Recent Secular Trends in Child and Adolescent Physical Activity and Sedentary Behavior Internationally: Analyses of Active Healthy Kids Global Alliance Global Matrices 1.0 to 4.0

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Background: We examined recent global secular trends in 5 indicators of child and adolescent physical activity and sedentary behavior (*Overall Physical Activity, Organized Sport and Physical Activity, Active Play, Active Transportation, and Sedentary Behavior*) and 4 influences on these (*Family and Peers, School, Community and Environment, and Government*). *Methods*: Active Healthy Kids Global Alliance letter grades (A+ to F) were assigned numbers from 15 to 2, with 0 assigned for missing/incomplete grades. Trends from Active Healthy Kids Global Alliance Global Matrices 1.0 (2014) to 4.0 (2022) were analyzed using linear mixed-effects models with level of economic development and gender inequity considered as potential moderators. *Results*: Report card grades were generally relatively stable. Trends generally did not differ significantly by level of economic development (except for *Active Transportation* and *Active Play*), but gender inequality did significantly moderate trends for most of the indicators, with higher gender inequality associated with more adverse changes in grades. The number of "incomplete" grades decreased over time, but this did not reach statistical significance. *Conclusions*: While trends varied within and between countries, physical activity and sedentary behaviors, and the influences on these behaviors globally, were relatively stable over the past decade or so, albeit at undesirable levels.

Keywords: children, exercise, global comparison, physical fitness, play, time trends, transportation, sport

Identifying secular trends in child and adolescent physical activity and sedentary behavior is important to understand changes in population health, intervention and policy needs and impact, and progress toward national and international targets. However, evidence on secular trends to date is limited. Children and adolescents were much more physically active in the distant past.[1–3] Recent secular trend evidence with some degree of global reach is scarce and limited to 11- to 15-year-olds.[4,5] Even among adolescents, Global School-Based Student Health Survey[4] trend data have been limited to just time in reported moderate- to vigorous-intensity physical activity and leisure-time sedentary behavior[4,5]—trends identified using the same questionnaire across many different sociocultural environments.

Reviews of secular trends in child and adolescent physical activity and sedentary behavior have emphasized many gaps and weaknesses in the evidence base.[6–8] These reviews identified evidence from the 1970s to 1990s and early 2000s rather than recent trends,[6–8] and included studies which measured different variables or the same variables measured in different ways.[6–8] However, it is likely that a global child and adolescent "physical activity transition" began in the second half of the last century.[8–10] There is a need for more recent secular trend evidence, ideally derived from more comparable and culturally valid study designs and methods.

Low levels of physical activity and high levels of sedentary behavior in childhood and adolescence are the norm now in most parts of the world[11–13] and are often established by early childhood,[14–16] so an improved understanding of recent global secular trends in children, with wider geographical reach, is desirable. Physical activity and sedentary behaviors are determined by macroenvironmental influences and so secular trends in these (eg, government policy and investment; community and local environment support/services) should also be identified. A number of indicators of physical activity and sedentary behavior in school-age children and adolescents, and the influences on those behaviors, have been measured using the harmonized Active Healthy Kids Global Alliance (AHKGA) Report Card Global Matrix methodology since around 2011.[11–13] While methods of measurement of these indicators can vary within and between countries, identification and grading uses a standardized protocol, including mentoring to encourage harmonization, and internal and external peer review. Indicators are only graded when local/national experts consider data to be broadly representative, recent, largely unbiased, and based on culturally appropriate methods. The AHKGA Global Matrix therefore represents an opportunity for an improved understanding of recent global secular trends in physical activity and related behaviors. In some individual countries, this methodology has been used to test for evidence of secular trends[17–22]: Behavioral grades have been stable or in slow decline in the past decade or so,

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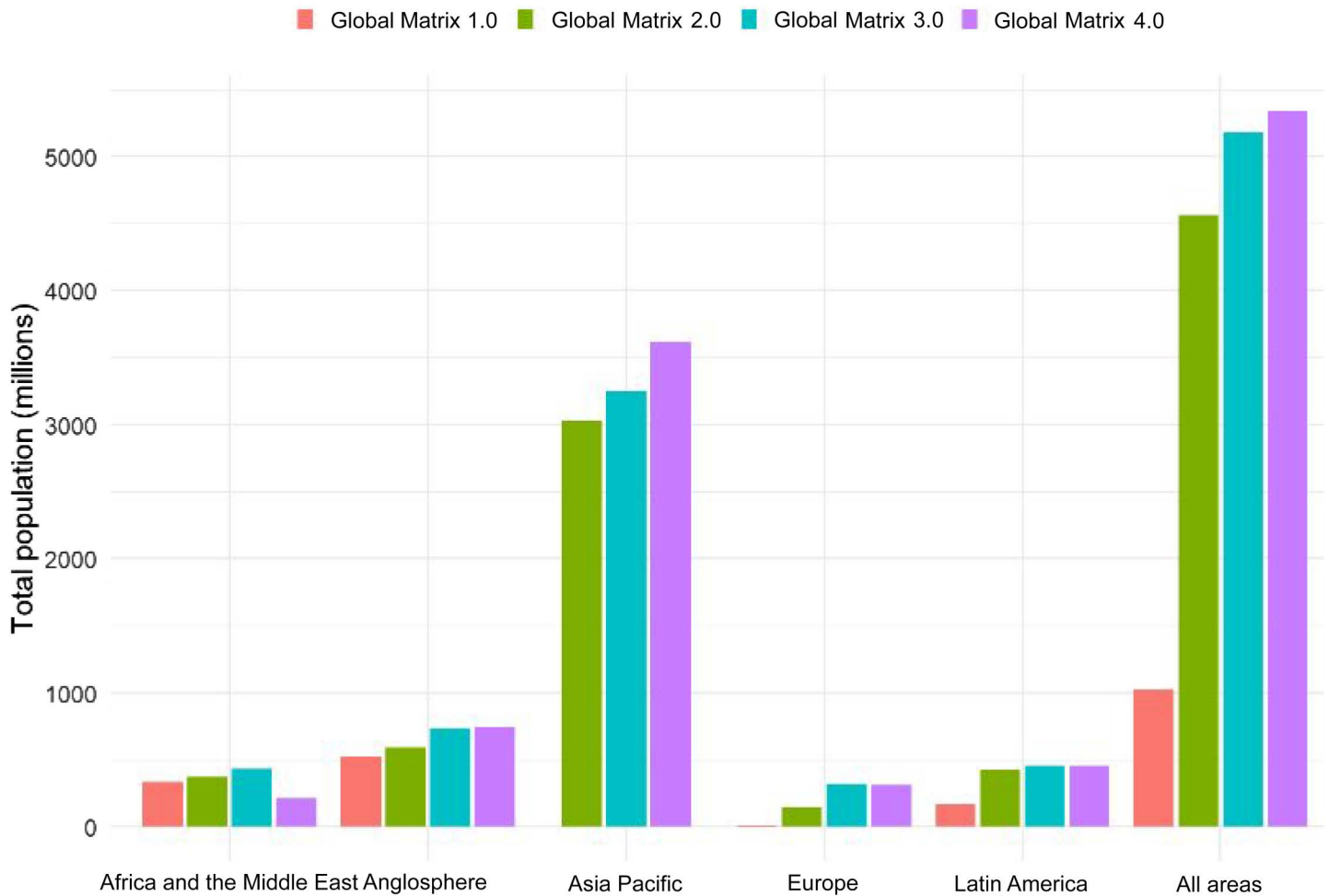
Figure 1 — Bar plot of participating countries' total population by Global Matrices 1.0 to 4.0.

while grades for influences on the behaviors have improved, but these secular trend analyses have been limited to a small number of countries. An analysis of secular trends from Active Healthy Kids Global Matrices 1.0 (15 countries) to 3.0 (49 countries)[13] found that most grades were stable over that period.

The passage of time, rapid demographic changes (eg, economic development and urbanization, increased availability of digital screens), new physical activity and sedentary behavior guidelines, policies, and targets, and the continuing geographic expansion of the AHKGA Report Cards, should all make it possible to identify global secular trends with greater confidence. The present study therefore aimed to test for recent secular trends in physical activity and sedentary behavior of children and adolescents globally by examining trends from the AHKGA Global Matrices from 2014 to 2022. More detailed discussion of pre-COVID-19 versus during COVID-19 findings is presented elsewhere.[22] Specifically, we aimed to answer the following research questions: What global changes in behavioral grades occurred, and did changes differ by level of country development? or country-level gender inequality?; Have sources of influence grades improved (eg, negligible government policy on physical activity in low- and middle-income countries identified in Global Matrix 1.0[11]), and did any changes vary by level of country development?; Have major gaps in surveillance been addressed over time, and did this vary by level of country development?

Methods

The present analysis included data from the AHKGA Global Matrices 1.0 to 4.0.[11–13,22] The Global Matrix was first published in 2014 and brings together researchers and other stakeholders who develop report cards following a harmonized process.[11–13,22] Supplementary Material (available online) depicts the geographic distribution of the countries that have participated in each of the versions of the Global Matrix. Details of the full harmonized methodology for assigning grades in Global Matrices 1.0 to 4.0 have been provided elsewhere.[11–13,22] In brief, for each of the Global Matrices (2014, 2016, 2018, and 2022) every participating nation/jurisdiction convened a research working group that followed a standard protocol. New nations/jurisdictions were assigned mentors to help them follow the protocol and to encourage standardization. Draft grade assignments were subject to consultation within each nation/jurisdiction and internal (AHKGA) and external peer review[22] before final grades were assigned and reported. To identify data for grade assignment, each research working group searched for credible, recent, and reasonably representative data on 6 behavioral indicators and outcomes (*Overall Physical Activity, Organized Sport and Physical Activity, Active Play, Active Transportation, Sedentary Behavior, and Physical Fitness*) and 4 sources of influence indicators (*Family and Peers, School, Community and Environment, and Government*). Each

research working group assigned letter grades (A+ to F; INC, incomplete where data were insufficient to assign a grade, eg, where data lacked credibility or no data were available) representing the prevalence of meeting published and well-defined international guidelines or other benchmarks.[11–13,22] The prevalence of INC grades by individual indicators over time was used in the present study as a proxy for trends in the completeness of surveillance.

For statistical analyses, letter grades across all Global Matrices were converted to integers which ranged from zero to 15 (missing = 0, INC = 0, F = 2, D− = 4, D = 5, D+ = 6, C− = 7, C = 8, C+ = 9, B− = 10, B = 11, B+ = 12, A− = 13, A = 14, A+ = 15). Country demographic data, such as population size, gross domestic product per capita, life expectancy, human development, and gender inequality indices were accessed through the Human Development Report Office (Statistical Data). Human Development Report Office data from 2014, 2016, 2018, and 2019 (the most current year) were linked to Global Matrix releases 1.0, 2.0, 3.0, and 4.0, respectively. Each nation/jurisdiction was categorized as low/medium, high, or very high Human Development Index (HDI) as described previously.[11–13,22] Overall grade scores represent the arithmetic mean of integer values across all 9 indicators which have been included since Global Matrix 1.0 (the Physical Fitness indicator was added in Global Matrix 3.0, and so secular trends in this indicator cannot be assessed yet). Trends in the other 9 report card indicators were therefore examined, and the possible moderating influences of income inequality (using the HDI) and gender inequality (using the Gender Inequality Index) were considered. The report card indicators analyzed for trends were therefore as follows: (1) *Overall Physical Activity*, (2) *Organized Sport and Physical Activity*, (3) *Active Play*, (4) *Active Transportation*, (5) *Sedentary Behavior*, (6) *Family and Peers*, (7) *School*, (8) *Community and Environment,* and (9) *Government*. Boxplots were rendered with the ggplot2 package.[23] The lme4 package[24] was used to fit linear mixed-effects models in order to quantify the trends in grade scores and grade counts across all 9 indicators across all 4 Global Matrices. Since the COVID-19 pandemic has had generally adverse impacts on levels of child and adolescent physical activity and sedentary behavior since 2020,[22,25,26] a covariate was created to account for whether country grades were based on data collected prior to the COVID-19 pandemic in 2020 (and so uninfluenced by pandemic restrictions on behavior) or after that point.[22] All summary statistics and analyses were done using RStudio (version 1.4.1103).

Results

Characteristics of Participating Nations Over Time

Demographic variables and summary grade data for all 9 report indicators from all Global Matrices are shown in Table 1. Between Global Matrices 1.0 and 4.0, the AHKGA expanded from 15 to 57 nations/jurisdictions (Figure 1)—both-HDI and Gross Domestic Product (GDP) were relatively stable over that period (Table 1 and Supplementary Material [available online]).

Trends in Indicators and Moderation by Level of Economic Development, Gender Inequality, and the COVID-19 Pandemic

The 5 behavioral indicators (Table 2) and 4 sources of influence indicators (Table 3) showed changes in grades which generally did not reach statistical significance, with the exception of modest improvements in both *Active Play* and *Active Transportation* (Table 2).

Trends in the report card indicators were generally not influenced significantly by level of economic development, with the exception of the trend in the *Active Transportation* grade (Table 2), which was significantly influenced by HDI. Compared with countries with very high HDI the *Active Transportation* Grade for countries with high HDI improved by 3 points (1 letter grade), and for the countries with low/medium HDI, it improved by just over 6 points (2 letter grades).

Trends in 3 of the 5 behavioral report card indicators (*Organized Sport and Physical Activity, Active Play, and Active Transportation*) were moderated significantly by level of gender inequality (Table 2), with each 1 SD increase in the Gender Inequality Index associated with 2 points (2/3 of a letter grade) decline. Trends in 2 of the 4 sources of influence report card indicators (*School and Community and Environment*) were also moderated significantly by gender inequality, with each 1SD increase in the Gender Inequality Index associated with 2 points decline (two-thirds of a letter grade) decline. For a third source of influence indicator, *Family and Peer Influence,* moderation by gender inequality almost reached significance.

Trends in grades were not influenced by our covariate which indicated whether GM 4.0 data were collected after the onset of the COVID-19 pandemic (Tables 2 and 3). Across the period between Global Matrices 1.0 and 4.0, the behavioral indicator *Active Play* and the influence indicator *Family and Peer Influence* were commonly graded as INC, in around 35% to 65% of all of the Global Matrices. The overall percentage of INC grades declined (though not significantly), indicating a possible trend toward improved surveillance. The number and percentage of grades available for the influence indicator Government improved steadily over time.

Discussion

Main Findings

The present study across the 4 Global Matrix releases (2014–2022) found that report card grades were generally relatively stable. Modest positive trends in *Active Play* and *Active Transportation* were observed, and moderation of trends by level of economic development was limited (except for *Active Transportation*). Reducing gender inequalities is an important aim of global physical activity strategies,[25] and the present study suggests that gender inequality was a significant moderator of trends in most of the indicators. An analysis of Global Matrix 4.0 data[22] shows that physical activity indicators declined globally as a result of COVID-19 pandemic mitigation measures, consistent with other evidence,[26,27] but the influence of COVID-19 on the trends analyzed in the present study was relatively minor because data collection for GM 4.0 occurred prior to the COVID-19 pandemic for most report card indicators in most countries.[22]

Comparisons With Other Studies

Reviews of child and adolescent physical activity secular trends[6–8] show that the evidence base had been biased toward adolescents and high-income countries, included only a small number of physical activity indicators (eg, neglecting many physical activity domains and the environmental influences on physical activity), and with the same questionnaires used across many different settings with no evidence of validity in different settings or cultural

Table 1 Summary of GM 1.0 to 4.0 Grade Data for All 9 Individual Indicators, Aggregate Indicators, and Participating Country Demographics

Variable	GM 1.0 (2014) n = 15		GM 2.0 (2016) n = 38		GM 3.0 (2018) n = 49		GM 4.0 (2022) n = 57	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
United Nations demographics								
Total population (millions)	68.13	83.15	120.1	305.7	107.4	277.9	100.8	268.0
Gross domestic product per capita (PPP)	29,626	21,188	34,964	22,273	33,957	20,769	34,548	20,358
Life Expectancy Index (range: 0–1)	0.82	0.16	0.87	0.12	0.88	0.10	0.90	0.08
Human Development Index, median (range: 0–1)	0.92	0.18	0.88	0.14	0.88	0.13	0.89	0.11
Gender Inequality Index, median (range: 0–1)	0.27	0.17	0.24	0.18	0.23	0.17	0.20	0.15
GM descriptive data								
Aggregate indicators								
Overall grade score (range: 0–15)	7.17	1.15	7.31	1.49	7.53	1.53	7.82	1.27
Behaviors grade score (range: 0–15)	6.48	1.57	6.61	1.88	6.96	1.61	6.84	1.68
Sources of influence grade score (range: 0–15)	7.59	2.87	8.21	2.27	8.22	2.49	8.77	2.19
A, B, and C grade counts (range: 0–9)	4.20	2.01	4.24	1.87	4.43	1.83	5.18	1.92
D and F grade counts (range: 0–9)	2.53	1.51	2.82	1.45	2.65	1.64	2.53	1.43
INC and missing grade counts (range: 0–9)	2.27	1.39	1.95	1.58	1.92	1.46	1.30	1.51
Individual indicators								
Overall physical activity grade score (range: 0–15)	6.07	2.71	5.16	2.55	5.02	2.30	5.53	3.19
Organized sport grade score (range: 0–15)	6.33	3.35	6.50	4.01	7.04	3.83	6.74	3.64
Active play grade score (range: 0–15)	2.60	3.98	3.21	4.05	2.67	3.66	3.88	4.24
Active transportation grade score (range: 0–15)	6.93	3.28	7.58	3.31	7.96	2.98	7.40	3.05
Sedentary behavior grade score (range: 0–15)	4.60	3.48	5.03	2.97	6.02	3.15	5.98	2.45
Family and peers grade score (range: 0–15)	2.93	3.84	3.97	4.04	3.82	4.18	6.09	4.30
School grade score (range: 0–15)	6.67	3.87	7.21	3.85	7.35	4.27	9.00	3.99
Community and environment grade score (range: 0–15)	6.73	4.92	6.05	4.92	6.53	4.74	7.70	4.25
Government grade score (range: 0–15)	6.00	4.68	7.26	4.07	7.18	4.25	8.25	3.46

Abbreviations: GM, Global Matrix; INC, incomplete; PPP, purchasing power parity.

Table 2 Linear Mixed-Effects Models Examining Trends in Behavioral Indicator Grade Scores Across All Global Matrices

Predictors	Overall physical activity grade score			Organized sport grade score			Active play grade score			Active transportation grade score			Sedentary behavior grade score		
	Estimates	CI	P	Estimates	CI	P	Log mean	CI	P	Estimates	CI	P	Estimates	CI	P
Intercept	4.52	3.00 to 6.05	<.001	5.98	4.32 to 7.65	<.001	−1.87	−3.28 to −0.46	.009	4.82	3.40 to 6.24	<.001	5.85	4.26 to 7.44	<.001
Global Matrix 2.0 (ref: 1.0)	0.01	−1.42 to 1.43	.990	0.34	−1.00 to 1.68	.618	0.81	−0.16 to 1.78	.103	1.22	−0.04 to 2.48	.057	−0.42	−1.87 to 1.03	.568
Global Matrix 3.0 (ref: 1.0)	0.02	−1.40 to 1.44	.981	0.94	−0.42 to 2.29	.175	0.62	−0.38 to 1.61	.22	1.45	0.19 to 2.71	.024	0.31	−1.14 to 1.76	.680
Global Matrix 4.0 (ref: 1.0)	0.71	−0.84 to 2.27	.368	0.92	−0.60 to 2.43	.235	1.22	0.05 to 2.40	.041	1.02	−0.37 to 2.41	.152	0.81	−0.79 to 2.41	.321
High HDI (ref: very high HDI)	0.50	−1.79 to 2.79	.668	−1.20	−4.22 to 1.81	.433	1.78	−0.69 to 4.25	.158	3.24	0.91 to 5.57	.006	−0.55	−3.02 to 1.93	.664
Medium and low HDI (ref: very high HDI)	2.29	−0.77 to 5.35	.143	2.14	−1.68 to 5.95	.272	4.93	1.60 to 8.26	.004	6.48	3.43 to 9.53	<.001	0.63	−2.65 to 3.91	.706
Gender Inequality Index (centered)	−0.43	−1.56 to 0.71	.464	−1.94	−3.37 to −0.51	.008	−1.49	−2.75 to −0.22	.021	−2.05	−3.19 to −0.91	<.001	0.46	−0.76 to 1.68	.462
At least some postpandemic data (ref: prepandemic data only)	0.40	−0.94 to 1.74	.560	−0.60	−1.96 to 0.76	.386	0.01	−0.91 to 0.93	.979	0.63	−0.59 to 1.85	.314	−0.84	−2.23 to 0.54	.233
Random effects															
σ^2	4.48			3.80			1.0			3.40			4.61		
τ_{00}	2.83 country			7.83 country			3.23 country			3.72 country			3.67 country		
ICC	.39			.67			.76			.52			.44		
n	63 country			63 country			63 country			63 country			63 country		
Observations	148			148			148			148			148		
Marginal R^2/ conditional R^2	.053/.419			.255/.756			.170/.803			.161/.599			.053/.473		

Abbreviations: CI, confidence interval; HDI, Human Development Index; ICC, intraclass correlation coefficient; INC, incomplete; ref, reference.

Table 3 Linear Mixed-Effects Models Examining Trends in Sources of Influence Indicator Grade Scores Across All Global Matrices

Predictors	Family and peers grade score			School grade score			Community and environment grade score			Government grade score		
	Estimates	CI	P	Estimates	CI	P	Estimates	CI	P	Estimates	CI	P
Intercept	3.29	1.12 to 5.45	.003	7.24	5.35 to 9.13	<.001	6.33	3.94 to 8.73	<.001	6.42	4.45 to 8.40	<.001
Global Matrix 2.0 (ref: 1.0)	0.45	−1.49 to 2.38	.649	−0.47	−2.07 to 1.13	.568	−0.43	−2.65 to 1.79	.704	0.52	−1.10 to 2.13	.531
Global Matrix 3.0 (ref: 1.0)	−0.02	−1.96 to 1.91	.98	−0.59	−2.19 to 1.02	.475	−0.02	−2.23 to 2.19	.985	0.64	−0.99 to 2.27	.441
Global Matrix 4.0 (ref: 1.0)	1.43	−0.71 to 3.57	.192	0.31	−1.48 to 2.10	.734	−0.02	−2.45 to 2.41	.984	1.44	−0.38 to 3.26	.121
High HDI (ref: very high HDI)	1.82	−1.68 to 5.32	.308	1.11	−2.15 to 4.37	0.504	−0.02	−3.68 to 3.64	.991	−0.20	−3.72 to 3.31	.910
Medium and low HDI (ref: very high HDI)	1.44	−3.16 to 6.03	.540	2.73	−1.47 to 6.92	.203	0.62	−4.25 to 5.49	.804	−0.54	−5.01 to 3.93	.813
Gender Inequality Index (centered)	−1.61	−3.33 to 0.10	.065	−2.77	−4.33 to −1.20	.001	−1.93	−3.74 to −0.11	.037	−0.31	−1.99 to 1.36	.713
At least some postpandemic data (ref: prepandemic data only)	1.62	−0.26 to 3.49	.091	1.24	−0.34 to 2.83	.124	1.66	−0.44 to 3.76	.121	0.19	−1.43 to 1.81	.816
Random effects												
σ^2	8.11			5.45			10.82			5.52		
τ_{00}	8.10 country			8.20 country			7.58 country			10.30 country		
ICC	.50			.60			.41			.65		
n	63 country			63 country			63 country			63 country		
Observations	148			148			148			148		
Marginal R^2/conditional R^2	.135/.567			.260/.705			.169/.512			.034/.663		

Abbreviations: CI, confidence interval; HDI, Human Development Index; ICC, intraclass correlation coefficient; ref, reference.

appropriateness.[28] In the present study, a harmonized methodology, data considered credible and culturally appropriate by local experts and other stakeholders, and mentoring and peer review to enhance standardization, was used to identify recent global trends. A recent systematic review[29] found secular declines in total volume of physical activity (step counts and accelerometer counts per minute) in children and adolescents, but the evidence was all from countries with very high HDI, and from the more distant past (of the 13 eligible child and adolescent studies only 1 covered the same period as the present study[29]). In addition, different devices were used in eligible studies in that review, making comparability problematic even with device-based measure data.[29] In summary, comparisons between the present study and previous studies of secular trends in physical activity should be made with caution.

Some previous studies which have considered trends over a similar time period to the present study suggested that physical activity may have remained relatively stable (but low) or declined slightly over the past 10 years, and sedentary behavior (especially recreational screen time) may have increased or remained relatively stable.[17–21] Canada stands out internationally in that it has very high-quality national surveillance of physical activity, with large and nationally representative measures of physical activity measured objectively (both with accelerometry and step counting) across a relatively long time period, measured in the same ways. Canadian surveys from 2007 to 2015 suggest no significant improvement in physical activity levels, with low levels across that period, but these high-quality data are restricted to one country and one physical activity indicator.[18,19,21]

Strengths and Limitations of the Present Study

The present study has a number of advantages relative to previous studies including the novelty and importance of wide geographical reach; recency of trend data; wide scope of data in terms of age range; assessment of both behaviors and the influences on physical activity and sedentary behavior; and use of a robust, culturally appropriate, and harmonized approach to assigning grades globally.

The present study also had a number of limitations. The Active Healthy Kids Global Alliance Global Matrix is restricted to school-age children and adolescents, so secular trends in the under 5-year-olds cannot be examined. The interpretation of trends should also consider potential temporal variations in data sources within countries (eg, dependence on different data sources across the period between Global Matrices 1.0 and 4.0) and changes in the benchmarks used between the Global Matrices. For example, the benchmark for overall physical activity changed from meeting the recommended amount of moderate- to vigorous-intensity physical activity *daily* in the first 3 Global Matrices to an *average across the week* in Global Matrix 4.0, in line with the new WHO guidelines.[30] Future analyses of other aspects of secular trends in Global Matrix data will be possible, and the AHKGA is open to data sharing with collaborators who are interested in such analyses.

Some subgroups within populations might have experienced more marked secular changes than others in the past decade or so. In Scotland, for example, childhood obesity prevalence increased dramatically in families with low socioeconomic status but was stable among those with high socioeconomic status[31] and for most report card indicators socioeconomic inequalities increased substantially in the decade prior to the COVID-19 pandemic.[32] Further analysis will also be required to examine the causes of secular

changes (or lack of secular changes), but the present study can help generate hypotheses about mechanisms, and stimulate further research (eg, on the influence of gender inequality on trends in many of the report card indicators).

Secular trends in a number of report card indicators might only become more discernible with methodological improvements in surveillance data (improved sampling, improved measurement, or both), and/ or the passage of time. For example, *Physical Fitness* was only added to the Global Matrix protocol in 2018 and so secular trends within the context of the Global Matrix cannot yet be identified. *Active Play and Family and Peer Influence* have been consistently difficult for many countries to grade, and so international secular trends cannot be discerned with high confidence—partly because of lack of data, but also because of methodological problems in assessing these indicators. Our observation of a modest secular improvement in *Active Play* should be regarded as promising, but tentative for now.

The present study also focused on changes in median grades over time across all of the report cards in the Global Matrices, and further analyses might reveal different patterns of secular change either within countries or between countries (eg, using latent class analysis). Despite these limitations, the present study represents a unique and robust assessment of recent (past decade or so) secular trends, the most comparable assessment over time (due to the harmonized methodology), and the most comprehensive and inclusive assessment to date (with global geographical reach; inclusion of children as well as adolescents; inclusion of sources of influences on physical activity and sedentary behavior as well as of the behaviors).

Conclusions

Our findings suggest that across the 4 Global Matrix initiatives (published between 2014 and 2022) time spent in physical activity and sedentary behaviors among children and adolescents globally, and the influences on these behaviors, were relatively stable, though for most of the report card indicators trends were more undesirable in countries with higher levels of gender inequality. If the global goal to reduce physical inactivity in adolescents by 15% by 2030[27] is to be met, the present study suggests that more urgent and substantial actions will be required in the rest of this decade. If global ambitions to reduce gender inequalities in physical activity among children and adolescents are to be achieved[25], the present study also suggests more urgent and more substantive attention is required.

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