



## Review Article

## Secular trends in physical activity in adolescents: A systematic review<sup>☆</sup>

André A. Pinto, PhD<sup>a</sup>, Adilson P.C. Marques, PhD<sup>b,c</sup> and Andreia Pelegrini, PhD<sup>a,\*</sup>

<sup>a</sup> Center of Health and Sports Sciences, University of Santa Catarina State, Santa Catarina, Brazil

<sup>b</sup> CIPER, Faculdade de Motricidade Humana, Universidade de Lisboa, Lisbon, Portugal

<sup>c</sup> ISAMB, Faculdade de Medicina, Universidade de Lisboa, Lisbon, Portugal

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### المخلص

**أهداف البحث:** تشير التقديرات إلى أن واحدا فقط من كل خمسة مراهقين يمارس نشاطا بدنيا كافيا، وقد يكون هذا مؤشرا على أن الشعور بالسلامة النفسية بين المراهقين قد انخفض على مر السنين. هدفت هذه المراجعة المنهجية إلى الإبلاغ عن وتلخيص المعرفة المتاحة حول الاتجاهات العلمية للنشاط البدني لدى المراهقين على مر السنين.

**طرق البحث:** تم البحث في سبع قواعد بيانات (شبكة العلوم، وسكوبس/السيفير، وميدلاين/بيميد، ساينس دايركت، وويلكس، و مؤشر التربية البدنية، وسبورت ديسكوس). وتم فحص 1809 دراسة. وفقا لإرشادات عناصر التقارير المفضلة للمراجعات المنهجية والتحليلات الوصفية (بريزما). تم فحص الأبحاث ذات الصلة حول الاتجاهات المعرفية عن النشاط البدني لدى المراهقين لإدراجها في توليف سردي. كما تم تقييم خطر التحيز في الدراسات المدرجة.

**النتائج:** استوفت 43 دراسة مع البيانات التي تم جمعها بين عامي 1969 و 2018 متطلبات التضمن، مع غلبة البيانات من الدول ذات الدخل المرتفع. تم تقدير النشاط البدني في الغالب عن طريق التقرير الذاتي، باستثناء سبع دراسات، وتوعدت السياقات والمجالات التي تم تحليلها. كانت هناك تقارير عن زيادة النشاط البدني في 16 دراسة (من 2.9% إلى 43.5%)، وانخفضت في 15 دراسة (-2.5% إلى -69.5%)، واستقرت في 22 دراسة (-12.0% إلى 14.4%).

**الاستنتاجات:** على الرغم من أنه قد لوحظ أن النشاط البدني قد زاد في بعض الدول، إلا أن المعلومات المتوفرة قليلة جدا في الدول المنخفضة والمتوسطة الدخل. يجب أن تدعم الجهود إجراء دراسات حول اتجاهات النشاط البدني لدى المراهقين من الدول المحرومة اقتصاديا.

**الكلمات المفتاحية:** صحة المراهقين؛ علم الأوبئة؛ النشاط البدني؛ أسلوب الحياة؛ صحة المجتمع

### Abstract

**Objective:** One in five adolescents has been estimated to perform sufficient physical activity (PA), thus potentially indicating that PA among adolescents has declined. This systematic review was aimed at reporting and summarizing the available knowledge regarding PA secular trends in adolescents over time.

**Methods:** Seven databases were consulted (Web of Science, Scopus/Elsevier, Medline/PubMed, ScienceDirect, Lilacs, Physical Education Index, and SPORTDiscus), and 1809 studies were examined. According to the PRISMA guidelines, relevant research on secular PA trends in adolescents was screened for inclusion in a narrative synthesis. The risk of bias in the articles included was also assessed.

**Results:** Forty-three studies with data collected between 1969 and 2018 met the inclusion criteria, and data from high-income countries predominated. PA was estimated predominantly by self-reporting, except in seven studies, and diverse contexts and domains were analyzed. Increased PA was reported in 16 studies (from 2.9% to 43.5%), decreased PA was reported in 15 studies (-2.5% to -69.5%), and no change was reported in 22 studies (-12.0% to 14.4%).

**Conclusions:** Although PA has increased in some countries, very little information is available in low- and middle-income countries. Efforts should support studies on PA trends in adolescents from economically disadvantaged countries.

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\* Corresponding address: Center for Health Sciences and Sport, University of Santa Catarina State, Rua Pascoal Simone, 358, ZIP CODE: 88080-350, Coqueiros, Florianópolis - SC, Brazil.

E-mail: [andrea.pelegrini@udesc.br](mailto:andrea.pelegrini@udesc.br) (Andreia Pelegrini)

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**Keywords:** Adolescent health; Epidemiology; Exercise; Lifestyle; Public health

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## Introduction

Physical inactivity is the fourth leading risk factor for mortality worldwide, and it contributes to millions of deaths annually.<sup>1</sup> An unprecedented report has indicated that the global public health costs of physical inactivity exceed \$ 31.2 billion per year.<sup>2</sup> This capital could be invested in other emergent health sectors if people were to incorporate physical activity (PA) into their lifestyles. In addition, approximately 3.9 million lives could be preserved annually if people met the moderate to vigorous physical activity (MVPA) guidelines.<sup>3</sup> The situation is so concerning that the World Health Organization reiterated the importance of countries decreasing the prevalence of insufficient PA in adolescents by 15% by 2030.<sup>4</sup>

Even if global guidelines exist with regarding PA frequency, duration, and intensity for different age groups,<sup>5</sup> future estimates are not promising. Given that the prevalence of sufficient PA tends to decline with increasing age, the finding that only 20% of adolescents meet the daily indications of 60 min or more of MVPA is gravely worrisome.<sup>6</sup> Additionally, many countries lack PA surveillance systems, which are important for monitoring the trends and effectiveness of public policies aimed at promoting PA.<sup>7</sup>

Discrete data on PA's secular trends<sup>7–11</sup> have suggested an increase in the proportion of adolescents not meeting the recommendations. For example, a survey focusing on objective measures of PA in populations (including adolescents) residing in eight high-income countries has suggested that PA declined between 1995 and 2017.<sup>12</sup> In low- and moderate-income countries, information on trends in PA measured objectively or through self-reporting in adolescents remains unclear.<sup>7</sup> Current PA surveillance data in adolescents from these countries have shown an extremely high prevalence of physical inactivity, averaging 78.4% for boys and 84.4% for girls.<sup>11</sup> Therefore, we hypothesized that, among these adolescents, PA has also decreased, particularly as socioeconomic divergence and the adverse realities of life in less affluent countries affect individual decisions regarding PA.<sup>13</sup>

In adolescents specifically, studies using representative or convenience samples have shown mixed results in PA trends assessed in specific contexts (e.g., active transport, leisure time, or sports practices).<sup>7,12</sup> Owing to the different PA contexts, in which it is possible to be active in some contexts but not others,<sup>7</sup> a comprehensive view of available declining trends would be valuable to guide the better decision-making by health professionals proposing PA

interventions. However, studies without representative samples limit the extrapolation of the trends observed to date.<sup>7</sup>

Thus, the trends in regular PA in different contexts must be compiled from representative probabilistic samples to verify whether the prevalence of AF has decreased over time. The available data from countries with different economic conditions may provide information on good monitoring practices and actions to promote PA. Analyzing PA trends may help governments evaluate their interventions and promote strategies promoting active lifestyles. Therefore, this systematic review was aimed at summarizing the available knowledge regarding PA trends in adolescent populations over time.

## Materials and Methods

### *Protocol and registration*

This review followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA),<sup>14</sup> and its protocol was registered in the PROSPERO international database of systematic reviews (protocol number: CRD42016047056). All peer-reviewed articles published until February 2022 in the electronic databases Web of Science, Scopus/Elsevier, Medline/PubMed, ScienceDirect, Lilacs, Physical Education Index, and SPORTDiscus without date or language restrictions were screened.

### *Search strategy*

For this review, PA was defined as any bodily movement produced by skeletal muscles that requires energy expenditure.<sup>15</sup> The tracing was performed with the Medical Subject Headings (MeSH) in English, combined with the Boolean operators “OR” and “AND”: (“secular trend” OR “time trend” OR “secular change”) AND (“adolescent” OR “adolescence” OR “youth” OR “schools” OR “teenagers”) AND (“motor activity” OR “locomotor activity” OR “physical activity” OR “exercise”). All articles read in full had their references examined manually to identify any other relevant evidence not retrieved in the electronic search.

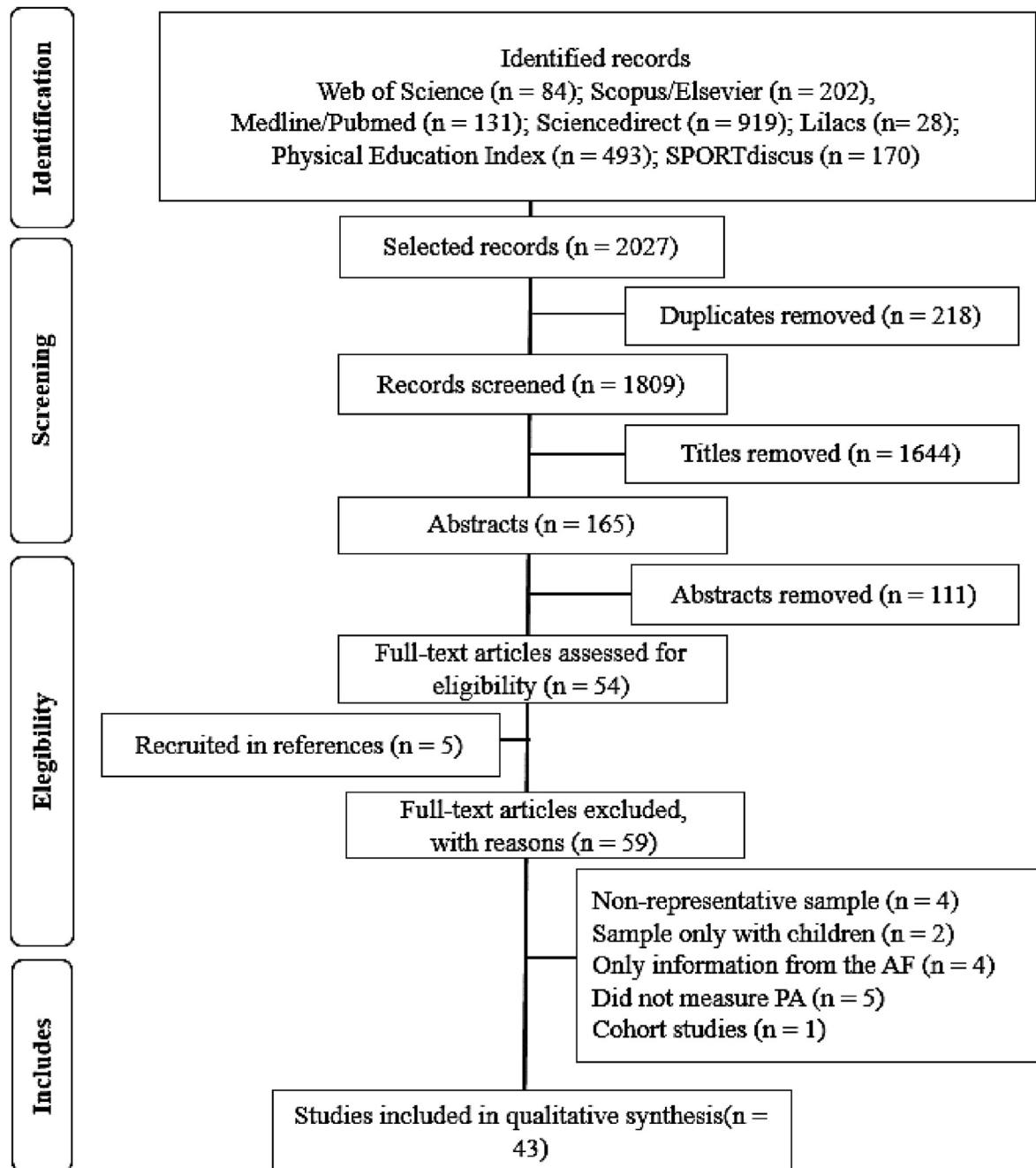
### *Eligibility criteria*

The articles meeting the following criteria were included: (1) evaluation of PA (objective or self-reported) in two or more temporal periods; (2) inclusion of representative samples; (3) investigation of adolescents (10–19 years) with the same age group in the analyzed periods or ability to obtain data for adolescents 10 years of age or older; and (4) publication in English, Spanish, or Portuguese. The exclusion criteria were as follows: (1) cohort studies whose samples were monitored over time, thus avoiding a possible effect of age on PA trends; (2) studies including children (<10 years of age) and adolescents without age-stratified analyzes; (3) studies comparing PA at two time points but using different instruments.

*Data collection and synthesis*

All reviewers participated in a calibration process before screening publications for review. After considering the eligibility criteria, we randomly selected a database used in the search for studies for the calibration process. Two independent reviewers performed the searches, and the selection of the articles was performed through reading of titles and abstracts by considering the eligibility criteria. The disagreements that emerged in this stage (fewer than ten) were selected and had their content read in full, thus leading the reviewers to reach a consensus. The included studies had the

following information extracted: author and year of publication; country of origin, comparative period; age range, sample size, type of PA measurement, and main results. The criterion of statistical significance presented in each study was used to determine the direction of the observed trends. Two reviewers extracted data, and a third independent reviewer verified the accuracy of the extraction. The PA measure was analyzed and presented in several formats in the studies, and was analyzed as an average or as a proportion. In this way, we decided to summarize the results of the studies descriptively, as also presented in the respective articles.



**Figure 1:** Flow diagram of the included studies.

### Risk of bias assessment

The critical evaluation of the articles was performed through a tool developed for studies that report prevalence data.<sup>16</sup> The tool consists of ten items that refer to the following questions associated with the study: adequacy, accuracy, validity of methods, interpretation, and applicability of the findings. For each “yes” or “no” answer, the study received 1 point, and negative answers were awarded 0 points; possible scores ranged between 0 and 10. Two independent reviewers assessed the risk of bias (with 91.2% agreement between the reviewers), and discrepancies were resolved with the participation of the third reviewer. The studies were classified as having a low (8–10 points), moderate (5–7 points), or high ( $\leq 4$  points) risk of bias.<sup>17</sup>

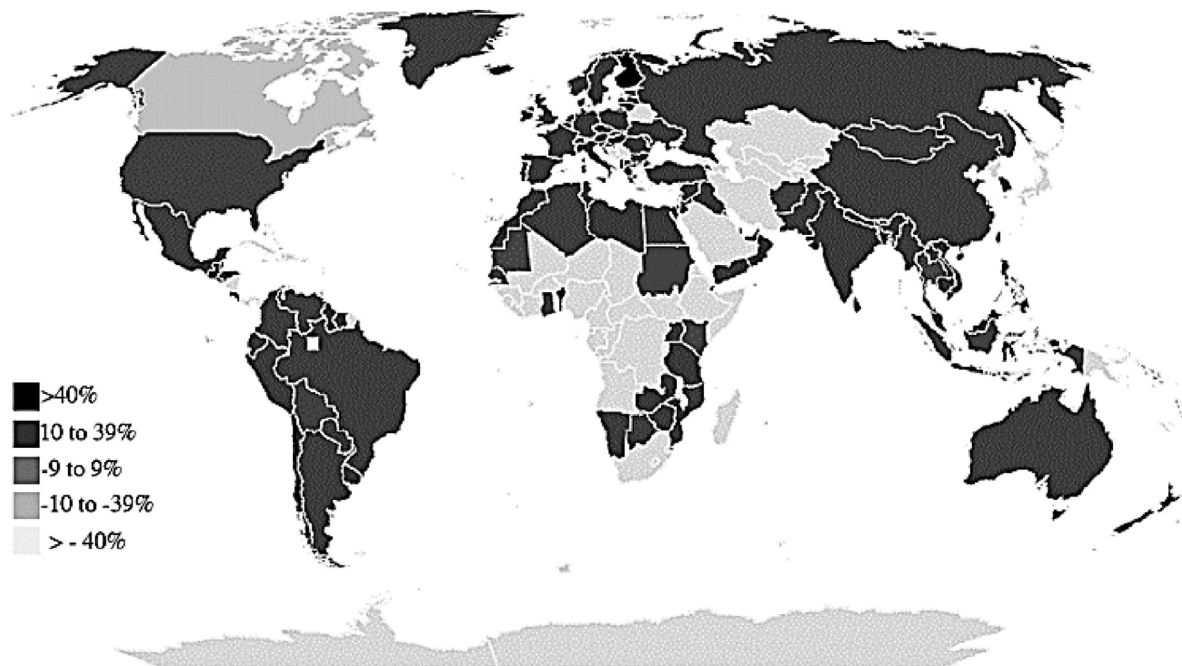
### Results

The screening of the seven electronic databases allowed us to initially identify 2027 articles, all in the English language. After the exclusion of duplicates, and articles with titles or abstracts incompatible with the theme of this work, 54 studies were considered eligible and were read in their entirety. Review of the references of these articles identified five additional potential studies. After a thorough analysis, 16 studies were excluded for the reasons shown in Figure 1. A total of 43 studies<sup>18–60</sup> reported evidence relevant to our review (see Fig. 2).

The main features of the included studies are presented in Table 1. These studies were conducted from 1969 to 2018, and the years of publication ranged from 2001 to 2021. At least seven studies reported data from adolescents in Finland,<sup>33,34,37,42,45,47,58</sup> and the minimum and maximum

comparison periods were 3 years<sup>29</sup> and 30 years,<sup>52</sup> respectively. Sample sizes ranged from 382<sup>54</sup> to 175,399<sup>28</sup> adolescents. Of the 43 included studies, 35 were at low risk of bias,<sup>18–32,34–36,38–42,46–50,52–57,59</sup> and 8 were classified as having a moderate bias risk.<sup>33,37,43–45,51,58,60</sup> Formal assessment of the risk of publication bias with a funnel plot was not feasible for the included studies, owing to the large number of studies using different measures to assess the outcomes, the discrepant number of samples, and the lack of necessary information to calculate effect sizes.

Trends in increased PA were reported in at least 16 studies (varying from 2.9% in Belgian adolescents to 43.5% in Finnish adolescents).<sup>25,26,28,31–33,37,42,45–47,49,50,52,55,60</sup> Twenty-two studies reported stable prevalence (from  $-12.0\%$  to  $14.4\%$ , both in Portuguese adolescents).<sup>18,20–25,29–31,34–36,39–41,47,48,50,54,56,57</sup> Of the 43 records found, 15 studies showed a decline in sufficient PA ( $-2.5\%$  in American adolescents to  $-69.5\%$  in Canadian adolescents).<sup>19,20,23,24,27,30,36,38,40,44,49,51,53,54,59</sup> Mixed results were observed in 12 studies.<sup>20,23–25,30,31,36,40,47,49,50,54</sup> Two studies did not present the values of the proportions in the comparison between periods, but we chose to include them because we believe that they would not alter the general direction of the trends found.<sup>43,58</sup> Nonetheless, opposite secular trends were observed in publications with data from Canada, the United States, and Australia. The data came mainly from high-income countries,<sup>18–22,24–29,31–39,41,42,44–50,52–55,57,60</sup> and the main contexts of PA investigated were MVPA in the prior 7 days or participation in sports. Most studies used questionnaire assessments, whereas only seven used objective measures (Table 2). We also present a graphical representation of where studies were performed on a world map to illustrate trends in PA.



**Figure 2:** Trends in physical activity in adolescents worldwide.

**Table 1: Characteristics of studies included in the systematic review.**

First author, year	Country or region/time period	Age/sample size	Risk of bias
Adams, 2006 <sup>18</sup>	United States/1993–2003	14–18 years/16,296–15,240	Low
Cameron, 2016 <sup>19</sup>	Canada/2005–2014	5–19 years/5500–5500	Low
Chillón, 2013 <sup>20</sup>	Spain/2001–2007	13–17 years/415–891	Low
Cho, 2020 <sup>21</sup>	Korea/2007–2015	10–18 years/2932–2203	Low
Clennin, 2018 <sup>22</sup>	United States/1991–2015	Grades 9–12/10,904–16,410	Low
Coll, 2014 <sup>23</sup>	Brazil/2005–2012	10–19 years/873–786	Low
Dalene, 2018 <sup>24</sup>	Norway/2005–2016	15 years/1348–1759	Low
Eisenmann, 2004 <sup>25</sup>	Canada/1981–1998	12–19 years/2940–1348	Low
Eisdóttir, 2008 <sup>26</sup>	Island/1992–2006	14–15 years/7018–7430	Low
Fernandes, 2018 <sup>27</sup>	Portugal/2006–2016	12–18 years/1010–1096	Low
Ghekiere, 2018 <sup>28</sup>	Europe/2002–2014	11–15 years/155,300–175,399	Low
Gortmaker, 2012 <sup>29</sup>	United States/2003–2006	12–19 years/1112–1072	Low
Guthold, 2019 <sup>30</sup>	146 countries/2001–2016	11–17 years/1.6 million	Low
Hardy, 2008 <sup>31</sup>	Australia/1997–2004	13–15 years/2026–1771	Low
Huhman, 2012 <sup>32</sup>	United States/2002–2006	9–13 years/3114–1200	Low
Huotari, 2010 <sup>33</sup>	Finland/1976–2011	13–16 years/643–579	Moderate
Huotari, 2018 <sup>34</sup>	Finland/2006–2010	15–16 years/2342–1290	Low
Inchley, 2005 <sup>35</sup>	Scotland/1990–2002	11–15 years/4070–4404	Low
Irving, 2003 <sup>36</sup>	Canada/1997–2001	Grades 7–13/2016–2188	Low
Laakso, 2008 <sup>37</sup>	Finland/1977–2007	12–18 years/2832–8390	Moderate
Lowry, 2001 <sup>38</sup>	United States/1991–1997	Grades 9–12/12,272–16,262	Low
Lowry, 2009 <sup>39</sup>	United States/1999–2007	14–17 years/15,349–14,041	Low
Mak, 2010 <sup>40</sup>	China/1995–2001	13–18 years/2932–5692	Low
Martins, 2019 <sup>41</sup>	Portugal/2002–2014	11–17 years/2617–2782	Low
Mathisen, 2019 <sup>42</sup>	Finland and Norway/1985–2014	11–15 years/7137–9218	Low
Melo, 2020 <sup>43</sup>	Brasil/2007–2018	6–17 years/6549–1416	Moderate
Mitáš, 2020 <sup>44</sup>	Czech Republic/2010–2017	15–19 years/579–403	Moderate
Nupponen, 2010 <sup>45</sup>	Finland/1979–2005	12–18 years/2832–8390	Moderate
Okely, 2008 <sup>46</sup>	Australia/1985–2004	12–15 years/1055–1226	Low
Palomäki, 2010 <sup>47</sup>	Finland/2003–2010	15–16 years/2258–1301	Low
Ryu, 2020 <sup>48</sup>	United States/2011–2017	Grades 9–12/13,516–12,437	Low
Salmon, 2005 <sup>49</sup>	Australia/1985–2001	11 years/557–926	Low
Samdal, 2007 <sup>50</sup>	Europe/1986–2002	11–15 years/28,886–30,553	Low
Santos, 2014 <sup>51</sup>	Mozambique/1992–2012	8–15 years/498–1187	Moderate
Scheerder, 2005 <sup>52</sup>	Belgium/1969–1999	12–20 years/8963–5000	Low
Sigmund, 2018 <sup>53</sup>	Czech Republic/2002–2014	11–15 years/4923–4599	Low
Sigmundová, 2011 <sup>54</sup>	Czech Republic/1998–2010	14–18 years/382–620	Low
Sigmundová, 2019 <sup>55</sup>	Europe and North America/2006–2014	11–15 years/167,176–161,764	Low
Silva, 2013 <sup>56</sup>	Brazil/2001–2011	15–19 years/5028–6529	Low
Steene-Johannessen, 2021 <sup>57</sup>	Norway/2005–2018	15 years/700–988	Low
Telama, 2009 <sup>58</sup>	Finland/1977–2005	12–18 years/2832–8390	Moderate
Thompson, 2009 <sup>59</sup>	Canada/2001–2006	12.2 and 16.4 years/1351–1244	Low
Westerståhl, 2003 <sup>60</sup>	Sweden/1974–1995	16 years/395–542	Moderate



**Table 2: Secular trends in physical activity in adolescents.**

Author	Main variable	Method	Trends
Adams <sup>18</sup>	Habitual PA	Self-report	■ Overall
Cameron <sup>19</sup>	Habitual PA	Pedometer	↓ Overall
Chillón <sup>20</sup>	Commuting PA	Self-report	↓ Girls ■ Boys
Cho <sup>21</sup>	Habitual PA	Self-report	■ Overall
Clennin <sup>22</sup>	Participation in physical education classes	Self-report	■ Overall
Coll <sup>23</sup>	Habitual PA and active commuting to school	Self-report	■ Habitual PA ↓ Active commuting to school
Dalene <sup>24</sup>	Habitual PA	Accelerometer	↓ Girls ■ Boys
Einsenmann <sup>25</sup>	Leisure PA	Self-report	↑ Leisure PA increased until 1988 ■ 1988 to 1998.
Eithsdottir <sup>26</sup>	Vigorous PA and participation in sports clubs	Self-report	↑ Vigorous PA ↑ Participation in clubs
Fernandes <sup>27</sup>	Habitual PA	Self-report	↓ Overall
Ghekiere <sup>28</sup>	Habitual PA	Self-report	↑ Overall for most countries.
Gortmaker <sup>29</sup>	Habitual PA	Self-report and accelerometer	■ Overall
Guthold <sup>30</sup>	Habitual PA	Self-report	■ Girls ↓ Boys
Hardy <sup>31</sup>	Habitual PA	Self-report	↑ Summer ■ Winter
Huhman <sup>32</sup>	Habitual PA	Self-report	↑ Overall
Huotari <sup>33</sup>	Leisure PA and participation in sports	Self-report	↑ Overall
Huotari <sup>34</sup>	Participation in sports	Self-report	■ Overall
Inchley <sup>35</sup>	Vigorous PA	Self-report	■ Overall
Irving <sup>36</sup>	Vigorous PA	Self-report	↓ Girls ■ Boys
Laakso <sup>37</sup>	Sports practices	Self-report	↓ 11-year-old adolescents
Lowry <sup>38</sup>	Participation in physical education classes	Self-report	↑ Overall ↓ Overall
Lowry <sup>39</sup>	Habitual PA	Self-report	■ Overall
Mak <sup>40</sup>	Participation in the organized sport	Self-report	■ Girls ↓ Boys
Martins <sup>41</sup>	Habitual PA	Self-report	■ Overall
Mathisen <sup>42</sup>	Participation in organized sports and leisure-time vigorous PA	Self-report	↑ Participation in organized sports ↑ Leisure-time vigorous PA
Melo <sup>43</sup>	Sports practices	Self-report	Missing comparison results
Mitás <sup>44</sup>	Habitual PA	Pedometer and self-report	↓ Overall
Nupponen <sup>45</sup>	Habitual PA	Self-report	↑ Overall
Okely <sup>46</sup>	Habitual PA	Self-report	↑ Overall
Palomäki <sup>47</sup>	Leisure PA	Self-report	↑ Girls ■ Boys
Ryu <sup>48</sup>	Habitual PA and participation in physical education classes	Self-report	■ Overall
Salmon <sup>49</sup>	Active commuting to school, participation in physical education and sports classes at school	Self-report	↓ Active commute to school; ↓ Physical education classes; ↑ Participation in school sports.
Samdal <sup>50</sup>	Vigorous PA and leisure PA	Self-report	↑ Finland ■ Other countries
Santos <sup>51</sup>	Habitual PA	Self-report	↓ Overall
Scheerder <sup>52</sup>	Sport practices	Self-report	↑ Overall
Sigmund <sup>53</sup>	Habitual PA	Self-report	↓ Overall
Sigmundová <sup>54</sup>	Habitual PA	Pedometer and self-report	■ Girls ↓ Boys
Sigmundová <sup>55</sup>	Vigorous PA	Self-report	↑ Overall for all countries
Silva <sup>56</sup>	Commuting PA	Self-report	■ Overall
Steene-Johannessen <sup>57</sup>	Habitual PA	Accelerometer	■ Overall
Telama <sup>58</sup>	Sports practices	Self-report	Missing comparison results
Thompson <sup>59</sup>	Habitual PA	Accelerometer	↓ Overall
Westerståhl <sup>60</sup>	Sports practices	Self-report	↑ Overall

Abbreviations: ↑ = statistically significant increase; ↓ = statistically significant decrease; ■ = stable; MVPA: moderate-to-vigorous physical activity; PA: physical activity.

## Discussion

This systematic review was conducted to summarize secular PA trends in the adolescent population. We identified 43 studies in adolescents, which were performed between 1969 and 2018 in various countries. Whereas some studies showed an increase in sufficient PA prevalence, many studies also had mixed results, which often showed opposite directions. Another notable result was that most data on PA trends came from high-income countries. Many studies—even those in high-income countries—used self-reported measures of PA.

Although 16 studies showed trends in increasing PA, it is unclear whether the prevalence of sufficient PA worldwide has increased over time. For example, whereas most of the data indicated an increase in PA in Finland,<sup>37,42,45,47</sup> mixed results were found in Canada,<sup>19,25</sup> Australia,<sup>31,46,49</sup> and the United States,<sup>18,29,32,38,39</sup> thus decreasing the certainty that the prevalence of sufficient PA has increased worldwide. Furthermore, the methodological heterogeneity among studies yielded results associated with specific PA contexts, such as sports<sup>37,40,42,48,58,60</sup> or leisure.<sup>25,47</sup> Therefore, we cannot deduce whether in other domains in these same studies, such as active commuting, the prevalence of PA has decreased. In the commuting domain, the evidence appears to be particularly scarce because only four studies investigated relevant trends.<sup>20,23,49,56</sup> Declines were observed in Spanish, Australian,<sup>49</sup> and Brazilian adolescents.<sup>23</sup> In contrast, another Brazilian study showed a stable prevalence.<sup>56</sup> Thus, we believe that this domain might have been neglected by researchers, despite being an interesting source of PA performed by adolescents most days of the week.<sup>7,61</sup>

Regarding the opposite trends observed in the synthesis of the studies, thus hindering understanding of adolescents' PA behaviors over time, the following hypotheses are proposed. (a) Differences at the country level can reveal specific difficulties affecting the success of strategies and actions developed to promote PA in adolescents. (b) The PA scenario in the adolescent population across all generations is similar; consequently, few researchers reported significant results, thus possibly indicating publication bias. (c) The PA area remains expanding, to the point that its researchers did not reach a minimum time, allowing changes in PA prevalence between the periods to be identified. (d) Finally, countries' health surveillance systems, regardless of economic background, might be in early stages and thus might not have had more than one available measure to examine possible PA trends.

Another notable result is the availability of data from high-income countries, thus reinforcing previous evidence indicating a lack of PA monitoring in low- and moderate-income countries.<sup>6,30</sup> Therefore, the existence and efficiency of public programs and policies in these countries aimed at promoting PA are gaps that must be filled in the future. To date, the effectiveness of policies that promote PA in high-income countries cannot be determined. However, trends of increasing PA have occurred in specific situations (e.g., participation in sports) in these high-income countries.<sup>26,37,52,60</sup> In one study, investment in sporting events was found to motivate adolescents in the search for sports practices in different spaces, thus increasing total PA.<sup>26</sup> In

this way, a country's income level can affect strategies aimed at increasing adolescent PA levels, thus contributing to public health and saving lives.<sup>2,3</sup>

The most used measure of PA was self-reporting, whereas only seven studies measured PA objectively with accelerometers<sup>24,29,57,59</sup> or pedometers.<sup>19,44,54</sup> The use of objective measures will be a challenge for many monitoring systems, including those in high-income countries. Like pedometers, accelerometers are instruments that provide objective measures of PA, notably the intensity and duration of PA.<sup>62</sup> However, these methods differ in the specific information on PA that they provide, and accelerometer measurements have been questioned.<sup>63</sup> Furthermore, the operational complexity and high cost of accelerometers hinders their use in public health efforts. Thus, pedometers, despite not providing the frequency, duration, and intensity of PA, is a relatively accessible measure with favorable possibility for use in monitoring PA trends.

Although other instruments that better assess PA are available, questionnaires were the most used method in the studies included in this review, because they are practical and inexpensive.<sup>64</sup> Self-administered questionnaires, despite providing measures quickly, have limitations associated with respondents' difficulties in remembering the frequency, duration, and intensity of PA performed in a past period.<sup>65,66</sup> Considering the advantages of questionnaires, we expected to find a greater number of studies on secular trends in PA, because many valid questionnaires are available to estimate the PA in populations.<sup>65</sup> For comparison purposes, the use of a single questionnaire would be challenging for the global public health bodies that evaluate self-reported PA in many countries, because many questionnaires comprise specific items and differ in PA practice time.<sup>64</sup> Thus, to obtain a better estimate of the prevalence of global PA and enable examination of trends, instruments that provide valid measures, subjective or not, for this purpose must be standardized.

### *Strengths and limitations*

The possibility of overlooking studies published in non-indexed journals cannot be ruled out, and data from government agencies that were not available in the searched literature should also be considered. The adolescents in the included studies were not subjected to interventions, but the possible influence of public policies favoring PA could not be ruled out, given that this aspect was not controlled for. Articles using repeated samples must be considered carefully, because they might have skewed the conclusions established from the compilation of their data. Finally, some relevant studies were probably not included, because of a lack of information in the titles or even in the abstracts of the articles. These limitations arise from the descriptive nature of this review, which only summarized the data on the secular trends of PA in adolescents, whereas a meta-analysis was not considered. The strengths of this work are its inclusion of studies in representative samples, its rigorous systematic approach, the lack of limitations on date or language in searches, the application of a tool assessing the risk of bias developed exclusively for prevalence studies, and the low risk of bias in the included studies.

## Conclusion

The present review shows that many studies have examined the secular trends of PA in adolescents. However, much remains to be done. PA, regardless of the context analyzed, increased in many studies, but the studies also showed mixed results. Therefore, it is not possible to state whether the global prevalence of PA in adolescents has declined over time. The findings also revealed a need for monitoring in moderate- and low-income countries, and in the use of a standard instrument to estimate PA. Although we were unable to support the hypothesis of the study, the findings show the importance of countries investing in public policies that promote PA during adolescence and to establish ways to monitor PA prevalence to identify the effectiveness of strategies.

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## Conflict of interest

The authors have no conflict of interest to declare.

## Ethical approval

The authors confirm that this review was prepared in accordance with COPE roles and regulations. Given the nature of the review, IRB review was not required.

## Consent

Because there were no participants in this study, consent was not required.

## Authors contributions

AAP, APCM, and AP conceived and designed the study, conducted research, evaluated the included studies, and wrote the final manuscript. APMC and AP analyzed and interpreted data, and developed the methods and the risk of bias in the included studies. AP supervised the entire process. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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