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Development and validation of the Global Adolescent and Child Physical Activity Questionnaire (GAC-PAQ) in 14 countries: study protocol

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ABSTRACT

Introduction Global surveillance of physical activity (PA) of children and adolescents with questionnaires is limited by the use of instruments developed in high-income countries (HICs) lacking sociocultural adaptation, especially in low- and middle-income countries (LMICs); under-representation of some PA domains; and omission of active play, an important source of PA. Addressing these limitations would help improve international comparisons, and facilitate the cross-fertilisation of ideas to promote PA. We aim to develop and assess the reliability and validity of the app-based Global Adolescent and Child Physical Activity Questionnaire (GAC-PAQ) among 8–17 years old in 14 LMICs and HICs representing all continents; and generate the 'first available data' on active play in most participating countries.

Methods and analysis Our study involves eight stages: (1) systematic review of psychometric properties of existing PA questionnaires for children and adolescents; (2) development of the GAC-PAQ (first version); (3) content validity assessment with global experts; (4) cognitive interviews with children/adolescents and parents in all 14 countries; (5) development of a revised GAC-PAQ; (6) development and adaptation of the questionnaire app (application); (7) pilot-test of the app-based GAC-PAQ; and, (8) main study with a stratified, sex-balanced and urban/rural-balanced sample of 500 children/adolescents and one of their parents/guardians per country. Participants will complete the GAC-PAQ twice to assess 1-week test–retest reliability and wear an ActiGraph wGT3X-BT accelerometer for 9 days to test concurrent validity. To assess convergent validity, subsamples (50 adolescents/country) will simultaneously complete the PA module from existing international surveys.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This will be the first physical activity (PA) questionnaire to be culturally adapted and validated for use among 8–17 years old across all inhabited continents and income levels.

⇒ The target sample of 7000 children and adolescents stratified by sex and urbanisation (eg, urban, rural) represents the most diverse ever used for the validation of a PA questionnaire for children and adolescents.

⇒ The use of an app with adaptable content should enhance data collection efficiency for younger children (eg, 8–10 years old) and respondents with limited reading ability, while minimising data entry errors.

⇒ Our questionnaire will be validated against ActiGraph accelerometers that have established reliability and validity, but underestimate PA during certain activities which may bias validity estimates towards the null hypothesis.

⇒ Self-reported measures of PA are at risk of recall and social desirability biases, but they provide important contextual information and are cheaper and generally easier to implement than accelerometers.

Ethics and dissemination Approvals from research ethics boards and relevant organisations will be obtained in all participating countries. We anticipate that the GAC-PAQ will facilitate global surveillance of PA in children/adolescents. Our project includes a robust knowledge translation strategy sensitive to social determinants of health to inform inclusive surveillance and PA interventions globally.

INTRODUCTION

Most children and adolescents worldwide do not meet current physical activity (PA) guidelines, which recommend an average of ≥60 min per day of moderate- to vigorous-intensity physical activity (MVPA).[1–5] This raises concern because insufficient physical inactivity is a major risk factor for non-communicable diseases, and is associated with lower academic achievement and higher risk of mental health conditions.[6–9] Many interventions have been developed to promote PA, but multiple reviews have highlighted a lack of tangible progress in addressing the global physical inactivity crisis.[4 10] Moreover, evidence consistently indicates that girls are less active than boys[1 3 11 12] and PA declines with age,[1 13–15] underscoring a need to promote PA early in life and address known disparities. Such disparities have also been reported based on characteristics such as socioeconomic status (SES), ethnicity and disability.[2 16 17]

In its Global Action Plan on Physical Activity 2018–2030, the WHO targeted a 15% reduction in the prevalence of insufficient PA among adolescents and adults by 2030.[7] Monitoring progress towards this goal is challenging due to significant gaps and disparities in current national and international surveillance initiatives.[1 18 19] Enhanced surveillance systems would allow for more precise cross-country comparisons of PA indicators, aligning with the missions of entities like the WHO and the Active Healthy Kids Global Alliance (AHKGA)[2] to encourage PA.

Presently, intercontinental PA surveillance initiatives for children and adolescents are limited by numerous issues.[1 2 18 20 21] First, public health surveillance of PA is underfunded globally as evidenced by the lack of data on children's PA in many countries across all levels of economic development.[18] Second, there are many inconsistencies in measures (eg, devices vs self-report; variation in self-report and proxy-report instruments) and definitions of achieving sufficient PA (eg, achieving ≥60 min/day of MVPA every day vs on average) that make it hard to compare data across countries.[1] Third, most PA questionnaires have been developed from predominantly urban samples from high-income countries (HICs), with insufficient efforts to adapt them to the cultural and socioeconomic contexts of low- and middle-income countries (LMICs) and minority groups in HICs.[1] Sound sociocultural adaptation is crucial to ensure comparability of PA estimates between countries while being attentive to issues of equity, diversity, inclusion, literacy levels and accessibility. Fourth, questionnaires used in large international studies tend to overlook active play, sport and work-related PA,[2] which may be substantial sources of PA. The need for an instrument that captures all domains of PA has been repeatedly identified.[1 2 18 22 23]

Among the domains that are overlooked, active play—'voluntary engagement in activity that is fun and/or rewarding, usually driven by intrinsic motivation, and involving PA of any intensity'[24]—is essential for children's physical, social and cognitive development.[25 26] It is considered a human right,[27] and it may be a more accessible and routine source of PA than organised activities, especially in low-income communities. However, a reliable and valid instrument to measure active play is lacking. Active play can occur indoors and outdoors,[24] though outdoor play is typically associated with higher PA levels and may provide additional benefits in terms of psychosocial health.[26 28 29]

Therefore, our primary objectives are to develop the Global Adolescent and Child Physical Activity Questionnaire (GAC-PAQ) and assess its reliability and validity based on child/adolescent and parent/guardian report across 14 countries providing large variability in climate, level of urbanisation, SES, ethnicity, languages spoken and Human Development Index. Our second objective is to generate the 'first available data' on active play and outdoor play in many of the participating countries and investigate how it varies by social determinants of health (eg, age, gender, education, ethnicity, (dis)ability) and across countries.

METHODS AND ANALYSIS

Project leadership and management

Our project is guided by a 13-member Steering Committee including researchers and knowledge users (online supplemental file 1). The Steering Committee selected participating countries to maximise variability in characteristics such as geographical location, languages spoken, country income, population density and Human Development Index. Next, they identified investigators who have demonstrated the capacity to conduct large-scale PA data collection. Participating countries include Brazil, Canada, China, Colombia, India, Malawi, Mexico, Nepal, New Zealand, Nigeria, Spain, Sweden, Thailand and the United Arab Emirates (figure 1). Table 1 provides country-level indicators for participating countries and a more detailed version of the table is available in online supplemental file 2. The country Lead Investigators, also listed in online supplemental file 1, are responsible for all aspects of study implementation in their country. The Coordinating Centre, based at the University of Lethbridge (Canada), is responsible for developing questionnaire drafts and the app (discussed below), producing training materials and manuals, organising regular team meetings, planning analysis methods, completing data transfer and funding agreements with each site and maintaining the knowledge translation plan. The study team also includes subcommittees that advise on matters related to accelerometry, knowledge translation and justice, equity, diversity and inclusion.

Study design

The development, adaptation and validation of the GAC-PAQ involves eight stages described below, some of which are occurring concurrently given our 3-year funding timeline. Table 2 summarises each stage and progress to date. Because stages involving data collection will use a cross-sectional design, we used the Strengthening the

Figure 1 Countries involved in the Global Adolescent and Children Physical Activity Questionnaire project. Note: Created with mapchart.net under a Creative Commons Attribution-ShareAlike 4.0 International License.

Reporting of Observational Studies in Epidemiology checklist[30] to prepare the study protocol.

Stage 1: systematic review of the psychometric properties of PA questionnaires

This stage began with an environmental scan of instruments used in multicountry studies including the Global School-based Student Health Survey (GSHS)[12] and Health Behaviour in School-aged Children Survey (HBSC)[31] to help inform the first draft of the GAC-PAQ. The scan revealed important gaps in coverage of PA domains (eg, active play, work) and under-representation of LMICs as reported previously.[1] Our full systematic review summarised the psychometric properties of existing PA questionnaires for preschoolers, children and adolescents, updating a previous review.[32] We registered the protocol in the Open Science Framework registry (https://doi.org/10.17605/OSF.IO/9KN73) and used the Consensus-based Standards for the selection of health status Measurement Instruments (COSMIN) guidelines for systematic reviews of Patient-Reported Outcome Measures[33] to minimise bias and ensure consistent reporting. Many of the included questionnaires whose psychometric properties were assessed in LMICs were developed in HICs, often with limited cultural adaptation, so results of the systematic review (submitted for publication) support the need for developing a new PA questionnaire.

Stage 2: development of the GAC-PAQ

First, Steering Committee members and country Lead Investigators were surveyed about their preferences regarding questionnaire format, reference period (eg, past week, past month, typical week), and how PA duration and intensity should be assessed. RL, MST and MRHA reviewed survey responses, developed a first draft in English and requested further feedback from the Steering Committee and Lead Investigators. When indicating their preferences, members were asked to think about the extant evidence, to consider the trade-off between usability and accuracy in data collected as well as how to minimise recall bias.

Stage 3: assessment of content validity

Once consensus was reached on the modifications, the revised draft was sent to global PA measurement/surveillance experts for content validation (Stage 3). These experts were identified in consultation with all country Lead Investigators. Experts completed an online survey assessing their agreement with four statements adapted from the COSMIN checklist[33 34] for each domain of the GAC-PAQ. Items were presented on a 5-point Likert scale from strongly disagree to strongly agree. The statements included: (1) 'Items refer to relevant aspects of the domain' (eg, the school domain); (2) 'Items are relevant for the target population (ie, 8- to 17-year-olds)'; (3) 'Items are relevant for the purpose of the measurement instrument'; and (4) 'Collectively, the items adequately reflect the domain'. Respondents were invited to provide qualitative feedback following each domain and at the end of the survey. We collected socio-demographic information from respondents (age, gender, country and work sector) for descriptive

Table 1 Characteristics of included countries

Region / country	Human development index	Gini index	World Bank income class	Population size	Official languages	City(ies) or region(s)	Annual mean temperature (°C)	Annual total precipitation (mm)
						Weather information for data collection sites		
Africa								
Malawi	0.483 Low	44.7 Medium	Low income	20 931 751	English, Chichewa	Blantyre and Zomba	22.6	848
Nigeria	0.539 Low	35.1 Medium	Lower-middle income	223 804 632	English	Whole country	27.2	1163
Asia								
China	0.761 High	46.7 High	Upper-middle income	1 425 671 352	Chinese	Shanghai	18.1	1388
India	0.645 Medium	35.7 Medium	Lower-middle income	1 428 627 663	Hindi, English	Ranjangaon, Pune	24.5	717
Nepal	0.602 Medium	32.8 Medium	Lower-middle income	30 896 590	Nepali	Dolkha	6.4	694
						Syangja	17.6	1621
						Rupandehi and Bardiya	24.4	1600
Thailand	0.777 High	34.9 Medium	Upper-middle income	71 801 279	Thai	North	26.9	1536
						Central and East	28.2	3836
						Northeast	26.9	1705
						South (East Coast)	27.6	2521
						South (West Coast)	27.7	3436
United Arab Emirates	0.890 Very high	32.5 Medium	High income	9 516 871	Arabic	Dubai	29.0	125
						Hatta	28.0	81
Europe								
Spain	0.904 Very high	33.0 Medium	High income	47 519 628	Spanish	Bilbao	14.7	1134
						Seville	19.2	539
						Madrid	14.5	371
						Badajoz	17.1	447
Sweden	0.945 Very high	26.9 Low	High income	10 612 086	Swedish	Stockholm	8.8	472
North America								
Canada	0.929 Very high	30.3 Medium	High income	38 781 291	English, French	Lethbridge	5.5	351
						Ottawa	8.8	1047
Mexico	0.779 High	41.8 Medium	Upper-middle income	128 455 567	Spanish	North	29.6	400
						Central	28.0	733
						South	31.4	1531
Oceania								

Continued

Table 1 Continued

Region / country	Human development index	Gini index	World Bank income class	Population size	Official languages	Weather information for data collection sites		
						City(ies) or region(s)	Annual mean temperature (°C)	Annual total precipitation (mm)
New Zealand	0.937 Very high	36.2 Medium	High income	5228100	English, Māori, NZSL*	Auckland	15.0	1814
						Wellington	14.1	1157
South America								
Brazil	0.765 High	53.4 High	Upper-middle income	216422446	Portuguese	Florianopolis	20.8	1506
						Campo Grande	23.5	1573
Colombia	0.767 High	51.3 High	Upper-middle income	52085168	Spanish	Bogotá	12.9	1091

The Human Development Index theoretically ranges from 0 to 1 and the Gini index theoretically ranges from 1 to 100. Weather data was only available at the national level in Nigeria.
*New Zealand Sign Language (NZSL) will not be used for the initial development of the questionnaire.

purposes, and used their feedback to prepare a revised version of the GAC-PAQ.

Stage 4: cognitive interviews in 14 countries

We conducted cognitive interviews (10–20 per country) with a convenience sample of children/adolescents and their parents/guardians that aims to provide diversity in sociodemographic characteristics. Before beginning these interviews, the questionnaire was translated into the languages of participating countries and back-translated to English for verification. Any discrepancies between the original and back-translated versions were resolved by the country Lead Investigators in consultation with their study staff, translators and, as needed, the study co-principal investigators (PIs) (RL and MST). The English version of the GAC-PAQ initially used for cognitive interviews with children/adolescents is provided in online supplemental file 3. This version included still images representing different intensities of PA to exemplify how questions would appear in the app as described under Stage 5. Interviewees in Stage 4 were asked to identify any words or items in the questionnaire that they find unclear and provide suggestions for improvement. Participants were encouraged to think aloud while responding and to ask any questions for clarification.[35 36] All interviews were audio-recorded and transcribed verbatim. The framework analysis method developed by Ritchie and Spencer,[37] was used to analyse interview data. This pragmatic approach allows both inductive and deductive issues to be considered and is well-suited to applied projects where a qualitative component is embedded in a larger quantitative study.[37] Two researchers with knowledge of the local context analysed the data for their country and compiled an Excel spreadsheet that includes challenges perceived by participants, suggestions for improvement, relevant quotes and participant sociodemographic characteristics. The spreadsheets from Stage 4 were merged and reviewed by the coordinating centre which proposed changes to the Steering Committee members and Lead Investigators. The revised version produced after this stage will be used to develop the app.

We made some modifications to the questionnaire based on feedback from the first eight interviews in Canada and mock interviews in Thailand. First, the order of the work and chores domains was reversed. With the initial version, some participants reported chores as work, so we expect that this revision will minimise double counting. Second, the questions about travel mode from school to home were eliminated because many participants indicated that they do not go directly from school to home (eg, they may go to a park or an after-school programme) and given evidence from a recent national longitudinal study in Canada where the difference in the prevalence of active transportation between the trips to and from school was less than 1% (Larouche et al, unpublished observations). Third, for similar reasons, we removed the question about travel mode from work to home. These modifications

Table 2 Stages of the Global Adolescent and Child Physical Activity Questionnaire (GAC-PAQ) development and validation process and summary of progress to date

Stage	Current status and expected completion	Progress to date
Systematic review of the psychometric properties of PA questionnaires	Complete	We used a similar search strategy as the previous review by Hidding *et al*.[32] We screened the PubMed, SPORTDiscus and Embase databases and 7050 potentially relevant articles were identified after removing duplicates. Titles, abstracts and full texts were screened by two reviewers and, when needed, a third reviewer was consulted to resolve discrepancies. The review included 85 papers and the manuscript has been submitted for publication. An environmental scan performed before the review identified no international questionnaire that covered all PA domains and had satisfactory test–retest reliability and construct validity.
Development of the GAC-PAQ	Complete	The first draft of the questionnaire was developed in November 2022. There were two rounds of feedback from members of the Steering Committee and Lead Investigators (see online supplemental file 1 for the list). The questionnaire was revised accordingly prior to content validation.
Assessment of content validity	Complete	137 experts from 29 countries were invited to complete an online survey to assess the content validity of the draft GAC-PAQ written questionnaire. The response rate was relatively low (46.0%) with 63 experts completing the survey. Of those who reported their country of origin, 52.5% are from HICs and 47.5% from LMICs. Based on the feedback, a new version of the GAC-PAQ was developed by the co-PIs (RL and MST) and project manager (MRHA). Then, additional feedback was requested from members of the Steering Committee and Lead Investigators and incorporated in the version used for Stage 4. The draft of this version of the GAC-PAQ in English is available in online supplemental file 3.
Cognitive interviews in 14 countries	Complete	Prior to the interviews, the questionnaire was translated into the languages of participating countries and back-translated to English for verification. The interview guide, consent and assent forms were also translated. The interviews were completed in February 2024.
Development of the app-based questionnaire in English	Underway. Expected completion by the end of June 2024.	The initial layout of the app was presented at the project team meeting in June 2023 and feedback was obtained from attendees. The app development team is addressing this feedback and creating an image bank for the app.
Production of the app-based questionnaire in multiple languages	Underway. Expected completion by the end of July 2024.	Images displayed in the app will be customised for participating countries to ensure cultural relevance. The text of the app and any questionnaire items modified following the cognitive interviews will be translated and back-translated to English for content verification.
Pilot study of the app	Not yet started. Expected completion by the end of October 2024.	Participating countries are identifying school authorities that will be involved in the pilot study and main study. The Coordinating Centre (University of Lethbridge, Canada) is developing standardised protocols for data collection to harmonise procedures and train study staff.
Main study	Not yet started. Expected completion by the end of November 2025.	The main study will begin in 2024 with data collection over 12 months to capture seasonal variations in weather and circannual behaviours.

This table is current as of 2 April 2024.
HICs, high-income countries; LMICs, low- and middle-income countries; PA, physical activity; PIs, principal investigators.

allowed us to shorten the questionnaire, which may be desirable from a surveillance perspective.

Stage 5: development of the app-based questionnaire

We believe that an app-based questionnaire provides many advantages over traditional paper-and-pencil questionnaires including: (1) a streamlined data collection process, facilitating surveillance and preventing data entry errors; (2) using familiar and ubiquitous devices (eg, tablets and smartphones) to facilitate completion of the questionnaire; and, (3) the ability to use both text-based and audio/video descriptions for users with disabilities or limited reading ability. Furthermore, Tremblay and colleagues[38] found that Canadian children as young as 7.7±0.5 years could recall their previous day's PA reasonably accurately when facilitative video cues were provided. Video and images can help clarify nuances between

different types and intensities of PA while ensuring consistency in directions provided to participants. The inclusion of narration and images also aims to facilitate the use of the GAC-PAQ as a self-administered survey in future research. The app will be designed to work on smartphones and tablets (with and without internet access to accommodate sites where such access can be limited); hence it will be a 'native' app rather than a web-based app. We intend to make the app freely available, so that it can be used at scale and tailored to different contexts. The app will be developed to comply with the European General Data Protection Regulation.
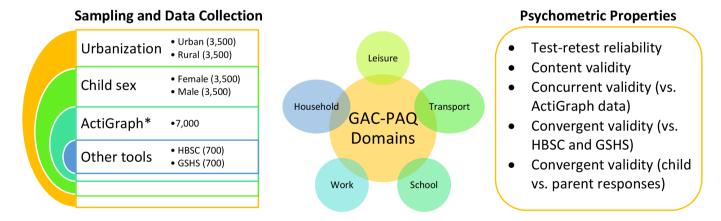
Stage 6: production of the app in multiple languages

This will involve the adaptation of the app to participating countries and the translation of app content following the approach described in Stage 3. We will use artificial intelligence (AI; specifically, MidJourney, ElevenLabs and Adobe Photoshop) to generate images illustrating the different types of activities and representing diversity in characteristics such as age, ability, ethnicity, size, sex and gender diversity. AI-generated images are realistic and do not require subjects' consent. Lead Investigators will have access to an image bank from which they can select culturally-relevant examples. Although questionnaire items will be the same, examples (written and visual) provided will be customised to each country. To illustrate different activity intensities (light, moderate and vigorous), country Lead Investigators and their teams will select appropriate examples from the Youth Compendium of Physical Activities[39 40] and may include other culturally-relevant activities. The app will be organised by the PA domains indicated in figure 2. At the beginning of each domain, there will be a screening question to determine if other questions in the domain apply. For example, in the school domain, children will be asked if they attended school in the past week. If they respond 'no', then subsequent questions about school will be deemed not applicable and thus skipped. This approach aims to enhance data quality by reducing completion time and the perceived irrelevance of questions.

Stage 7: pilot study of the app

Prior to deploying the main study, we will pilot test the app-based GAC-PAQ with a convenience, but sex-stratified and urban-/rural-stratified sample of 30 child–parent dyads per country. We will use country-specific definitions of urban and rural areas to ensure the relevance of our findings for knowledge users. Because peri-urban/suburban areas are near the centre of the continuum between rural and urban areas and more difficult to operationalise consistently between countries, we will recruit schools in urban and rural areas only. For Stages 7 and 8, children and adolescents will complete the questionnaire on tablets provided by the study team. Country investigators will be asked to consider the best way for the parents to complete the questionnaire (eg, on their own time on their phone or tablet vs in-person on tablets purchased for the study) based on considerations such as access to mobile devices. Following completion of the GAC-PAQ, we will ask participants to rate their satisfaction with the questionnaire on a 5-point Likert scale from poor to excellent that will include emojis to facilitate comprehension for younger participants. We will also provide an opportunity for participants to type comments about their experience in the app at the end of the survey. Their feedback will be considered by the Steering Committee and Lead Investigators when preparing the final version of the app. All study staff will be trained to use the same protocol to administer the questionnaire, which will be translated as needed to ensure compliance. We will create standard operating procedures (SOPs) for the administration of the GAC-PAQ and other questionnaires (ie, HBSC, GSHS) and for collecting accelerometry data. We will discuss the SOPs at a monthly team meeting, then investigators will be asked to train their staff.

Figure 2 Sampling variables, instruments used in the main study and domains assessed by the Global Adolescent and Children Physical Activity Questionnaire (GAC-PAQ) project. Notes: Numbers in parentheses represent the number of participants in each stratum across 14 participating countries. The analytical sample size for ActiGraph data will depend on adherence to the protocol described in Stage 8. The right column indicates the psychometric properties that will be assessed in the study. GSHS: Global School-Based Student Health Survey; HBSC: Health Behaviour in School-Aged Children Survey.

Stage 8: main study

Each country will recruit a sex-balanced and urban-/rural-stratified sample of 500 children/adolescents and one of their parents/guardians. Table 3 summarises the country-specific adaptations of the sampling strategy and highlights planned efforts to ensure the diversity of the sample in terms of age, SES, climate, geography, ethnicity/nationality, etc. In some participating countries, a substantial proportion of children and adolescents do not attend school (eg, India, Malawi, Nepal). They are routinely excluded from international PA surveys like the GSHS and the HBSC,[12 31] thus reducing their external validity. To minimise potential bias, we will also recruit children through community-based and faith-based groups in such countries. Our sampling strategy is tailored to each participating country (eg, different school systems), using a similar approach to the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)[41] and the International Study of Movement Behaviours in the Early Years.[42] Data collection will be staggered, with each site completing data collection over a full calendar year to capture seasonal variations in weather and circannual behaviours. We aim to achieve reasonable heterogeneity to challenge the robustness of the GAC-PAQ across diverse socio-demographic and cultural circumstances.

We will ask participants to complete the GAC-PAQ twice, 8 days apart. We will also collect data on variables including child/adolescent gender (where culturally acceptable), sex, age, ethnicity/country of birth, urban/rural living location, whether the child/adolescent has a disability or chronic condition and SES indicators. These variables may contribute to differences in reliability/validity (objective 1) and/or predict engagement in active play (objective 2). To compare the GAC-PAQ with questionnaires employed in previous international studies examining the prevalence of PA (convergent validity), we will ask a random subsample of 50 adolescents per country to complete the PA modules from the GSHS[12] and HBSC.[31] Figure 2 summarises data collection plans for Stage 8.

We will examine the concurrent validity of the questionnaires (GAC-PAQ, HBSC and GSHS) against PA estimates from hip-worn ActiGraph wGT3X-BT (Pensacola, Florida) accelerometers collected over seven consecutive days. The ActiGraph has good to excellent validity for measuring PA,[43] including among children with physical disabilities.[44] Accelerometers are increasingly used in population-based studies,[13 45 46] making them an appropriate comparison measure of free-living PA. The ISCOLE 24-hour accelerometry protocol will be adopted, which resulted in much higher wear time than protocols wherein participants are asked to wear the device during waking hours only.[47 48] Accelerometry data will be processed to estimate non-wear time, sleep time, sedentary time, light-intensity, moderate-intensity and vigorous-intensity PA, MVPA, total counts/min and total steps/day. The last two measures represent total PA and will be compared with the reported time spent in PA across all domains from the GAC-PAQ. Cut-points to determine the non-wear time and different PA intensities will be selected based on the best available evidence at the time of analyses. When research staff distribute accelerometers to participants, children/adolescents and parents/guardians will be asked to complete the GAC-PAQ for the previous week. Accelerometry data collection will begin in the late afternoon of the first day to capture sleep on the first night. On day 9, research staff will pick up accelerometers and ask children/adolescents and parents/guardians to complete the GAC-PAQ a second time, for the week corresponding to accelerometer wear. This will minimise the temporal mismatch between the questionnaire and accelerometer data. The deployment of accelerometers for 9 days will ensure that we get one full week of data.

Patient and public involvement

Given the importance of ensuring that questionnaire items are relevant and comprehensible, cognitive interviews are being conducted with children/adolescents and parents/guardians in Stage 4. Similarly, participants' experience with the app-based version of the questionnaire will be assessed in Stage 7. Participants' feedback will be synthesised by the Steering Committee and Country Lead Investigators to help simplify questions and improve the experience of app users. Furthermore, three knowledge users on our Steering Committee (RCC, LMV and KR) were intentionally selected based on their expertise in PA epidemiology, measurement and surveillance methods. They work in national governmental agencies responsible for surveillance (Statistics Canada, Public Health Agency of Canada) or in a national non-profit organisation that promotes PA (ParticipACTION). They are well-positioned to provide input on the feasibility of the GAC-PAQ for use in population monitoring and help mobilise findings. Several students in New Media and Computer Science from the University of Lethbridge are also contributing to the development of the app under the supervision of RH-B.

Training and capacity building

Capacity building has been included from the project inception, beginning with the inclusion of country Lead Investigators as co-applicants on the main grant application, and the inclusion of LMIC priorities in the study design. Lead Investigators are also responsible for providing feedback on different versions of the GAC-PAQ, recruiting staff and trainees, and they share the responsibility of training with the Principal Investigators and Project Manager. Across participating countries, we expect that ≥40 students, trainees and early-career researchers will be involved in the project. A 2-day in-person meeting was held before the International Society for Behavioural Nutrition and Physical Activity conference (Uppsala, Sweden; June 2023) where the project was first introduced to the broader scientific community through a symposium. Investigators from 12 participating countries

Table 3 Sampling methods for each participating country

Country	Sampling methods
Brazil	Primary and secondary schools will be selected from high and low SES regions across different areas of the country. Additionally, schools situated in coastal and non-coastal cities will also be included. We will include private and public schools.
Canada	Primary and secondary schools will be selected in urban and rural areas within the regions of Lethbridge, Alberta (population ~100 000) and Ottawa, Ontario (population ~1 000 000). We will include public and catholic schools in both regions as well as French schools in Ottawa. Schools located in higher and lower income neighbourhoods relative to the median household income of their census metropolitan area will be invited.
China	Primary and secondary schools will be selected in urban and rural areas in the Shanghai metropolitan area (population ~24.9 million). We will include public and private schools from two districts, representing urban and rural areas, respectively. A multistage stratified cluster sampling method will be used.
Colombia	Primary and secondary schools will be selected in low, middle and high economic areas within urban areas and low-income in rural areas in Bogotá Colombia (overall population ~7 200 000 including ~2 000 000 children and adolescents). Bogotá is the capital city of Colombia and the largest city with urban and rural areas. We will include a convenience, but stratified sample of public or private schools. Schools will be selected based on SES and urban vs rural location areas. In Colombia, schools in rural areas are all low-income.
India	Students from schools in the city of Pune, India (population ~3.9 million) will be invited to participate. Both government-funded and private schools located in Pune (urban centre) and rural jurisdictions ~60 km from Pune will be included to ensure recruitment from across SES groups. Stratified random sampling will be used to recruit an equal proportion of males and females across different grade levels. Out-of-school adolescents will be recruited via a random sampling of households with children or adolescents. These households will be identified from an existing registry. Additional sampling from local community centres and temples will ensure the recruitment of children and adolescents across age groups.
Malawi	Primary and secondary schools will be selected in the urban and rural areas of Blantyre (total population ~1 300 000) and Zomba (total population ~900 000) districts in Southern Malawi. We will include public, private, and religious schools in the two districts. Out-of-school adolescents will be identified through (1) school records and youth clubs community-based groups within the settings located within the catchment area of the selected schools; and (2) households with under 18s in selected communities surrounding the sampled schools. Households with under 18s will be identified through existing registries maintained by community leaders.
Mexico	Primary and secondary public and private schools will be selected in urban and rural areas within the central, north and south regions of Mexico, to ensure the inclusion of diverse populations. In Mexico schools in rural areas are all low-income. We will also recruit children through sports centres, community-based and faith-based groups.
Nepal	Schools (representing public and private) of urban and rural areas from three ecological regions of the country – Mountain (Dolkha), Hills (Syangja) and Terai/Plains (Repandehi and Bardiya)—will be selected purposively. Schools of varying SES will be identified with the support of the provincial government and/or the local government. A convenient but stratified sampling method will be used to recruit participants. Out-of-school children and adolescents will be identified from the records of local government, youth clubs and/or the schoolteachers in specific study sites.
New Zealand	Primary, intermediate and secondary schools within the greater regions of Tāmaki Makaurau Auckland and Te Whanganui-a-Tara Wellington (the two largest cities by population in Aotearoa New Zealand), will be sent information sheets and assents/consents to participate. From these schools, we will obtain consent and assent from students and from these potential participants recruit 500 children and adolescents stratified by age, ethnicity, sex, SES and urbanisation.
Nigeria	A convenient but stratified sampling method will be used to recruit participants into the study. Participants will be selected from primary and secondary schools (balanced by public and private schools and area-level SES) in the rural and urban areas of Osun State in South West Nigeria. Area-level SES will be determined by information from the National Population Commission and/or expert judgement using information about property values and aesthetics and building quality in the neighbourhoods.
Spain	Primary and secondary schools will be selected in urban and rural areas within the regions of Madrid (population ~6 700 000), Andalusia (population ~8 500 000), Basque Country (population ~2 200 000) and Extremadura (population ~1 000 000). We will include public and private schools in all regions. Schools located in higher and lower income neighbourhoods relative to the median household income of their census metropolitan area will be invited.
Sweden	Primary and secondary schools will be selected in urban and rural areas within Sweden (ie, Stockholm area, medium and smaller cities). The schools will be selected to represent different SES areas.

Table 3	Continued
Country	**Sampling methods**
Thailand	Primary and secondary schools will be selected from urban (Bangkok, population 5 588 222) and rural areas (Nakhon Pathom province, population 920 729) of Thailand. To accommodate for the variance between schools, the sample will be stratified proportionately based on school size. Within the schools, balanced samples will be drawn with respect to sex and grades.
United Arab Emirates (UAE)	Dubai Emirates has the largest and most diverse population in the UAE with school-aged children in private and public (governmental) primary and secondary (high) schools. Public schools are sex-segregated and primarily include UAE nationals. Most private schools are co-educational (a mix of expatriate and UAE national children). A multistage stratified random sampling technique will be used to ensure that the overall sample is representative of primary and secondary school children attending both private and public schools in Dubai. During Stage 1, private and public schools will be split into two groups. Private schools will be divided into five strata based on the predominant nationality of students attending the school (eg, European/North American, Emirati, Middle Eastern, South Asian and South-East Asian) and public (governmental) schools will be split by sex and school cycle (ie, cycle 2 or 3). Next, private schools will be stratified using annual school fees as a proxy of SES. Data on student nationality and annual school fees is publicly available. The total sample size will be allocated proportionately to the population size of children in each stratum to yield a representative and proportionate sample. Once a school is randomly selected, a list of classrooms will be compiled for each year group in the school. A simple random sample of classrooms will be selected from each school to achieve the proportionate sample. The consenting students in the selected classrooms will form the final sample.

SES, socioeconomic status.

attended the in-person meeting and two Investigators attended online. The meeting covered all phases that will be overseen by the Lead Investigators. It was at that meeting that the revisions to the draft questionnaire used for the cognitive interviews were decided. It included an accelerometer training session led by Dr Esliger and a presentation of the initial app design led by RH-B. Lead Investigators are required to submit monthly progress reports including details about recruitment progress and challenges and to participate in monthly Zoom meetings. This enables the Principal Investigators and Project Manager to monitor progress and intervene as needed.

Sample size justification
In the multicountry reliability studies for the widely used adult-focused Global Physical Activity Questionnaire[49] and International Physical Activity Questionnaire,[50] correlations between repeated measures for total PA ranged from r=0.67–0.73 and r=0.46–0.96, respectively. Craig et al[50] also reported that, in most study sites, correlation coefficients exceeded r=0.80. Based on the formula proposed by Walter et al,[51] 205 participants per country would be needed to achieve a power of 0.8 at an alpha of 0.05, assuming an expected intra-class correlation coefficient (ICC) of 0.70 (p_1) and a minimally acceptable level of reliability of 0.6 (p_0). Based on this calculation, a sample of ~500 parent–child dyads per country should provide sufficient power for sex-stratified and/or gender-stratified within-country analyses, allowing for 20–25% missing data. Within-country analyses will also be separately stratified by age (8–11 vs 12–17 years) and urbanisation (urban vs rural). Our target sample size per country is higher than psychometric studies for adult questionnaires[49 50] and should provide adequate power to

examine the concurrent validity between the GAC-PAQ and accelerometry-measured PA.

Statistical analyses
Objective 1
In Stage 3, we will assess content validity based on the proportion of experts who agree or strongly agree with the statements for each domain. If agreement is <75% for any domain, we will revise the questionnaire items based on experts' feedback and repeat the assessment of content validity. While there is no universal threshold for determining expert agreement, Delphi studies and psychometric studies often use thresholds ranging from 70% to 80%.[32 52] In Stage 8, we will derive estimates of PA from the GAC-PAQ. To do this, we plan to use midpoints for the response options that are provided as ranges. Next, we will give weight to these midpoints to account for the fact that, for example, children and youth are not engaging in MVPA for the entire duration of their physical education period.[53 54] Then, we will calibrate the GAC-PAQ against accelerometry data following a process similar to Saint-Maurice et al[55] to improve our estimates of PA.

We will assess test–retest reliability and convergent validity with ICCs for continuous variables and kappa coefficients and percent agreement for categorical variables.[30] We will use Cicchetti's[56] descriptors to qualify ICCs and kappa values as 'excellent' (≥0.75), 'good' (0.60–0.74), 'fair' (0.40–0.59) and 'poor' (<0.40). To verify the stability of the measures, we will use repeated measures analysis of variances (or Kruskal-Wallis tests if data are not normally distributed) to compare item and scale means between the test and retest. We will use Pearson correlations to assess the concurrent validity of the questionnaires

against accelerometer data and compare the GAC-PAQ with measures of the corresponding constructs from the HBSC and the GSHS. We will use Bland-Altman[57] plots to represent the limits of agreement between questionnaire estimates and accelerometry-measured total PA and MVPA. We will also assess the convergent validity of the GAC-PAQ by comparing scores from children/adolescents and parents/guardians. Our main analyses of reliability and validity will be stratified by country, sex and gender. We will only ask children/adolescents to report their gender in countries where it is deemed culturally appropriate (ie, by investigators and research ethics boards). Adopting such an approach will allow us to examine both biological (sex) and socio-cultural (gender) differences when possible. For comparison purposes, we will perform secondary analyses to examine how psychometric properties differ by social determinants of health, including age, disability, ethnicity (where acceptable), parent education, etc.

Objective 2

We will use descriptive analyses to summarise active play and outdoor time. Next, we will use sex-stratified generalised linear mixed models to investigate the correlates of these activities while accounting for the nesting of children within schools/organisations and countries as random effects.[58] We will first run bivariate models and retain variables associated with active (or outdoor) play at a liberal threshold of $p < 0.20$ as candidates for inclusion in multivariable models.[59] Then, we will use a backward selection process to obtain parsimonious multivariable models by removing non-significant variables ($p > 0.05$). In general, we will use a similar approach to investigate the correlates of overall PA and domain-specific PA. Based on an intersectionality perspective, we will also explore interactions between sex, gender and multiple social determinants of health given the emerging evidence showing that membership of multiple under-privileged groups (eg, women from visible minorities with low income) increases the risk of physical inactivity in Canadian and Brazilian adults.[60 61]

ETHICS AND DISSEMINATION

Ethical approval has been obtained for Stages 3 and 4 from institutional review boards of all institutions with researchers involved in data collection. The names of the institutional review boards and protocol number for these stages are reported in online supplemental file 4. In some countries, investigators have obtained ethical approval for Stages 7 and 8, while in other countries, ethical approval is pending. Participants in the content validation survey were invited by email, and received an information letter indicating that, by proceeding to the survey, they were providing implied consent. For Stages 4, 7 and 8, written informed consent and assent will be required from parents/guardians and children/adolescents, respectively (except for some countries where

adolescents can provide consent). Approval will also be requested from school boards and/or other organisations participating in the study.

A data-sharing agreement will be implemented between participating institutions and the Coordinating Centre (Canada) before sharing de-identified data. The agreement will be signed by parties at the Coordinating Centre and collaborating institutions. Collaborating institutions will retain ownership of their data. Data sets will be password-protected and encrypted prior to transfer, and only research team members will have access to data. Secure server space will be provided at the Coordinating Centre to store data collected through the app. Researchers not involved in the study can request data access, and if approved, they would need to sign a data-sharing agreement with the Coordinating Centre. Efforts will be made to integrate the de-identified accelerometry data set with the International Children Accelerometry Database.[13] Publication policies will follow principles of justice, equity, diversity and inclusion. We developed a publications policy and a publications committee to ensure the representation of graduate students, trainees and early career investigators as lead authors of presentations and articles.

Knowledge translation plan

We will work with ParticipACTION whose mailing list includes >46 300 subscribers to ensure that findings are communicated in an appealing format for diverse target audiences, thus maximising reach and optimising uptake. Similar dissemination will be orchestrated through the Steering Committee and Lead Investigators' networks. Study objective #2 focuses on improving the measurement of active play, addressing a gap that has been repeatedly identified by the AHKGA and ParticipACTION among others.[2 62–64] Our study will substantially reduce the number of country report cards assigning 'incomplete' grades to the active play indicator in the Global Matrix initiative due to a lack of available data.[2 62 65 66] The Report Card on Physical Activity for Children and Youth is a widely used and successful knowledge translation tool developed by MST and adopted by researchers and practitioners in>70 countries that synthesises the best-available data on children and adolescents PA.[2 62 65–67]

We also plan several end-of-grant knowledge translation activities. We will develop a user manual to assist users in appropriately administering the GAC-PAQ as intended. The GAC-PAQ will be made freely available via the AHKGA website and promoted through team members' networks. Moreover, the Co-PIs are founding members of Outdoor Play Canada and the Play, Learn, and Teach Outdoors Network (PLaTO-Net) which collectively have >700 members. These organisations will help disseminate results to practitioners, policymakers, researchers and advocates. We will host workshops/events in many participating countries and submit lay articles to The Conversation and other platforms to summarise, among others: (1) the development and psychometric properties of the

GAC-PAQ; (2) the main findings for the comparison of PA and active play between countries; and (3) where to access the GAC-PAQ. We will submit abstract/symposia proposals for presentation at international PA conferences. Likewise, we plan to submit ≥20 manuscripts to leading PA/public health journals. Finally, team members will communicate findings via their websites, newsletters and social media channels, using relevant, handles, tags, and mentions.

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