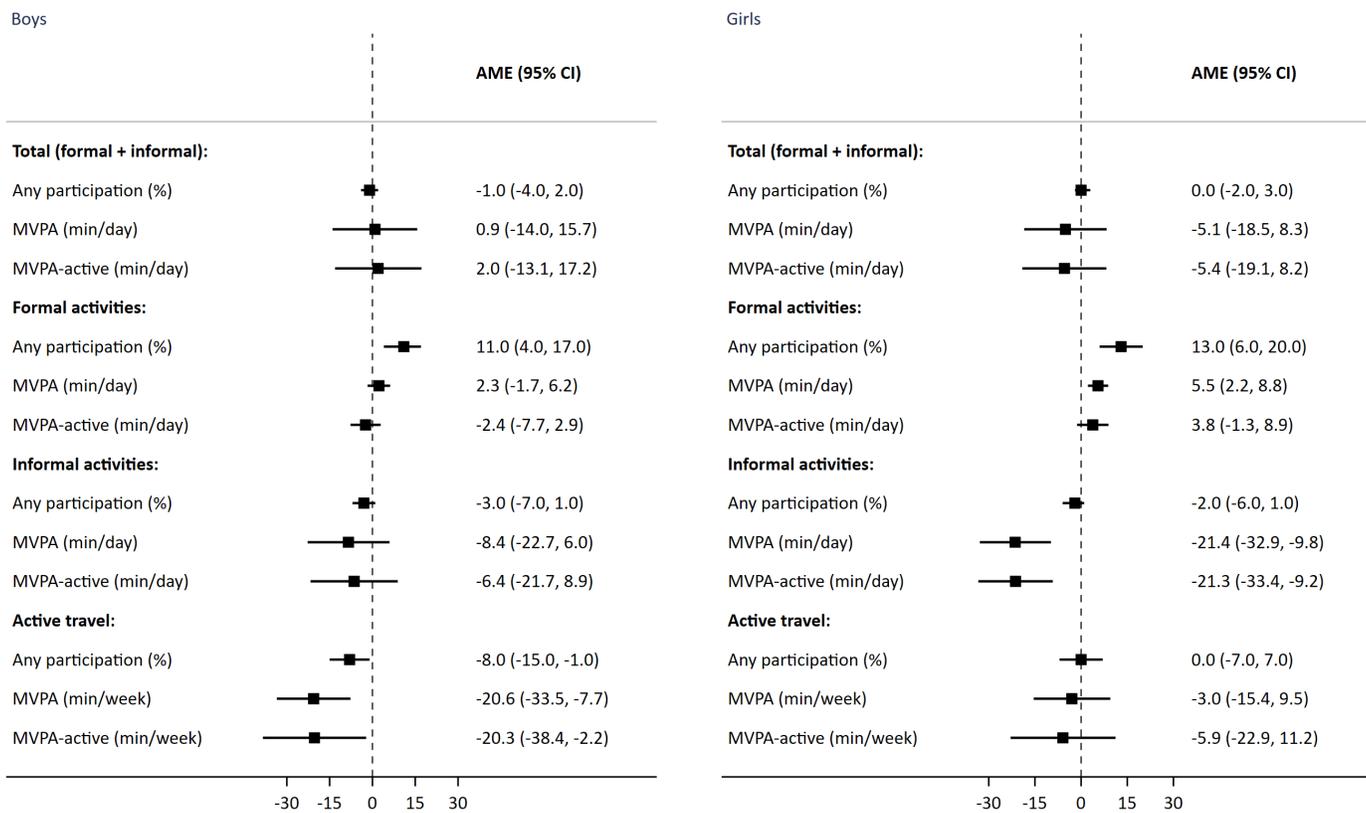


Figure 3

AMEs for three MVPA outcomes by gender in England Legend Fig 3: AMEs represent difference between adolescents in high-income versus low-income households in: (i) any participation (%); (ii) min/day MVPA (average amongst all participants, including those who did none); and (iii) min/day MVPA-active (average amongst those who did any). AMEs evaluated at fixed values of the confounders: aged 11-12 years and having a healthy weight

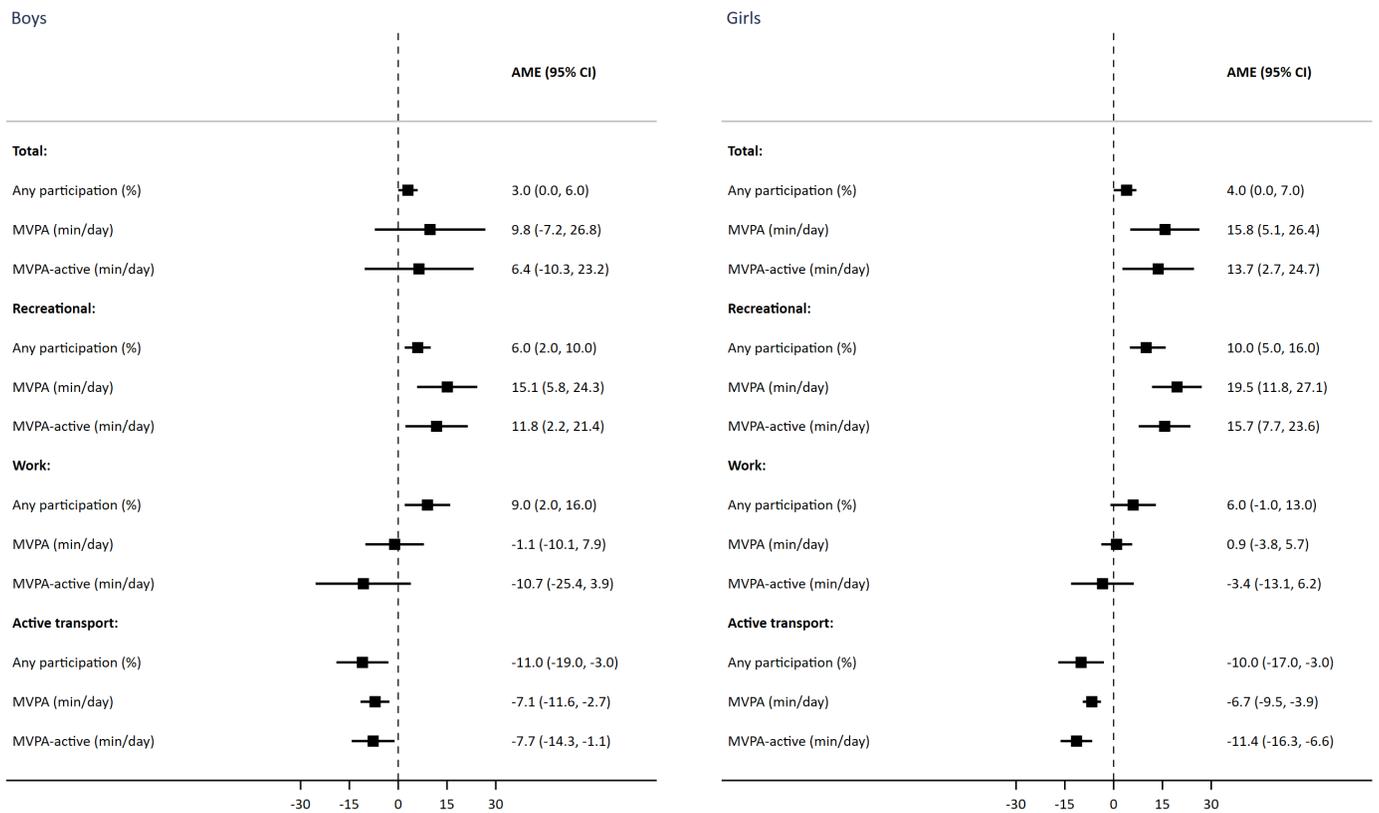


Figure 4

AMEs for three MVPA outcomes by gender in the United States Legend Fig 4: AMEs represent difference between adolescents in high-income versus low-income households in: (i) any participation (%); (ii) min/day MVPA (average amongst all participants, including those who did none); and (iii) min/day MVPA-active (average among those who did any). AMEs evaluated at fixed values of the confounders: England: aged 12-15 years; non-Hispanic White, and having a healthy weight.