

Physical Activity 1



Physical activity behaviours in adolescence: current evidence and opportunities for intervention

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Young people aged 10–24 years constitute 24% of the world's population; investing in their health could yield a triple benefit—eg, today, into adulthood, and for the next generation. However, in physical activity research, this life stage is poorly understood, with the evidence dominated by research in younger adolescents (aged 10–14 years), school settings, and high-income countries. Globally, 80% of adolescents are insufficiently active, and many adolescents engage in 2 h or more daily recreational screen time. In this Series paper, we present the most up-to-date global evidence on adolescent physical activity and discuss directions for identifying potential solutions to enhance physical activity in the adolescent population. Adolescent physical inactivity probably contributes to key global health problems, including cardiometabolic and mental health disorders, but the evidence is methodologically weak. Evidence-based solutions focus on three key components of the adolescent physical activity system: supportive schools, the social and digital environment, and multipurpose urban environments. Despite an increasing volume of research focused on adolescents, there are still important knowledge gaps, and efforts to improve adolescent physical activity surveillance, research, intervention implementation, and policy development are urgently needed.

Introduction

Young people aged 10–24 years constitute 24% of the world's population.¹ This population includes, as per the *Lancet* Commission on adolescent health and wellbeing,² younger adolescents (10–14 years), older adolescents (15–19 years), and young adults (20–24 years), and will be referred to as such throughout this Series paper.³ Both the *Lancet* Commission² and the WHO Global Accelerated Action for the Health of Adolescents⁴ concluded that investing in adolescent health and wellbeing will yield a triple benefit—ie, today, into adulthood, and for the next generation.² Although adolescence is generally considered a healthy period in a person's life, many non-communicable diseases (NCDs) that manifest later in life are, partly, the result of modifiable risk behaviours established during this time, such as smoking, unhealthy dietary patterns, and low levels of physical activity.^{5,6} During the past three decades, there have been major global trends in adolescent health.⁷ Although a decrease in adolescent disease burden has been observed in many countries during the past 25 years, almost one in five (324 million; 18%) adolescents globally are now overweight or have obesity,⁷ and there is an increasing burden of adolescent mental health disorders (including depression and anxiety).^{8,9} It is estimated that 962·8 million adolescents (53% globally) now live in multi-burden countries, where they face a so-called triple burden of health problems, including infectious diseases, injury and violence, and NCDs.⁷ Global agendas, therefore, encourage increased efforts to develop a better understanding of, and potential solutions for, health and wellbeing during adolescence.^{2,4,10,11} To support these efforts, *The Lancet* launched the 2020 Campaign on child and adolescent health.¹²

Physical inactivity is associated with many NCDs and substantial economic costs on a global scale.^{13,14} Physical inactivity has been estimated to account for 5·3 million deaths per year,¹³ and is estimated to cost at least US\$54 billion in direct health-care costs, of which \$31 billion is paid by the public sector.¹⁴ Although physical inactivity is recognised as a global pandemic,¹⁵ much of the evidence has come from studies of adults,^{13,16,17} in whom its effects on NCDs become apparent.¹⁸ However, evidence suggests that the prevalences of NCDs (eg, type 2 diabetes¹⁹) and NCD risk factors (eg, hypertension²⁰ and obesity²¹) in adolescence are increasing. Acknowledging the health risks of long-term neglect of adolescent health and wellbeing, the *Lancet* Commission on adolescent health and wellbeing² proposed 12 headline indicators to track progress in adolescent health. However, despite the known health risks of physical inactivity across the life course,^{13,17,22} and the alarmingly low levels of physical activity in the global population,²³ no indicator related to physical activity was included. Therefore, physical activity appears to have low priority in adolescent health. It is crucial and timely to refocus the global prevention agenda in adolescence to include physical activity.

It is important that a better understanding of adolescent physical activity is developed, such that effective strategies can be implemented. The implementation of policies and interventions to promote physical activity has the potential to contribute to achieving many of the UN Sustainable Development Goals (SDGs) for 2030.²⁴ WHO's Global Action Plan on Physical Activity 2018–2030²⁵ shows how the promotion of physical activity can help reach multiple SDGs. Beyond its direct contribution to SDG 3 (good health and wellbeing),²⁵ co-benefits of promoting physical

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This is the first in a [Series](#) of three papers about physical activity

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Key messages

- The amount of physical activity is low and screen use is ubiquitous among adolescents across the globe; within-country socioeconomic differences vary by country context—adolescents from high socioeconomic backgrounds have better activity profiles than those from low socioeconomic backgrounds in high-income countries (HICs), with the reverse true for low-income and middle-income countries (LMICs)
- Adolescent physical inactivity probably contributes to key global health problems, including cardiometabolic and mental health disorders, but the evidence is weak; obesity and mental health problems might become auxiliary drivers of physical inactivity, increasing the risk of morbidity and mortality
- Supportive social and built environments are key drivers of adolescent activity behaviour, and successful policy action should aim for directing change in these areas; adolescents benefit from built environments that promote a range of activity behaviours (including active travel, play, and sport), and a supportive social environment in and out of school; access to supportive built environments is unequally distributed, particularly in LMICs
- Schools offer an effective avenue to increase physical activity among adolescents, but school-based initiatives have had little success overall and research involving older adolescents (15–19 years) is scarce; there is a need for sustained implementation of multicomponent programmes, co-designed with adolescents, and such interventions require context-specific support for schools to ensure effective implementation and sustainability
- Many young people across the globe, particularly those aged 15–24 years, are not in educational settings and alternative strategies to reach this population are required; with widespread access to the internet and some evidence of effectiveness, the potential contribution of eHealth and mHealth approaches contextualised to adolescents' needs and life circumstances should be explored
- The reasons to instigate change are different for decision makers in health, policy, education, and among adolescents themselves; understanding the benefits associated with physical activity, and tailoring messaging around the outcomes most salient to the specific audience will help drive change at multiple levels of a complex system
- Observational and interventional evidence on adolescent physical activity behaviours comes largely from HICs and younger adolescents (10–14 years); increased knowledge from LMICs, individuals not in school, and older adolescents going through major life transitions (eg, starting employment and parenthood) is urgently required to curb rapid rises in the health consequences of physical inactivity

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See Online for appendix

activity in adolescents include contributions to SDG 5 (gender equality) and, based on the increasing evidence linking physical activity to academic achievement^{26,27} and the crucial role of physical education in high-quality education, SDG 4 (quality education). This Series paper provides an overview of up-to-date evidence on adolescent physical activity behaviours, including prevalence, determinants, and consequences, and provides recommendations for action in research and practice. The term physical activity behaviours is used to capture both physical activity and sedentary behaviour; we will indicate when evidence is specific to a type of behaviour.

Adolescence and young adulthood: a period of transition

Adolescence is a key period of human development as psychological and biological changes occur rapidly during this phase of life.^{4,6} Adolescence and young

Search strategy and selection criteria

We identified data for this Series paper by searching Ovid MEDLINE, Embase, PsycINFO, Web of Science, and Scopus using search terms related to adolescents and physical activity for all reviews. For the reviews on health outcomes, additional terms for prospective study design and cardiometabolic or mental health outcomes were included (see appendix pp 13–34 and appendix pp 35–50 for full details). We only included articles published from database inception to Dec 5, 2019, (cardiometabolic health) or to Dec 2, 2019, (mental health) that presented quantitative data on the association between physical activity in individuals aged 10–24 years and cardiometabolic or mental health at least a year later. All languages were considered.

For the umbrella reviews on correlates and interventions, additional terms for systematic reviews and correlates or interventions (see appendix pp 51–77 for full details). Only review articles published from Jan 1, 2012, to Dec 4, 2019, that provided a quantitative synthesis and included individuals aged 10–24 years.

adulthood represent substantial transitions in responsibilities and lifestyles in many cultures, as young people shift from school settings to various different pathways, including higher education, family, military, workforce, or unemployment. It is important to be mindful of the global variation in the timings of these pathways. For example, globally, the proportion of adolescents aged 12–14 years who are not in educational settings is 15·9% and 36·3% for adolescents aged 15–17 years, but figures are as high as 36·6% for adolescents aged 12–14 years and 57·8% for adolescents aged 15–17 years in sub-Saharan Africa.²⁸

In European and North American cultures, young adulthood is characterised by great variability in demographics (eg, income and housing), self-perceptions, identity exploration, and increased participation in risk behaviours.^{11,29} Globally, the age of achieving biological maturation is decreasing.^{30,31} At the same time, the age of attaining several so-called adult milestones has risen in high-income countries (HICs; eg, age at first marriage,³² mother's age at first birth,³³ and age at completing education).³⁴ It is unclear whether these social trends are mirrored, at least to some extent, in low-income and middle-income countries (LMICs), although global evidence suggests that the prevalence of early marriage³⁵ and early childbearing³⁶ in LMICs have been declining during the past three decades. This change increases the duration of instability, key life transitions, and growing responsibilities. In this important period, decision-making autonomy increases, and lifestyle habits, including physical activity, become established and entrenched, offering substantial opportunities for interventions that can have lifelong and intergenerational health implications.^{37–39}

Physical inactivity and sedentary behaviour as problems in adolescence

Physical inactivity

WHO recommends that children and adolescents younger than 18 years accumulate at least an average of 60 min per day of moderate-to-vigorous intensity physical activity, whereas people who are 18 years or older should accumulate at least 150–300 mins of moderate intensity physical activity or 75–150 mins of

vigorous intensity physical activity per week, or an equivalent combination.⁴⁰ Similar guidelines have been adopted by many countries across WHO regions. The discrepancy of recommended physical activity between ages reflects the different evidence bases used to develop public health guidelines. In adults, a major focus has been on the prevention of NCDs and premature mortality, whereas the focus in childhood and adolescence has been on improving fitness,

Panel 1: Progress and challenges with physical activity surveillance in adolescents

Increasing physical activity surveillance in adolescents

- There has been a substantial increase in the number of countries with self-reported physical activity surveillance data for adolescents since the 2012 *Lancet* Physical Activity Series; data from 105 countries were available for the 2012 report, compared with 120 countries in 2016,¹⁷ and 146 countries in the 2020 report⁴²
- Several countries are now integrating device-based measures of physical activity into their population surveillance systems; some examples of device-based surveillance among adolescents include:
 - Canada has used accelerometers to measure physical activity in the Canadian Health Measures Survey annually since 2007
 - The USA included accelerometers in the National Health and Nutrition Examination Survey in 2003–06 (waist worn), and again in 2011–14 (wrist worn)
 - Australia included pedometers in the Australian Health Survey in 2011–12
 - Malta used accelerometers to measure physical activity in a nationally representative sample of adolescents in 2012
 - Portugal used accelerometers to measure physical activity in a nationally representative sample of adolescents in 2006–08
 - In Norway, accelerometers were used to measure physical activity in nationally representative samples of adolescents in three waves of data collection between 2005–17

Challenges and recommendations

- The age span of 10–24 years encompasses two sets of aerobic physical activity guidelines (an average of 60 mins daily for individuals 17 years or younger; 150 mins per week for individuals 18 years and older), making comparisons of proportions meeting guidelines problematic; there is no scientific reason why the dose of physical activity at which health benefits occur changes so substantially at age 18 years; strengthening the scientific evidence base from which to identify quantitative health-related physical activity thresholds during the transition between adolescence and young adulthood is, therefore, an important area for future research
- Adolescent physical activity surveillance would benefit from the use of a combination of self-report and device-based assessment; surveillance should consist of repeated

- cross-sectional surveys at a minimum every 5 years, done throughout the year to account for seasonal variations; reporting of data should support the progress of reducing inequalities in participation of physical activity (eg, inequalities in age, sex, geographical location, and socioeconomic status)
- Current surveillance efforts rely on various self-report questionnaires and devices, making comparison across countries and regions difficult; collection of physical activity data across the entire year to account for seasonal variation is made more complex by patterns of school and holiday periods, which differ from country to country; harmonisation of questionnaires and the development of algorithms to generate comparable estimates is paramount
- Data from low-income countries continue to be scarce; only eight (26%) of 31 low-income countries contributed self-reported adolescent physical activity data to the latest report (Guthold and colleagues⁴²); nationally representative device-based physical activity data from low-income countries are non-existent; efforts should focus on improving surveillance globally
- The vast majority of self-reported surveillance data records adolescents attending secondary school; surveillance data of adolescents not in schools is generally scarce, and methods to record this population should be developed
- Physical activity surveillance should capture domain-specific and type-specific information to inform interventions; data on specific aspects of adolescent physical activity, such as sports and walking or cycling for transport, are currently inconsistent and often not comparable across countries, yet important for physical activity promotion
- Surveillance of screen use has typically focused on television viewing and computer use; as the ways in which adolescents interact with screens is changing rapidly, surveys now need to incorporate more contemporary indicators capturing the multitude of ways in which adolescents use screens
- The use of different intensity cut-points across ages when analysing device-based physical activity data makes comparisons across ages and between studies difficult; comparison between studies is also complicated by different wear protocol and data processing decisions, and we encourage the increased use and sharing of raw accelerometer data to enable such comparison

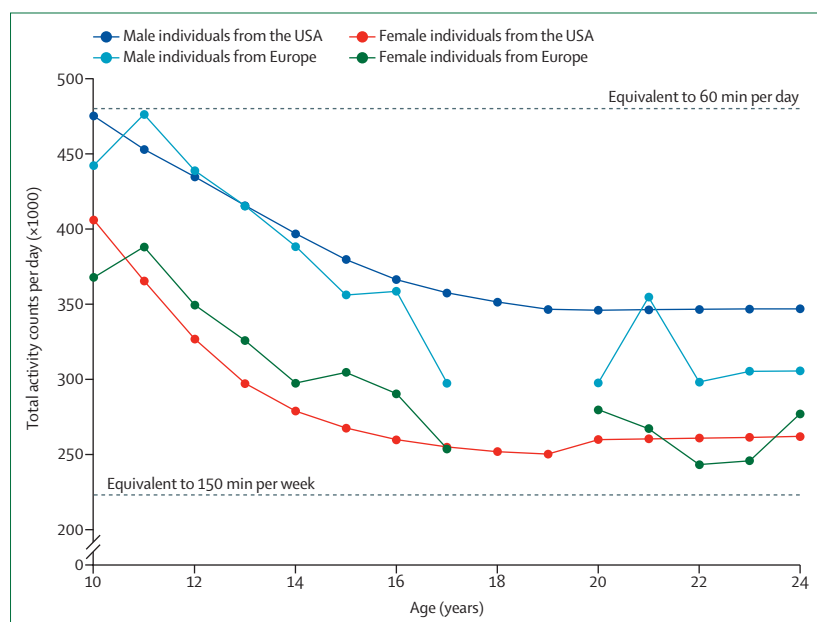


Figure 1: Overall physical activity (expressed as total activity counts) from accelerometry in US and European male and female adolescents and young adults aged 10–24 years

Data for US individuals are smoothed 50th percentiles from the National Health and Nutrition Examination Survey 2003–06.^{46,47} Data for individuals from Europe are age-specific median values from the Determinants of Diet and Physical Activity Knowledge Hub; no data were available for individuals aged 17–20 years.^{38,40} Dotted lines indicate the estimated total activity counts recommended by the adolescent guidelines (60 min per day) and young adult guidelines (150 min per week).⁴⁰ See appendix pp 2–3 for methodological details.

developing coordination and movement control, and maintaining a healthy bodyweight. It is unlikely that the amount of physical activity that has health benefits changes substantially at the age of 18 years, but there is sparse evidence to inform quantitative health-related physical activity thresholds for young adults. The health benefits of physical activity in older adolescents and young adults is an important area for future research.

The drastic difference in the recommended amounts of physical activity for individuals aged 18 and older, compared with individuals younger than 18 years, also affects the ability to adequately monitor trends in physical activity compliance across the whole adolescent and young adult age range. For example, global surveillance data indicate that approximately 20% of individuals younger than 18 years, but 73% of adults (≥ 18 years), are classified as sufficiently active.^{41,42} Overall, global data availability is strongest for adolescents attending school. An analysis of data of 1.6 million students from 146 countries, territories, and areas,⁴² has provided an update on the physical activity prevalence data that was presented by Hallal and colleagues²³ in the first *Lancet* Physical Activity Series in 2012. With self-reported data, this analysis showed that, in 2016, 81.0% of adolescents aged 11–17 years were physically inactive, with a lower prevalence in boys (77.6%) than in girls (84.7%). These data constituted a slightly decreased prevalence of physical inactivity for boys (80.1% in 2001), but negligible

change for girls (85.1% in 2001). There was no clear pattern according to country economic group. Although within-country socioeconomic differences could not be established, wider evidence suggests that these differences could vary across the globe; in HICs, the association is equivocal, whereas in Brazil, for example, adolescents from low socioeconomic backgrounds have been shown to be more active overall than those from high socioeconomic backgrounds.^{43,44} Sources of physical activity also differ among countries, with work and household physical activity contributing more to overall adult physical activity in LMICs and leisure physical activity contributing more in HICs.⁴⁵ The collection of comparable and detailed physical activity data across countries is difficult, given, for example, the country-level differences in seasonal variation and school attendance.

Monitoring absolute amounts of activity, as opposed to guideline compliance, might provide a better representation of differences in physical activity across the adolescent and young adult age range. Although it can be estimated on the basis of self-reported measures, there is a growing list of countries and regions that have begun monitoring physical activity using pedometers and accelerometers (panel 1). Figure 1 presents accelerometer data from US and European individuals aged 10–24 years. These data show that men and boys are consistently more active than are women and girls, and that there is a clear trend for decreasing physical activity with advancing age in early and late adolescence. However, amounts of physical activity become more stable in young adulthood. This finding is supported by evidence that the amount of activity tracks reasonably well from adolescence into adulthood.⁵⁰ Although the mechanisms through which tracking occurs are not well known (eg, habit formation, early experience and skill development, or self-selection), these data emphasise the importance of promoting physical activity in adolescents as a focus for public health policy. Figure 1 also shows the crucial influence of the changing guidelines on our understanding of physical activity prevalence across adolescence and young adulthood; median values are generally below recommended amounts for adolescents, but above recommended amounts for adults.

Sedentary behaviour

Over the past decade, time spent sitting and reclining while expending little energy (ie, sedentary behaviour) and engagement in specific sedentary activities (eg, screen-based behaviours) have rapidly emerged as potential additional risk factors for adolescents' health and wellbeing.^{51,52} WHO does not provide quantitative guidelines for sedentary time.⁴⁰ However, country-specific guidelines have been developed. For example, Australia and Canada recommend less than 2 h recreational screen time per day for individuals younger than 18 years,^{53,54} and the UK recommends that all citizens "minimise the amount of time spent being sedentary".⁵⁵ These variations,

together with evidential uncertainties of its health effects, complicate global surveillance of sedentary behaviour. Self-reported global surveillance data on sedentary behaviour are available for adolescents in two large international school-based surveys: Health Behaviour in School-Aged Children and the Global School-based Student Health Survey (details on methods and results in appendix pp 4–12). Across the 97 countries with information on sitting in Global School-based Student Health Survey, 25% of boys and 24% of girls aged 13–15 years reported sitting for longer than 3 h per day, in addition to sitting at school and for homework (figure 2). Although the prevalence of individuals who reported sitting for 3 h or longer per day was similar across low, lower-middle, and upper-middle income countries, it was twice as high for boys and girls from HICs compared with all other income groups. Country prevalence ranged from 9% (Pakistan) to 61% (Kuwait) among boys, and from 7% (Pakistan) to 70% (Barbados) among girls.

The ways in which adolescents interact with screens has changed rapidly, posing a challenge for global surveillance of screen-based behaviour. For example, although television viewing was the main source of US adolescents' screen time in the late-1970s, in 2016, it made up only 25% of their overall screen use.³⁷ This change indicates that television viewing and computer use might no longer be appropriate metrics for sedentary behaviour surveillance and that we need contemporary indicators that capture the multitude of ways in which adolescents use screens. Nevertheless, we drew on the most recent data on adolescent screen use from a range of countries to present prevalence. The Health Behaviour in School-Aged Children study assessed television use and playing computer or video games in up to 38 European countries (appendix pp 4–12). The prevalence of adolescents aged 11–15 years who watch television for 2 h or longer on weekdays was 60% for boys and 56% for girls (figure 2). Country prevalence of adolescents who watch television for 2 h or longer on weekdays ranged from 45% (Switzerland) to 69% (Wales) among boys, and from 40% (Switzerland) to 72% (Bulgaria) among girls. Prevalence of adolescents playing computer and video games for 2 h or longer on weekdays was 51% for boys and 33% for girls, ranging from 32% (Switzerland) to 68% (Denmark) for boys and from 11% (Finland) to 47% (Netherlands) for girls. Prevalence of both behaviours was consistently higher for boys than for girls but was similar across country income groups. However, as with physical activity, the socioeconomical patterning of screen use varies by country context, as shown by a review identified in our umbrella review of correlates and determinants (appendix pp 51–61 and panel 2).⁶¹ Specifically, adolescents from high socioeconomic backgrounds in HICs are less likely to engage in high levels of screen-based behaviour than are those from low socioeconomic backgrounds, but this association is reversed in LMICs. The difference between HICs and LMICs in socioeconomic patterns of

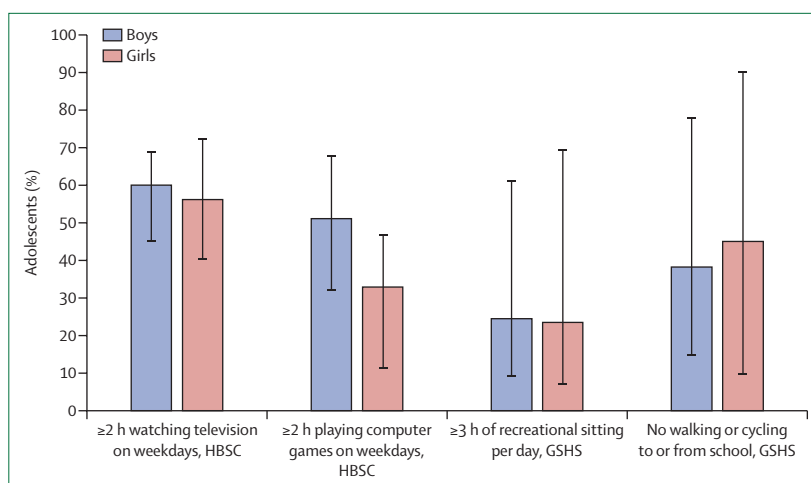


Figure 2: Physical inactivity in boys and girls (aged 11–15 years)

Percentage of boys and girls engaging in physical inactivity behaviours; error bars show the range recorded across countries. The data on prevalence of boys and girls watching television for more than 2 h or more on weekdays are from the HBSC study³⁶ with a cohort of 206 529 children from 37 countries from 2014. The data on prevalence of boys and girls playing computer games for 2 h or more are from the HBSC study with a cohort of 219 460 children from 38 countries from 2014.³⁶ The data on prevalence of 3 h or more of recreational sitting per day are from the GSHS with a cohort of 388 359 children from 97 countries from 2003–17. The data on prevalence of boys and girls who do not walk or cycle to or from school are from GSHS with a cohort of 303 629 children from 73 countries from 2003–17. See appendix pp 4–12 for methodological details. HBSC=Health Behaviour in School-aged Children. GSHS=Global School-based Student Health Survey.

screen time shows the importance of context in identifying problems and solutions.

Health consequences of adolescent physical activity behaviours

These high amounts of adolescent inactivity and sedentary behaviour come with short-term and long-term consequences for health and wellbeing. There is large variation in the consequences considered important to different stakeholders. Although evidence on reducing morbidity and health-care cost might appeal to health professionals and policy makers, academic achievement and mental health might be a priority for educators and parents, whereas wellbeing, social integration, and having fun are more salient for adolescents.⁶² High-quality evidence across this broad range of outcomes is required to achieve positive change at individual, population, and systems levels. For example, although evidence of the importance of physical activity for NCD prevention could help push physical activity promotion up the policy agenda, it is unlikely that adolescents will change their behaviour for the benefit of distal health consequences. The more immediate benefits of physical activity are likely to be more relatable to adolescents.

The prevalence of obesity increases rapidly during adolescence and young adulthood.⁶³ Its causes are complex and multifactorial, but evidence suggests prevention is crucial as adolescents who are overweight or have obesity are unlikely to improve their weight status as they progress into young adulthood.⁶⁴ Increasing physical activity and reducing sedentary behaviour are considered important

Panel 2: Informing solutions: progress in correlates and intervention research into adolescent physical activity behaviours

In the first *Lancet* Physical Activity Series published in 2012, Bauman and colleagues⁵⁸ summarised the global evidence on correlates of physical activity and Heath and colleagues⁵⁹ summarised interventions to promote physical activity, including evidence on children and adolescents. For this paper on adolescent physical activity, we sought to identify the progress made since these initial publications. We did two complementary umbrella reviews addressing the correlates and determinants of physical activity in adolescence and the effect of interventions to promote physical activity in adolescence.

Correlates and determinants of adolescent physical activity behaviours

We identified 13 systematic reviews published since Jan 1, 2012. Most reviews had a specific focus, such as an ecological domain of influence (eg, interpersonal), location (eg, school), country (eg, United Arab Emirates), or population (eg, North American Indigenous populations or Chinese). Across the reviews, 713 papers were included, of which 19% reported on longitudinal studies, which constitutes a substantial increase in the proportion of longitudinal studies from Bauman and colleagues⁵⁸ (when 13.5% of the reviews included both cross-sectional and longitudinal evidence) and an improvement to the evidence base since 2012. A greater focus on modifiable factors indicates a clear shift from the evidence base in 2012, which was dominated by non-modifiable factors. Reviews included evidence from across the globe, but were still predominately from western Europe, North America, and Australia. Few studies were included from Africa (ten studies), or central America and South America (27 studies, of which 21 were from Brazil). The evidence shows that associations are likely to be context specific, evidenced by a review showing that the association between socioeconomic position and adolescent sedentary behaviour is negative in high-income countries, but positive in low-income and middle-income countries.⁵² Transferability of the current evidence base to understudied populations might, therefore, be difficult. More research that aims to understand the context-specific drivers of physical inactivity is required to inform effective intervention development and implementation. Furthermore, future research should adopt longitudinal designs, study older adolescent and young adult

populations, investigate the relative importance of different factors to identify targeted action, and focus attention on biological-level, environmental-level, and policy-level influences (including commercial determinants of health) and how these interact with other correlates. This research should include consideration of the diverse effects of macro-environmental changes, such as climate change across the globe.

Interventions to change adolescent physical activity behaviours

We identified 13 systematic reviews published since Jan 1, 2012. All but one systematic review predominantly included studies in early adolescence, with one review focusing on young adults at university or college. The evidence base was largely drawn from HICs, with sparse representation of LMICs. Seven reviews focused specifically on interventions in the school setting, with one additional review investigating the effectiveness of approaches set in universities and colleges, which was also the only review that included studies in young adults. In general, previous interventions have had a minimal effect on adolescents' physical activity, especially interventions that have been evaluated using device-based measures. On the basis of the evidence identified, we provide the following research recommendations. First, a shift in focus and innovative thinking is required to tackle physical activity behaviours beyond early adolescence. Solutions need to address the challenges faced by young people as they transition into higher education, employment, marriage, or parenthood. Second, research on school-based and community-based interventions should focus on mechanisms of change (mediation), implementation (ie, adoption, dose delivered, reach, fidelity, and sustainability), and the determinants of implementation (eg, feasibility, adaptability, and acceptability).⁶⁰ Poor implementation in original studies probably explains the lack of consistency in the effectiveness of different types of physical activity interventions targeting adolescents, and there is sparse evidence on the extent to which interventions have been delivered as intended. Finally, researchers are encouraged to develop, implement, and evaluate adolescent physical activity interventions in low-income and middle-income countries.

for preventing unhealthy weight gain, with extensive review-level evidence available.⁶⁵ The associations between adolescent sedentary behaviours and adiposity are very small and there is scarce evidence that the association is causal⁶⁶ or independent from physical activity.⁶⁷ Intuitively, higher amounts of physical activity prevent gains in adiposity. However, the association is likely to be bidirectional (ie, high bodyweight leading to less physical activity).⁶⁸ To understand and prevent a potentially vicious cycle of increasing bodyweight and decreasing activity behaviour, and whether weight loss might lead to increases in activity, future research should establish a firm

understanding of the causal association between physical activity (of different volumes and intensity) and unhealthy weight gain in adolescence.⁶⁹

To establish the relationship between adolescent physical activity and the less frequently studied later cardiometabolic health outcomes, we systematically reviewed the literature assessing the prospective associations (where assessment of the physical activity behaviour preceded the outcome) with blood pressure, type 2 diabetes, and the metabolic syndrome (appendix pp 13–33 for details on methods and results). Only one study examined the association between physical

activity in adolescence and type 2 diabetes in adulthood and found no association.⁷⁰ Within adolescence and young adulthood (outcome measured at age ≤ 24 years), the evidence for an association between physical activity and the metabolic syndrome and blood pressure was equivocal. The evidence was stronger for outcomes measured in adulthood (age > 24 years), with some evidence of a long-term negative association between physical activity and the metabolic syndrome, but not with blood pressure. Physical activity and sedentary behaviours during adolescence might be associated with some medium-term and long-term cardiometabolic health outcomes, but the strength of the current evidence is generally low.

Mental health problems are a growing global public health concern in adolescence.⁸ Trial-based evidence suggests that physical activity appears to be a promising intervention for adolescents with depression.⁷¹ Many mental health problems have their origins in adolescence, and the role of physical inactivity in its development is poorly understood, with a range of neurobiological, psychosocial, and behavioural pathways hypothesised.⁷² Cross-sectional studies are problematic due to the hypothesised bidirectional association between mental health and physical activity, with evidence suggesting that mental health problems are likely to lead to decreases in physical activity and increases in sedentary behaviour.⁷³ We reviewed the literature assessing prospective associations with anxiety and depression in healthy adolescents (appendix pp 34–50 for details on methods and results). The results suggest that there is consistent evidence for an absence of a prospective association between adolescent physical activity and later symptoms of depression and anxiety, but that the association of depression and anxiety in later life with sedentary time is more equivocal. These findings might be due to the measure of physical activity and mental health outcome and due to the small effect sizes expected in a generally healthy population. Indeed, a large-scale study showed that an additional 1 h per day of accelerometer-assessed sedentary time in early adolescence was associated with an 8–11% deterioration in depression scores in adolescents aged 18 years.⁵² Higher physical activity was negatively associated with later depressive symptoms. These positive findings need to be interpreted cautiously as the benefits might be difficult to achieve; compared with baseline amounts, they would require a 14% decrease in sedentary time or a 57% increase in time spent in physical activity, whereas a 22% increase in sedentary time and no change in physical activity were observed during the 4 year follow-up.

It is important to note that sedentary behaviour has predominantly been operationalised as engagement in so-called traditional screen-based behaviours. Given the radical shift in the way adolescents interact with screens, there is a need for an improved understanding of the generalisability of these research findings to the present

generation of adolescents. Furthermore, a more sophisticated approach to studying screen-based behaviours and their impact on adolescent health and wellbeing than is currently used might be warranted, including differentiating between quantity and quality of behaviours and their importance for health. Adult-based research suggests that sedentary behaviours that are mentally passive (ie, behaviours requiring minimal mental demands, such as television viewing and listening to music), but not mentally active behaviours (which increase mental demands, such as reading and video gaming), are associated with an increased risk of depression.⁷⁴ This research suggests that not all time spent sedentary is equal, and the importance of this for adolescent health requires additional exploration.

In summary, physical activity behaviours in adolescence might be associated with some medium-term and long-term health outcomes, but the evidence base is generally weak. However, these findings should be interpreted in light of the various limitations of the available evidence—eg, the overall scarcity of evidence and global representation, the predominant use of self-reported exposures, small sample sizes due to attrition, and imperfectly measured or unmeasured confounders. Additional high-quality research is needed to strengthen the case for investment in adolescent physical activity behaviours to prevent health problems. This research will require large sample sizes, device-based exposure measurement, follow-up during and beyond adolescence, appropriate assessment of confounders, and robust analytical approaches with prespecified subgroup analyses to establish causality.

Inactive adolescents: correlates, determinants, and potential solutions

For decades, research has been dedicated to understanding why some people are more active than others.⁷⁵ Such inquiry regarding the correlates and determinants of physical activity behaviours aims to identify subpopulations at risk of physical inactivity and understand its modifiable causes to inform intervention efforts. Meanwhile, interventions have been tested around the world to identify potential solutions to physical inactivity with variable success.⁶⁸ Physical inactivity has been recognised as a “wicked problem” created and perpetuated by the complex system within which it occurs.⁷⁶ As such, identifying solutions requires researchers not to ask whether an intervention works, but to identify whether and how it contributes to reshaping a system favourably.⁷⁷ This paradigm shift led WHO to adopt a systems framework for their Global Physical Activity Action Plan on Physical Activity,²⁵ which aspires to create active societies, environments, people, and systems.⁷⁸ In this section, we aimed to summarise the current literature on the correlates, determinants, and interventions with an acknowledgment of the complexity of these issues and the biological, social, and commercial determinants of

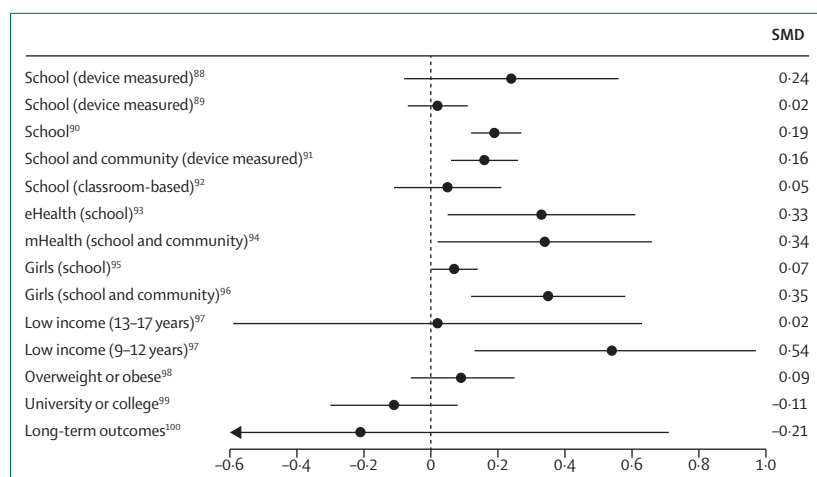


Figure 3: Effects of interventions to promote physical activity or reduce sedentary behaviour in adolescents by setting or group

SMD with 95% CI error bars from original systematic reviews. See appendix pp 62–73 for review methods and detailed results. SMD=standardised mean difference.

health in which they operate and with which they interact. We focused on three key components of the adolescent physical activity system: schools and educational settings, which are particularly important channels and locations for adolescent physical activity promotion; the social and digital environment, which offers both challenges and potential for behaviour change; and the urban environment, which is increasingly recognised as a crucial and upstream strategy to tackling population-level physical inactivity.

The role of schools and other educational settings

Across the globe, schools are considered an important avenue to health promotion, reaching adolescents largely irrespective of their background characteristics. In recognition, WHO and the UN Educational, Scientific and Cultural Organization launched global standards to support their initiative, Making Every School a Health Promoting School.⁷⁹ School-based interventions also dominate the adolescent physical activity promotion literature. To better understand the opportunities and challenges this setting provides, we draw on the school-based evidence from our umbrella reviews on correlates and determinants of physical activity behaviours and on interventions to change physical activity behaviours (panel 2; appendix pp 51–73 for details on methods and results). Our umbrella review of correlates and determinants identified four reviews considering aspects of the school's policy, social, or physical environment.^{80–83} Together, this evidence suggests that the availability of within-school sports and activity in specific school areas was positively associated with overall adolescent physical activity. However, access to sports equipment, adult supervision, overall teacher support, and quantity of physical education provision were not associated with adolescents' physical activity levels. The most active

physical education classes were those that fostered a mastery climate (ie, focusing on individual or team development rather than competition), were done outdoors, and included team games. Physical education and after school sport provision are key ways for schools to contribute to physical activity promotion. Evidence suggests that the quality and content of these provisions, in addition to the absolute quantity, are crucial for their success. Specifically, offering in-school sports competitions and outdoor physical education and fostering of a mastery-focused motivational climate in physical education appear to be salient targets for schools.⁸⁴ High-quality sport and physical education programmes are needed to develop adolescents' physical literacy⁸⁵ and they provide opportunities to develop lifelong physical activity skills to facilitate physical activity independence⁸⁶ and long-term enjoyment, although the programmes might not necessarily translate into higher overall activity in the short term.⁸⁷ It is important to note that this evidence is predominantly drawn from younger adolescent populations in HICs; physical education is not typically mandated in senior school years,⁶⁰ making it difficult for students to maintain physical activity while preparing for their final exams, whereas, in LMICs, there might be a need for provision of basic conditions (eg, trained staff, materials, and environments).

Overall, the intervention evidence included in our umbrella review suggests that physical activity promotion efforts in schools and universities or colleges have been mostly unsuccessful in changing physical activity behaviours (figure 3).^{88–100} Larger effect sizes were typically observed in studies using self-report measures than those using accelerometers, highlighting potential reporting bias. Emerging evidence has identified that poor implementation of programmes is a major barrier to the success of school-based interventions.^{101–103} Poor implementation is potentially due to programme drift and voltage drop as interventions progress from evaluating efficacy and effectiveness to dissemination.¹⁰⁴ Interdisciplinary research, involving behavioural science, implementation science, education, and input from adolescents themselves is needed to optimise intervention effects. Multicomponent interventions (ie, comprehensive school-based physical activity programmes)^{105,106} appear to be more successful than single component interventions, particularly for adolescent girls, and intracurricular interventions (ie, those delivered as part of the curriculum) have stronger effects than extracurricular interventions. Curricular interventions are more closely aligned with teachers' core responsibilities and potentially face fewer barriers to implementation than extracurricular interventions. Although there is a need to scale-up multi-component whole-school interventions, research should continue to identify implementation strategies and integrate approaches into the realities of the educational system. Although challenging, instigating changes at the government-policy level could maximise reach and change

mindsets that promoting physical activity is incongruent with the educational system's remit. Finally, there is a need for novel interventions targeting and attracting older adolescents and young adults in educational settings as these groups have been largely neglected in previous research.

The challenges and opportunities of the social and digital environment

Adolescence is a period of growing independence, during which peers' and friends' social support becomes increasingly influential compared with adults' (ie, parents and teachers). Our umbrella review identified three reviews specifically focused on the role of social support in adolescent physical activity (appendix pp 51–61),^{82,83,107} Together, these reviews showed that social support from family and friends is positively associated with physical activity in early and late adolescence, although the effect sizes are small. The association between physical activity and teacher support was equivocal. Parental support was studied in specific components, showing that encouragement and provision of instrumental support from both parents were positively associated, but the evidence for the benefit of parental coparticipation in physical activity and parental modelling was sparse. Few studies investigated associations with friends' support. These findings suggest the ongoing importance of parental social support in adolescence, which should be considered in future adolescent intervention efforts. Moreover, the importance of friends' social networks and the opportunities this offers for interventions should be explored,¹⁰⁸ as well as the sources and types of social support relevant for young adults.

The digital revolution has radically changed ways of living and communicating, especially in young generations. In 2015, 95% of adolescents aged 15 years globally had access to the internet at home¹⁰⁹ and, in 2017, in sub-Saharan Africa, 63% of individuals aged 18–29 years owned a smartphone.¹¹⁰ During this digital revolution, the global prevalence of physical inactivity in adolescents aged 11–17 years has remained stable at around 80%,⁴² suggesting that increased digital media access and use might not be a key driver of adolescent physical inactivity. Instead, digital media might be replacing other traditional forms of sedentary behaviour; the percentage of US adolescents aged 16–17 years who read a book or magazine daily declined from 60% in the late-1970s to 16% in 2016, and, between 2010 and 2016, adolescents aged 13–18 years substantially decreased their use of so-called legacy media (ie, books, magazines, newspapers, movies, and television).⁵⁷ As noted earlier, greater time spent in mentally passive sedentary behaviours, such as television viewing, might have negative consequences for mental health. This new digital reality provides opportunities for reaching the large proportion of adolescents and young adults who are not in formal education. Our interventions umbrella review (appendix

pp 62–73) identified two reviews focused on the effectiveness of digitally delivered (eHealth and mHealth) physical activity promotion interventions.^{93,94} These reviews show potential of eHealth and mHealth interventions for changing adolescents' activity behaviours in the short term, particularly when integrated with other intervention components (eg, school-based environmental changes), and should be explored further. Crucially, these interventions should be sensitive to the social and environmental changes that are a natural part of the adolescent transitionary period, tailored to the adolescent's life stage (eg, starting employment and parenthood), and be mindful of inequalities in smartphone ownership, particularly in LMICs.¹¹¹

Adolescents in urban environments

Currently, 55.3% of the world's population reside in urban environments and this proportion is expected to increase.¹¹² Improvements to urban environments to facilitate physical activity for transportation and recreation is a recommended strategy for physical activity promotion.¹⁵ Global research in adults has shown positive associations between objectively ascertained urban environmental attributes and accelerometer-assessed physical activity, specifically for net residential density, intersection density, public transport density, and number of parks.¹¹³ Our umbrella review (appendix pp 51–61) identified a dearth of review-level evidence on environmental influences on adolescents' physical activity published since 2012. One review,¹¹⁴ which included 19 studies in HICs, showed positive effect sizes in both early and late adolescence for built environmental features promoting play (including sports and fitness), walking, as well as both walking and play. Larger effect sizes were observed for older adolescents and for those environmental features that promoted both play and walking, suggesting that a multipurpose design of the urban environment is important, particularly as adolescents become older. As also noted by other reviews,¹¹⁵ the evidence base is mainly cross-sectional and does not contain evidence from LMICs, where access to positive environments might be more strongly socioeconomically patterned than in HICs. To better inform policy and practice, research needs to move towards longitudinal designs and to consider the effects of environmental interventions on adolescent behaviour in natural experimental evaluations.

Active travel is an important contributor to adolescent physical activity,^{116,117} and promoting active travel is one of the opportunities identified in the Global Action Plan on Physical Activity 2018–2030.²⁵ Active travel also supports achievement of the Paris Agreement (ie, net zero emissions), which is suggested to result in 1.15 million fewer annual deaths than currently due to increased active travel.¹¹⁸ Figure 2 shows the prevalence of active travel to school among adolescents aged 13–15 years across 73 countries in the Global School-based Student Health

Panel 3: Best buys for increasing physical activity in adolescent populations

Schools are ideally placed to provide younger and older adolescents with a dose of physical activity while equipping them with the necessary knowledge, skills, and confidence to be active across the lifespan. Ideally, schools should implement multicomponent interventions that include physical education, physical activity during school hours (eg, active lunch and recess breaks, and classroom physical activity breaks), physical activity before and after school (eg, active transportation to school and extracurricular activities), staff involvement, and family and community engagement. Aligning with the WHO and UN Educational, Scientific and Cultural Organization initiative Making Every School a Health Promoting School,⁷⁹ this whole-school approach is known as a comprehensive school-based physical activity programme (CSPAP) and is considered the gold standard for increasing physical activity in youth.^{59,89}

In general, school-based physical activity interventions targeting adolescents have been minimally successful. However, interventions involving all or multiple CSPAP components typically result in moderate effect sizes. An example is the Physical Activity 4 Everyone (PA4E1) programme, implemented and evaluated in ten Australian secondary schools.¹⁰² PA4E1 included seven CSPAP components: enhanced physical education lessons, individualised student physical activity plans, enhanced school sport programme,

provision of programmes and equipment during breaks, modified school policies to engage students with low activity levels, after school community sport and fitness programmes, and parental engagement. Intervention schools were supported to implement PA4E1 with six evidence-based implementation strategies. After 2 years, students in the intervention schools were engaging in an additional 7 min of moderate-to-vigorous physical activity per day, compared with those in the usual care control group. It is important to note that CSPAPs require substantial financial and logistical support, which might not be attainable in many low-income countries and high-income countries.

Many adolescents across the globe are not in formal education, and there is an urgent need for non-school-based approaches to physical activity promotion. There is emerging evidence for the efficacy of physical activity interventions involving eHealth (ie, internet-based) and mHealth (ie, mobile phone apps and text messaging) technology. Combining eHealth and mHealth technology with traditional intervention strategies, such as school-based environmental change or education, appears to be more effective than technology-only interventions. Considering the ubiquity of mobile devices and the high amounts of internet access among adolescents globally, such approaches are likely to have extensive reach and should be explored.

Survey (appendix pp 4–12). An average of 38% of boys and 46% of girls reported never walking or cycling to school. Although this prevalence increased slightly with country income, differences were very large between individual countries, ranging from 15% (Benin) to 78% (United Arab Emirates) among boys, and from 10% (Vietnam) to 90% (Niue) among girls, indicating substantial scope for improvement in many countries. National-level differences in social, built, and natural environments have probably contributed to this variability, although there is sparse evidence exploring this suggestion. However, of note, for many adolescents across the globe, active transportation is a necessity and not a choice. Additionally, travel patterns of individuals not in school have not been captured by the Global School-based Student Health Survey. In addition to recording travel patterns of individuals in school, it might be especially important in LMICs to advance research on adolescents' travel behaviours beyond school travel to other mostly overlooked destinations (eg, friends' and relatives' residences, shops and markets, work, and household water collection points) that might be important contributors to the overall physical activity.

Conclusions

Adolescence is a life stage that is a crucial for the development of healthy behaviours, but adolescent physical activity behaviours and their association with medium-term and long-term outcomes are poorly

understood. Adolescents are not sufficiently active and this inactivity is unequally distributed globally and within societies. A whole systems approach with radical change at social, environmental, and systems levels, through multidisciplinary and cross-sectorial collaboration, is required to tackle this problem (panel 3). Although multicomponent programmes, including tailored support for schools, are most likely to be successful, many adolescents across the globe are not in education, and alternative strategies to reach this population are required (eg, changes to the built environment or digital interventions). There is promising observational and interventional evidence on adolescent physical activity behaviours, yet major challenges with implementation remain and more studies from LMICs, of individuals not in school, and of older adolescents and young adults going through major life transitions, are urgently needed to meet the promise of the triple benefit of adolescent health promotion.

Contributors

EMFvS, UE, DD, and PTK conceptualised the Series paper, and EMFvS drafted the text with crucial contributions from all authors. EMFvS, UE, and DL led the systematic reviews; IC-S, AH, and ALO contributed to screening, data extraction, and synthesis. RG and PTK led on collation and analysis of surveillance data. EMFvS and UE verified the data; all authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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