INTERNATIONAL JOURNAL OF -EXERCISE SCIENCE-

Original Research

Validity and Reliability of the 'Feelfit®' Accelerometer in Evaluating Physical Activity and Sedentary Time in Children: A Comparative Study with Two Different Accelerometers

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Abstract

International Journal of Exercise Science 18(2): 794-810, 2025. https://doi.org/10.70252/NOCK5583 Accurate physical activity (PA) measurement is crucial for public health surveillance. While self-report questionnaires are commonly used, they have limitations, especially in young children. An affordable and user-friendly device like Feelfit® offers a promising alternative particularly for countries with limited research resources. This study aimed to evaluate Feelfit®'s performance against the widely used ActiGraph® accelerometer in measuring PA among children. A quasi-experimental design was applied. Thirty-nine children (19 boys; 20 girls; aged 11.4 ± 0.5 years) wore both Feelfit® and ActiGraph® during sequentially specified activities of varying intensity ranging from sedentary to vigorous. Data were analysed using paired t-tests, Bland-Altman plots, and intra-class correlation coefficients (ICCs) to assess agreement, precision, and reliability. Feelfit® showed good agreement with ActiGraph® for moderate-to-vigorous PA (MVPA) but overestimated sedentary time and underestimated light PA. It demonstrated better precision for MVPA but low reliability for light PA. Intra-class correlation coefficients were moderate for MVPA (ICC = 0.43), but poor for sedentary time (ICC = 0.11). Feelfit® is a suitable option for measuring MVPA in children, offering acceptable validity and reliability compared to ActiGraph®. However, improvements are needed for accurate measure of sedentary and light activities. Despite these limitations, Feelfit®'s affordability and ease of use make it a valuable tool for use in small- to large-scale research and in resource-limited settings.

Keywords: Measurement accuracy, public health surveillance, research resources, physical activity, children

Introduction

Monitoring physical activity (PA) levels in children is crucial for understanding movement behaviours and promoting their health and well-being. Regular participation in PA can reduce the risks of childhood obesity and associated health conditions.[1,2] PA contributes to children's growth and development, positively impacts cognitive functions, and overall brain health.[3-5] However, assessing PA in children is challenging because of the unique patterns and characteristics of their PA. Unlike adults, children's PA is highly transitory in nature, involving short and intermittent bouts of different types of PA undertaken for different durations which are often very short.[6] Therefore, valid and reliable PA measurement instruments are critical not only for public health surveillance, but also intervention programs designed to promote PA in this population group. Currently, subjective instruments, i.e., self-report questionnaires, are the most common method used to collect PA data from children, particularly at the population level. As reflected in a global pooled analysis of 1.6 million school-going adolescents from 146 countries/territories/areas,[7] PA prevalence estimates at regional or global levels could only rely on PA data collected from questionnaire, despite limitations in terms of accuracy and potential biases.[8] The device-based measured PA data are limited to only a few high-income countries.[9] This is primarily due to the high costs associated with purchasing devices, installing specialized software, and requiring technical expertise to manage and analyse the data. Low- and middle-income countries, or researchers with limited research resources, often find it challenging to utilize this approach, particularly for population-level research. To overcome this issue, there is a need for cost-effective and user-friendly alternatives.

This is particularly true in Thailand, as in other countries, where factors such as age, sex, geographic location, and parental or peer support significantly influence the PA levels of children and adolescents.[10,11] Local evidence revealed that a majority of PA research in children and youth from 2009 to 2019 used questionnaires to collect PA data.[12] A large number of studies used the questionnaire originally designed for adults, such as the *Global Physical Activity Questionnaire*,[13-15] and the *International Physical Activity Questionnaire*,[16,17] despite adaptations made by Thai researchers for use in children.[12,18] This raises significant concerns about the quality of research, as many studies fail to provide explicit explanation how adjustments were made with those questionnaires and references to their validity and reliability in assessing PA in children and youth.[12] Combined with the limitations of device-based methods—such as high costs and the need for technical expertise—there is a clear need for more affordable, user-friendly tools to support PA surveillance and advocacy efforts at national and global levels. Moreover, the target age group in this study (approximately 10-12 years) represents early adolescence, a stage marked by the onset of puberty and individual differences in body image, body composition, and physical performance, which can influence PA and often contribute to reduced participation.[19-21] These biological and behavioural changes present challenges for accurately measuring PA in this age group, reinforcing the need for appropriate methodological approaches. In response to these concerns and the aforementioned limitations of the device-based measurement in terms of affordability and technical skills required, a more affordable and

user-friendly device is needed to support national and global public health surveillance and advocacy.

Technological advancements have eased the development of accelerometer-based PA trackers, offering more affordable and less complex options for an objective method to monitor children's PA levels. Ideally, these tools should not only be developed to have the capability to accurately monitor PA patterns across different population groups, but also be user-friendly, and minimize financial constraints. The balance among the precision, ease of use, and affordability is critical to facilitate comprehensive research that can inform public health policies and interventions on a national scale. 'Feelfit®', a PA tracker developed by Department of Biomedical Engineering, Faculty of Engineering at Mahidol University, was intentionally designed to optimize the balance. Rather than monitoring real-time intensity during PA sessions, as is common with more costly commercial devices, Feelfit® is designed to assess overall PA by estimating the duration of moderate-to-vigorous physical activity (MVPA) in minutes. This approach aligns with PA surveillance efforts aimed at determining whether children meet the World Health Organization's recommendations at the population level.[22] To support this objective, the use of accelerometer-based trackers requires rigorous validation to ensure reliability and accuracy. Feelfit® has previously been tested in adult samples, demonstrating high accuracy in both calorie estimation (over 80%) and classification of PA intensity levels (over 90%).[23] Given these promising results, further evaluation is warranted to determine its suitability for use in children and youth. Although not considered the gold standard, the ActiGraph® wGT3X-BT is a widely used commercial device in PA research and has demonstrated acceptable validity and reliability in measuring children's activity patterns, including frequency, intensity, and duration.[24,25] However, there is currently limited evidence on the reliability and validity of Feelfit® for measuring PA in younger populations. To address this gap, the present study aimed to comprehensively assess the test–retest reliability and criterion validity of Feelfit® by comparing its performance with that of the ActiGraph® wGT3X-BT, using Puyau's et al. cut-points,[26] which have been validated and shown to be effective for assessing children's PA in a laboratory setting.

Methods

Study Design and Setting

This quasi-experimental study design was employed to systematically gather PA data within a controlled laboratory setting among children. The experiment was conducted at Sports and Exercise Laboratory, College of Sports Science and Technology at Mahidol University. To ensure comprehensive data collection, each participant was required to visit the laboratory on two separate occasions within a one-week period. The study protocol received approval from the institutional review board (Ref: MU-CIRB 2024/005.0501) and was carried out in accordance with the Belmont Report of 1979, the Declaration of Helsinki of 2013, the Council for International Organizations of Medical Sciences (CIOMS) of 2016, and the International Conference on Harmonization Good Clinical Practice (ICH-GCP). This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science,[27] Before participating in the study, written informed consent and assent were obtained from

parents or legal guardians and from the children respectively. Data collection took place from January 2024 to February 2024.

Sample Size Calculation

The sample size was calculated based on a medium effect size (dz = 0.50) with a significance level of 5%, and a power of 90% using G*Power 3.1.[28] Initially the required sample size (28) was determined based on the non-centrality parameter (δ = 2.65) and T-value (Tα = 1.31). Subsequently, the sample size was increased to 37-40 participants to accommodate predictable dropouts of 30%.

Participants

Thirty-nine healthy children (19 boys and 20 girls), aged 11.4 ± 0.5 years, were recruited using a purposive sampling technique at the school level and a snowball sampling technique at the student level. The participants were from a primary school in Nakhon Pathom, a neighbouring province to Bangkok. The participants were selected based on their willingness and capability to engage in MVPA for the whole period of study. Eligible participants were required to have a body weight within -1.5 to +1.5 standard deviations of the growth reference data for their age and gender,[29,30] with no history of cardiovascular diseases or asthma, and no orthopaedic conditions that could impede their ability to participate in PA. Medical history of the participating children was obtained by interviewing parents or legal guardians, and the Physical Activity Readiness Questionnaire for Everyone[31] was used to screen participants prior to their involvement in the study.

Instruments and Key Outcome Measures

Feelfit® measures human movement acceleration along three axes to estimate calories burned (kcal). Beyond calorie expenditure, Feelfit® calculates PA intensity by analysing the acceleration of users' movement. The acquired acceleration is categorized into five intensity levels, expressed as percentages. The methodology for calculating work-kinetic energy in three dimensions and determining energy usage using by Feelfit® is described in elsewhere.[23] To achieve comprehensive PA tracking, Feelfit® integrates three essential components to provide a comprehensive solution for tracking PA. First, it includes a PA analysis algorithm with two operational modes: challenge mode and free activity mode. The challenge mode allows users to set time limits for their exercise, creating a stimulating and competitive environment. In contrast, the free activity mode, designed primarily for research, allows for unrestricted exercise time, giving users complete freedom in their activity duration. Second, devices' hardware is responsible for directly measuring PA. Third, a data analysis system processes and interprets the collected data. Collectively, these three components establish Feelfit® as a versatile tool for the detailed analysis, observation, and interpretation of PA.

Feelfit® is specifically designed for hip placement and was equipped with the MMA8452Q accelerometer, which provided 3-axis acceleration data with a maximum range of ±4G (where G represents acceleration due to gravity). This accelerometer features an 8-bit resolution and

operates at a sampling frequency of 25 Hz. Using data from its internal accelerometer, the device calculates various metrics, including steps taken, calories burned, and minutes spent across five distinct levels of PA intensity. The intensity levels are based on the Metabolic Equivalent of Task (MET) classification for children and youth, categorised as sedentary (≤ 1.5 METs), light (1.6 – 2.9 METs), moderate (3.0 – 5.9 METs), and vigorous (≥ 6.0 METs).[32] These MET categories, validated in both adult and paediatric populations,[33,34] offer a comprehensive depiction of PA intensities encountered by participants. The Feelfit® display shows activity duration in hours and minutes (hh:mm), and data can be recorded manually, eliminating the need for additional software. Figure 1 illustrates the Feelfit® device and its display screen.

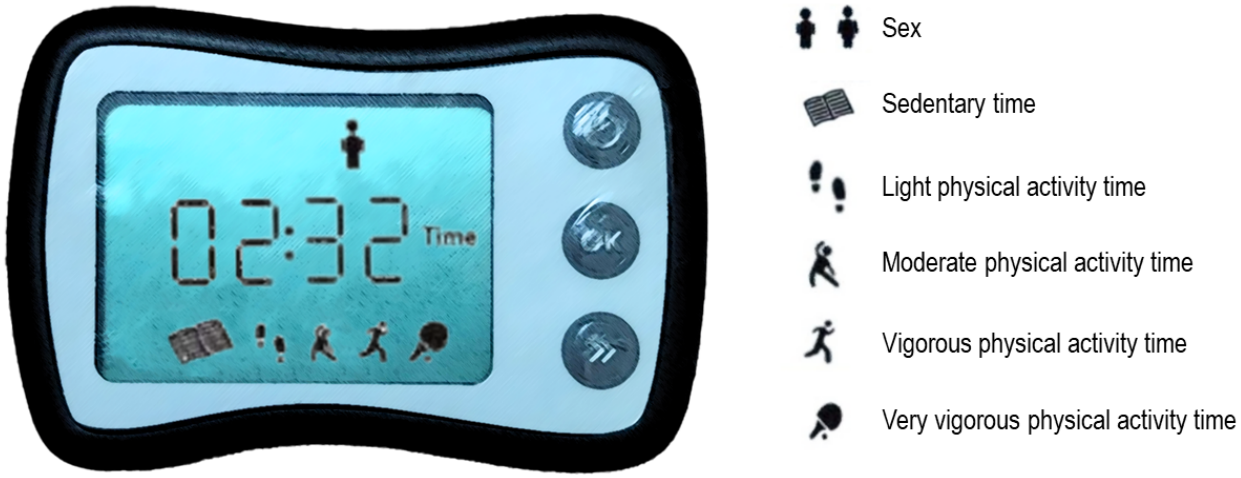

Figure 1. The display screen of the Feelfit® device

Along with the Feelfit®, participants wore an ActiGraph® triaxial accelerometer (model wGT3X-BT; ActiGraph LLC, USA) on the opposite hip to provide a comparative standard. The ActiGraph® captures movement along three axes and measures vertical accelerations within a range of ±8.0 G, recording raw acceleration data at 1-second intervals and uses Actilife software (version 6.13.4) for data processing and management, allowing for automated download and analysis upon device connection. For this study, data were collected in 15-second epochs—a setting recommended for capturing the short, intermittent bursts of activity typical in children.[33,35] Average counts per minute (cpm) were calculated and classified into intensity levels using the Puyau et al. cut-points,[26] which are based on vertical axis counts and have been validated for children aged 6 to 16 years.[26] These cut-points categorize activity as sedentary (≤ 799 cpm), light (800–3199 cpm), moderate (3200–8200 cpm), and vigorous (≥ 8200 cpm). The use of the Puyau et al. cut-points in this study is justified by their alignment with the age group tested and

their demonstrated validity in controlled, laboratory-based protocols similar to the current design; additional technical specifications and details about the ActiGraph® wGT**3**X-BT device are available on the manufacturer's website (https://ametris.com/actigraph-wgt3x-bt)

Body mass (kg) was measured using an analogue scale (ACCUNIQ BC300, Thailand) with participants wearing light clothing and no shoes or socks. Height was measured with a portable stadiometer following standardized WHO procedures.[36] Body mass index (BMI) was then calculated using weight to squared height (kg/m^2).

Protocol

Both Feelfit® and ActiGraph® devices were worn concurrently throughout the experiment. To control for potential placement bias, the devices were swapped between trial: if the Feelfit® was worn on the left hip during the first trial, it was swapped to the right hip during the second trial, with the same approach applied to the ActiGraph®. Each device was secured using an elastic belt positioned at the anterior superior iliac crest of the hip, following the manufacturer's default settings. To ensure the reliability of measurements, all devices were initialized simultaneously for each participant, ensuring synchronization and preventing timing discrepancies.

The protocol aimed to assess the accelerometer's reliability and validity in detecting different PA levels in children under controlled conditions. Participants completed a 26-minute sequential protocol consisting four distinct PA intensities, with specific instructions provided throughout the session. The protocol started with 5 minutes of sedentary behaviour (quiet sitting, 1.3 METs), followed by 5 minutes of light-intensity PA (standing still, 1.7 METs). After a 3-minute rest period (quiet sitting), participants performed 5 minutes of moderate-intensity PA by walking on a motorized treadmill at 2.5–3.0 mph (3.5–4.1 METs). Another 3-minute rest period (quiet sitting) was provided before concluding with 3 minutes of vigorous-intensity PA (jumping jacks interspersed with 2-minute rest periods, 6.1 METs). MET values were estimated using energy expenditure data for 10-12-year-olds.[34] Scheduled rest periods between activities of different intensities were incorporated to ensure comfort, reduce fatigue, and maintain compliance among the children, resulting in approximately half of the total protocol time (13 minutes) being spent in sedentary behaviour. Adherence to the protocol was carefully monitored, and any unintended deviations, such as postural changes, were recorded for subsequent analysis.

Statistical Analysis

Statistical analyses were performed using IBM SPSS version 28 (IBM Corp, Armonk NY). The primary dependent variables of interest for this study were the steps count and the minutes spent on activities at different intensity levels, as measured by each device. Step counts (steps) and the time recorded by each device for specific PA intensities (minutes) were presented as Mean ± S.D. Paired t-tests were used to evaluate the mean differences between the ActiGraph® and the Feelfit® devices. Agreement between the devices was assessed using the standard error of the mean (SE). A p-value of less than 0.05 ($p < .05$) was considered statistically significant, and results were presented with 95% confidence intervals (95% CI).

The precision of the measurements obtained from both devices was evaluated using the coefficient of variation (CV%), with smaller values indicating higher measurement consistency and better reliability.[37] Test-retest reliability of both devices was analysed using the intraclass correlation coefficient (ICC) for each activity. The ICC was calculated using a two-way mixed model under consistency, with values ≥ 0.4 considered satisfactory (ICC = 0.81–1.0, excellent; 0.61–0.80, very good; 0.41–0.60, good; 0.21–0.40, fair; and 0.00–0.20, poor).[38] The internal consistency of both devices was assessed using Cronbach's alpha (α), where an α value ranging from 0.70 to 0.90 was considered acceptable.[39] Bland-Altman plots were used to evaluate systematic bias and agreement between the Feelfit® and ActiGraph® devices, providing a visual interpretation of both bias and random error across measurements.[40]

Results

A comparison of PA data collected using Feelfit® and ActiGraph® devices revealed significant differences in assessing time spent in sedentary, light and vigorous activities (Table 1). Reliability and internal consistency of Feelfit® and ActiGraph® accelerometer in sedentary and PA time are shown in Table 2. Bland-Altman plots illustrate the agreement between the two devices in measuring step counts and PA duration across different intensity levels (Figure 2).

Table 1. Comparison of sedentary and physical activity measured by Feelfit® over ActiGraph® (n=39)

Activity	Activity monitor	Mean ± S.D.	Mean Difference ± SE (% of difference)	95% CI	*p*	CV% (Precision)
Step count (steps)	ActiGraph®	1083.67 ± 112.80	33.12 ± 16.98 (3.05%)	0.69 to 66.95	0.055	10.4
	Feelfit®	1116.80 ± 145.97				13.1
Sedentary time (minutes)	ActiGraph®	15.66 ± 1.02	2.23 ± 0.14 (14.24%)	1.94 to 2.51	< 0.001	6.6
	Feelfit®	17.89 ± 0.83				4.6
Light PA time (minutes)	ActiGraph®	5.53 ± 1.35	2.34 ± 0.17 (42.31%)	1.98 to 2.70	< 0.001	24.5
	Feelfit®	3.19 ± 0.98				30.7
Moderate PA time (minutes)	ActiGraph®	2.00 ± 1.45	0.28 ± 0.15 (14.00%)	0.02 to 0.59	0.072	72.5
	Feelfit®	2.28 ± 0.88				38.6
Vigorous PA time (minutes)	ActiGraph®	2.89 ± 0.78	0.26 ± 0.08 (9.34%)	0.10 to 0.43	0.002	27.0
	Feelfit®	2.62 ± 0.62				23.8
MVPA time (minutes)	ActiGraph®	4.89 ± 1.28	0.01 ± 0.16 (0.40%)	-0.31 to 0.33	0.937	26.9
	Feelfit®	4.91 ± 0.96				19.7

PA = physical activity; MVPA = moderate-to-vigorous physical activity; CI = confidence intervals; CV = coefficient of variation; SE = standard error of the mean; SD = standard deviation

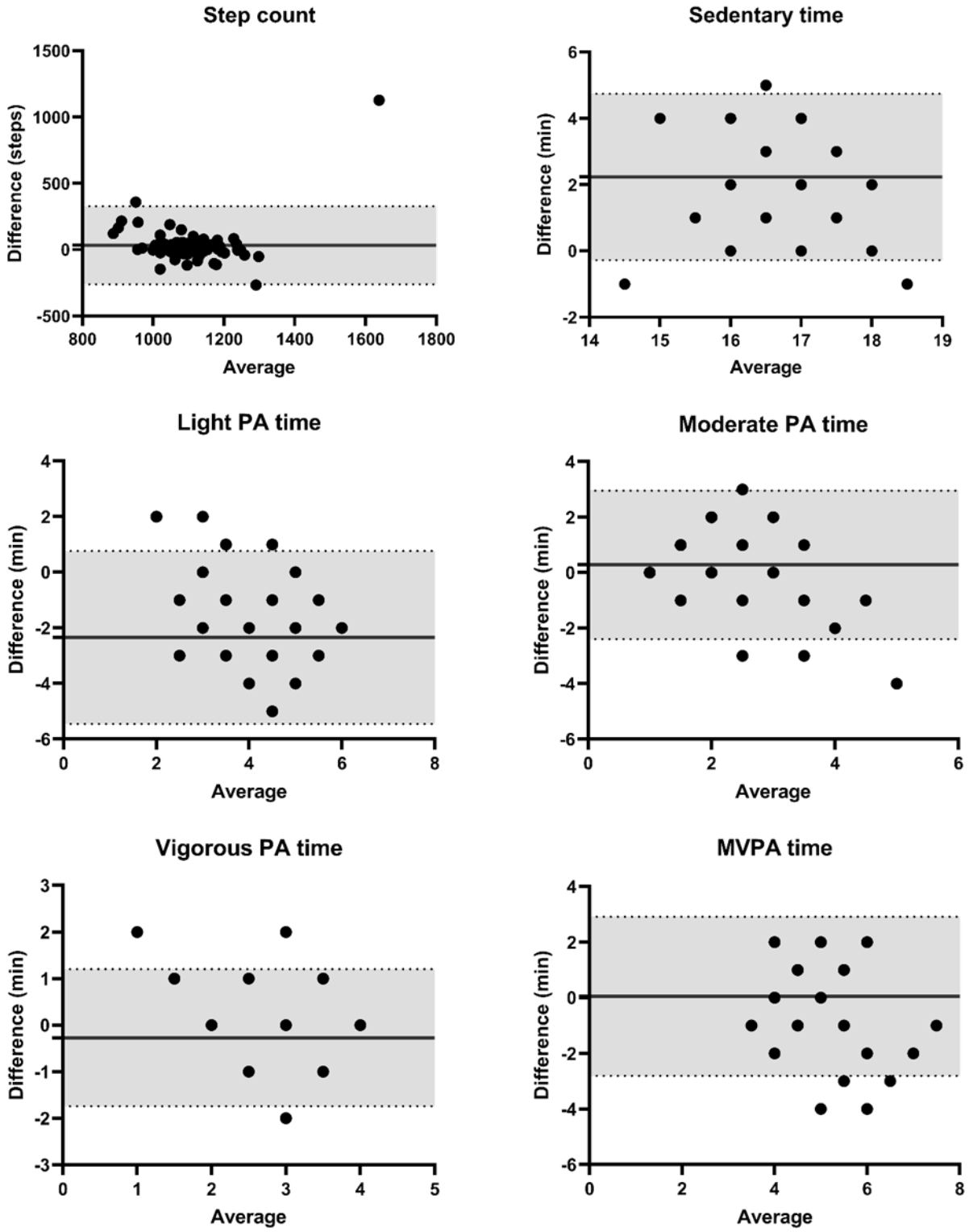

Figure 2. Bland-Altman plots comparing step counts and minutes spent in different physical activity intensities between the Feelfit® and ActiGraph® devices. (Note: Some dots overlap; The thick line represents the mean difference and the dashed line shows its 95% limits of agreement.)

Table 2. Reliability and internal consistency of Feelfit® and ActiGraph® accelerometer in sedentary and physical activity time (n=39)

Activity	ActiGraph®			Feelfit®		
	ICC	95% CI	Cronbach's α	ICC	95% CI	Cronbach's α
Step count (steps)	0.19	-0.52 to 0.57	0.19	0.04	-0.86 to 0.50	0.06
Sedentary time (minutes)	0.24	-0.35 to 0.58	0.26	0.11	-0.71 to 0.54	0.11
Light PA time (minutes)	0.26	-0.34 to 0.61	0.27	0.59	0.23 to 0.79	0.59
Moderate PA time (minutes)	0.47	0.00 to 0.72	0.48	0.51	0.08 to 0.74	0.51
Vigorous PA time (minutes)	0.33	-0.27 to 0.65	0.35	0.39	-0.16 to 0.68	0.41
MVPA time (minutes)	0.42	-0.11 to 0.69	0.42	0.43	-0.08 to 0.70	0.43

ICC = intra-class correlation coefficient; ICC values ≥ 0.4 were considered satisfactory (Relative reliability), ICC = 0.81–1.0, excellent; 0.61–0.80, very good; 0.41–0.60, good;0.21–0.40, fair; and 0.00–0.20, poor

Step Count

The Feelfit® device recorded a slightly higher average step count (1,116.80 ± 145.97 steps) than the ActiGraph® (1,083.67 ± 112.80 steps), with a non-significant mean difference of 33.12 ± 16.98 steps (p = 0.055). Precision was slightly lower for Feelfit® (CV% = 13.1%) compared to ActiGraph® (CV% = 10.4%). Both devices showed poor reliability, with low ICC values (ActiGraph®: 0.19; Feelfit®: 0.04) and Cronbach's alpha scores (ActiGraph®: 0.19; Feelfit®: 0.06).

Sedentary Time

Feelfit® recorded significantly more sedentary time than ActiGraph® (17.89 ± 0.83 min vs. 15.66 ± 1.02 min; mean difference: 2.23 ± 0.14 min, p < 0.001). Feelfit® showed higher precision (CV% = 4.6) compared to ActiGraph® (CV% = 6.6). Reliability was fair for ActiGraph® (ICC = 0.24, Cronbach's alpha = 0.26) but poor for Feelfit® (ICC = 0.11, Cronbach's alpha = 0.11).

Physical Activity Time

ActiGraph® recorded significantly more light PA time than Feelfit® (5.53 ± 1.35 min vs. 3.19 ± 0.98 min; mean difference: 2.34 ± 0.17 min, p < 0.001), but with lower reliability (ICC = 0.26, Cronbach's alpha = 0.27) compared to Feelfit® (ICC = 0.59, Cronbach's alpha = 0.59). Feelfit® demonstrated lower precision (CV% = 30.7). For moderate PA time, Feelfit® recorded slightly more time than ActiGraph® (2.28 ± 0.88 min vs. 2.00 ± 1.45 min; p = 0.072) with better precision (CV% = 38.6). Reliability was good for both devices (ActiGraph®: ICC = 0.47, Cronbach's alpha = 0.48; Feelfit®: ICC = 0.51, Cronbach's alpha = 0.51). In vigorous PA time, ActiGraph® reported significantly higher values (2.89 ± 0.78 min vs. 2.62 ± 0.62 min; mean difference: 0.26 ± 0.08 min, p = 0.002), though Feelfit® showed slightly better precision (CV% = 23.8). Both devices

demonstrated fair reliability (ActiGraph®: ICC = 0.33, Cronbach's alpha = 0.35; Feelfit®: ICC = 0.39, Cronbach's alpha = 0.41).

Moderate-to-Vigorous Physical Activity

When combining moderate and vigorous PA into MVPA time, both devices recorded nearly identical results (Feelfit®: 4.91 ± 0.96 min vs. ActiGraph®: 4.89 ± 1.28 min), with no significant difference (mean difference: 0.01 ± 0.16 min, 0.40%, p = 0.937). Feelfit® exhibited better precision (CV% = 19.7), while both devices demonstrated good reliability. ActiGraph® had an ICC of 0.42 (95% CI: -0.11 to 0.69) and Cronbach's alpha of 0.42. Feelfit® showed similar reliability with an ICC of 0.43 (95% CI: -0.08 to 0.70) and Cronbach's alpha of 0.43.

Discussion

This study assessed Feelfit®'s validity and reliability against ActiGraph® in measuring PA across different intensities in children. Results indicated high validity of Feelfit® for measuring MVPA, though reliability was moderate. MVPA times recorded by both devices were nearly identical, which is crucial given the importance of MVPA in public health research and PA promotion advocacy. MVPA is the main metric of interest as it is used to assess children's (5-17 years old) adherence to the global PA recommendations.[41] The accelerometers have been consistently shown to offer criterion validity in various PA studies, although some limitations remain in certain contexts.[24,25,42] Ongoing international discussions are focused on establishing standard protocols for analysing and reporting accelerometer data. Challenges include variability in data cleaning methods and cut-points, which complicates international comparisons.[43] However, in the scope of behavioural epidemiological studies, which seek to determine the prevalence of sufficient PA according to WHO guidelines,[32] accelerometers remain one of the most reliable tools, outperforming self-reported questionnaires.[44] The findings of this study highlight Feelfit®'s potential for practical applications among children, particularly in resource-limited settings such as Thailand and other similar countries. However, improving its reliability in measuring MVPA should be a priority for future iterations of the device.

With regard to the technical aspects of accelerometer use, many validated cut-points exist to classify children's PA intensity, including those developed by Evenson et al.[45] and Freedson et al.[46] Each set differs in sensitivity and specificity, influenced by factors such as the device model, epoch length, and calibration protocol. The use of different cut-points can significantly affect data analysis and study outcomes.[37] Evenson's cut-points are widely recommended for assessing PA in children and adolescents due to their high classification accuracy across various intensity levels, making them particularly well-suited for capturing the sporadic and intermittent nature of movement in free-living settings.[31] In contrast, Freedson's cut-points—among the earliest and most influential in the field of accelerometery—were originally developed for adults and later adapted for paediatric populations. Their calibration is typically based on structured activities such as treadmill walking and running, making them a common choice for studies conducted in controlled laboratory environments.[46,48] Nevertheless, this current study applied the Puyau et al. cut-points,[26] which have been validated and proven effective for assessing children's PA in a laboratory setting. Additionally, the activities and age

range in this study closely aligned with those used in Puyau et al. cut-points validation. However, it is important to acknowledge their limitations. The Puyau's cut-points have not been fully validated in free-living contexts, where children's PA often involves unstructured, spontaneous movements that differ from controlled activity bouts.[49] This lack of validation raises concerns about their applicability to real-world settings. Moreover, few studies have thoroughly evaluated how well different cut-points perform in capturing unstructured play,[50] which may more accurately reflect children's habitual activity patterns. As such, future research should aim to validate Feelfit® across multiple cut-point frameworks, particularly in ecologically valid settings, to enhance the generalizability and practical relevance of PA measurement in children.

Another key finding was that Feelfit® significantly overestimated sedentary time compared to ActiGraph®, raising concerns about potential overreporting sedentary behaviour when relying solely on Feelfit® data. In contrast, Feelfit® significantly underestimated light PA compared to ActiGraph®, suggesting it may not accurately capture low-intensity activities. This discrepancy could partly be due to the minimal physiological distinction between sedentary and light activity, which may challenge the device's ability to differentiate between these two intensity levels. This limitation should be carefully considered in research requiring precise light PA measurements. For step counts, Feelfit® demonstrated its suitability as an instrument, with counts differing slightly from those recorded by ActiGraph® but showing no statistically significant difference. However, minor discrepancies should be noted in contexts where high measurement precision is required.

The Bland-Altman plot shows a mean difference close to zero, indicating minimal bias between Feelfit® and ActiGraph®. However, the presence of data points outside the 95% limits of agreement highlights instances where the devices differ significantly, despite overall good agreement. When considering PA intensity, the Bland-Altman plots for sedentary, light, moderate, and vigorous activities reveal varying levels of agreement. For sedentary and moderate activities, the mean differences are close to zero, suggesting good alignment between the devices. In contrast, the mean differences for light and vigorous activities are more pronounced, indicating that Feelfit® may underestimate or overestimate these intensities relative to ActiGraph®. This discrepancy could be due to the differing sensitivity of the devices to low- and high-intensity movements.

Nevertheless, the majority of data points for all activity intensities remain within the 95% limits of agreement, suggesting that while variability exists, the devices are generally consistent in their measurements. Researchers should interpret these differences with caution, particularly when precise measurement of light and vigorous PA is critical for study outcomes. Further investigation into the sources of variability, such as device algorithms or sensitivity thresholds, may help improve measurement accuracy across PA intensities.

The comparison between the Feelfit® device and the ActiGraph® must account for differences in settings and configurations, particularly in sampling frequency and data processing, which significantly affect PA measurement. The Feelfit® device operates at a sample frequency of 40 milliseconds, updating activity data every 5 seconds, with intensity levels determined by

averaging accumulated activity levels.[23] In contrast, the ActiGraph®'s settings differ, and this discrepancy could lead to variations in capturing PA intensity. Specifically, epoch length—the time interval over which data is aggregated—plays a critical role in accurately representing PA, especially in children. Research shows that shorter epoch lengths, such as 15 seconds, are more sensitive to the short bursts of high-intensity activity typical in children's behaviour, while longer epochs, such as 60 seconds, tend to smooth out these bursts, potentially underestimating PA intensity.[51] Research has shown that shorter epochs provide a better reflection of children's dynamic activity patterns compared to longer epochs, reinforcing the importance of using appropriate configurations for accurate data collection.[25] Consequently, using longer epochs might lead to misclassification of activity levels, which can influence health outcome correlations and the overall assessment of children's PA patterns.[51] These findings emphasize the need to carefully configure accelerometers to ensure accurate PA data collection in paediatric populations.

Therefore, when comparing the two devices, it is crucial to consider how these differences in settings might influence the data collected, particularly in real-world settings where children's activity patterns are highly variable. More research is needed to determine how these technical differences impact the reliability and validity of Feelfit® compared to ActiGraph®, especially in free-play scenarios where children's PA is less structured and more representative of daily life. Understanding these differences will be essential in refining the use of accelerometers in both research and practical applications.

When comparing Feelfit® and ActiGraph®, it is essential to consider how differences in device settings might influence data collection, particularly in real-world scenarios where children's activity patterns are highly variable. This is especially relevant given that traditional definitions of light PA often fail to capture children's natural movement patterns; their real-life activity typically involves complex, playful, and sporadic movements that challenge the utility of standard light PA classifications.[52] Consequently, these variations can significantly affect the accuracy and reliability of measurements, especially in free-play situations where PA is less structured and more reflective of daily life. Further research is needed to evaluate how such technical differences impact the validity of Feelfit® compared to ActiGraph®, particularly in capturing the dynamic and intermittent nature of children's movements.

A notable limitation of Feelfit® is its display format, which records activity duration in hours and minutes (hh:mm) and immediately presents the results on the device's screen. While this feature may be convenient for practical applications or user feedback, it poses challenges for research purposes, particularly in behaviour assessment. Ideally, PA measurement devices should follow a "black-box" design, where no data or results are visible to participants or assessors during the measurement period. This design ensures that movement behaviour remains natural, unintentional, and uninfluenced by the presence of visible feedback.[53,54] The immediate display of activity duration on the Feelfit® screen can unintentionally alter behaviour, as participants may adjust their activity levels based on visible feedback, reducing ecological validity, especially in real-world settings like unstructured play where natural movements are key. Researchers should address this limitation by covering the screen during

data collection or instructing participants to avoid checking it. Future iterations of Feelfit® could incorporate a researcher-only access mode or delayed display to ensure unbiased assessments, improving its utility for accurately capturing natural movement behaviour in research.[54]

Addressing these technical disparities through further refinement of the Feelfit® device—such as improving data resolution and enhancing sensitivity to variable activity intensities—could increase its utility and reliability. Additionally, understanding how device algorithms process movement data will be key in ensuring comparable outcomes across different accelerometers, ultimately enhancing their role in both research and real-world settings.

Feelfit®'s affordability, portability, and ease of use make it a practical tool for large-scale implementation in school settings, especially in low- and middle-income countries. Its use could facilitate systematic monitoring of students' PA levels, enabling data-driven interventions and policies that promote healthier behaviours. This is supported by our findings, which demonstrate that Feelfit® provides reliable estimates of step count and MVPA under structured conditions. Integrating PA tracking into the school environment may also increase awareness among educators and administrators, fostering a culture that values PA as essential for children's health and overall well-being.

Feelfit® demonstrated good precision, particularly for MVPA and step counts, when compared to ActiGraph®, despite showing low reliability for light PA. While suitable for measuring PA in children aged 10-12 years, Feelfit® tended to overestimate sedentary time and underestimate light PA, which may limit its accuracy in studies focusing on these specific activity intensities. Technical issues, such as sampling frequency, epoch length, and activity duration resolution, further reduced Feelfit®'s sensitivity, particularly in dynamic, real-world settings like unstructured play. Refining the device's algorithms and addressing display limitations is essential to enhance its utility for both research and practical applications. By improving its accuracy for specific activity intensities and overall reliability, Feelfit® can better contribute to effective monitoring, intervention, and promotion of PA in children.

Acknowledgements

The authors would like to thank all the children who participated in the study and their parents for allowing them to take part. This research project was supported by the Thai Health Promotion Foundation (Ref: 66.00382), The Foundation was not involved in the study's design, execution, interpretation of the results or the preparation of this manuscript.

References

1. Michel J, Bernier A, Thompson LA. Physical activity in children. *JAMA Pediatrics*. 2022;176(6):622-622. https://doi.org/10.1001/jamapediatrics.2022.0477

2. Wyszyńska J, Ring-Dimitriou S, Thivel D, et al. Physical activity in the prevention of childhood obesity: the position of the European Childhood Obesity Group and the European Academy of Pediatrics. *Front Pediatr.* 2020;8:535705. https://doi.org/10.3389/fped.2020.535705

3. Gao Z, Chen S, Sun H, Wen X, Xiang P. Physical activity in children's health and cognition. *Biomed Res Int.* 2018;2018:8542403. https://doi.org/10.1155/2018/8542403

4. Garrett J, Chak C, Bullock T, Giesbrecht B. A systematic review and Bayesian meta-analysis provide evidence for an effect of acute physical activity on cognition in young adults. *Commun. psychol.* 2024;2(1):82. https://doi.org/10.1038/s44271-024-00124-2

5. Morales JS, Alberquilla del Río E, Valenzuela PL, Martínez-de-Quel Ó. Physical activity and cognitive performance in early childhood: a systematic review and meta-analysis of randomized controlled trials. *Sports Med.* 2024;54(7):1835-1850. https://doi.org/10.1007/s40279-024-02020-5

6. Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The level and tempo of children's physical activities: an observational study. *Med Sci Sports Exerc.* 1995;27(7):1033-41. https://doi.org/10.1249/00005768-199507000-00012

7. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child Adolesc Health.* 2020;4(1):23-35. https://doi.org/10.1016/S2352-4642(19)30323-2

8. Kang M, Mahar MT, Morrow Jr JR. Issues in the assessment of physical activity in children. *J Phys Educ Recreat Dance.* 2016;87(6):35-43. https://doi.org/10.1080/07303084.2016.1192943

9. Sallis JF, Bull F, Guthold R, et al. Progress in physical activity over the Olympic quadrennium. *Lancet.* 24 2016;388(10051):1325-36. https://doi.org/10.1016/s0140-6736(16)30581-5

10. Widyastari DA, Saonuam P, Rasri N, Pongpradit K, Katewongsa P. Prevalence and trends of physical activity in Thai children and young people: pooled panel data analysis from Thailand's Surveillance on Physical Activity 2012-2020. *Int J Environ Res Public Health.* 2021;18(19):10088. https://doi.org/10.3390/ijerph181910088

11. Amornsriwatanakul A, Lester L, Bull FC, Rosenberg M. Ecological correlates of sport and exercise participation among Thai adolescents: A hierarchical examination of a cross-sectional population survey. *J Sport Health Sci.* 2023;12(5):592-605. https://doi.org/10.1016/j.jshs.2020.04.012

12. Chinapong S, Maphong R, Promjun T, Amornsriwatanakul A. Physical activity in Thai children and youth aged 0-22 years: a systematic review. *J Health Syst Res.* 2021;15(2):231-249.

13. Bull FC, Maslin TS, Armstrong T. Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *J Phys Act Health.* 2009;6(6):790-804. https://doi.org/10.1123/jpah.6.6.790

14. Katewongsa P, Pongpradit K, Widyastari DA. Physical activity level of Thai children and youth: evidence from Thailand's 2018 report card on physical activity for children and youth. *J Exerc Sci Fit.* 2021;19(2):71-74. https://doi.org/10.1016/j.jesf.2020.11.002

15. Thongpaeng S, Sorncharoen P, Preechasuk L, Santiprabhob J. Dietary intake and physical activity of Thai children and adolescents with type 1 diabetes mellitus. *Nutrients.* 2022;14(23):5169. https://doi.org/10.3390/nu14235169

16. Craig CL, Marshall AL, Sjöström M, et al. International Physical Activity Questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc.* 2003;35(8):1381-1395. https://doi.org/10.1249/01.Mss.0000078924.61453.Fb

17. Pengpid S, Peltzer K, Kassean HK, Tsala Tsala JP, Sychareun V, Müller-Riemenschneider F. Physical inactivity and associated factors among university students in 23 low-, middle- and high-income countries. *Int J Public Health.* 2015;60(5):539-549. https://doi.org/10.1007/s00038-015-0680-0

18. Liangruenrom N, Suttikasem K, Craike M, Bennie JA, Biddle SJH, Pedisic Z. Physical activity and sedentary behaviour research in Thailand: a systematic scoping review. *BMC Public Health.* 2018;18(1):733. https://doi.org/10.1186/s12889-018-5643-y

19. Sawyer SM, Afifi RA, Bearinger LH, et al. Adolescence: a foundation for future health. *The Lancet.* 2012;379(9826):1630-1640. https://doi.org/10.1016/S0140-6736(12)60072-5

20. Karchynskaya V, Kopcakova J, Madarasova Geckova A, Klein D, de Winter AF, Reijneveld SA. Body image, body composition and environment: do they affect adolescents' physical activity? *Eur J Public Health.* 2022;32(3):341-346. https://doi.org/10.1093/eurpub/ckac022

21. Gallant F, Hebert JJ, Thibault V, Mekari S, Sabiston CM, Bélanger M. Puberty timing and relative age as predictors of physical activity discontinuation during adolescence. *Sci Rep.* 2023;13(1):13740. https://doi.org/10.1038/s41598-023-40882-3

22. Reilly JJ, Aubert S, Brazo-Sayavera J, Liu Y, Cagas JY, Tremblay MS. Surveillance to improve physical activity of children and adolescents. *Bull World Health Organ.* 2022;100(12):815-824. https://doi.org/10.2471/blt.22.288569

23. Arnin J, Anopas D, Triponyuwasin P, Yamsa-ard T, Wongsawat Y. Development of a novel classification and calculation algorithm for physical activity monitoring and its application. *Signal and Information Processing Association Annual Summit and Conference (APSIPA),* 2014 Asia-Pacific. 2014:1-4.

24. Sasaki JE, John D, Freedson PS. Validation and comparison of ActiGraph activity monitors. *J Sci Med Sport.* 2011;14(5):411-6. https://doi.org/10.1016/j.jsams.2011.04.003

25. Karas M, Bai J, Strączkiewicz M, et al. Accelerometry data in health research: challenges and opportunities. *Stat Biosci.* 2019;11(2):210-237. https://doi.org/10.1007/s12561-018-9227-2

26. Puyau MR, Adolph AL, Vohra FA, Butte NF. Validation and calibration of physical activity monitors in children. Obes Res. 2002;10(3):150-157. https://doi.org/10.1038/oby.2002.24

27. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. *Int J Exerc Sci.* 2020;12(1):1-8. https://doi.org/10.70252/EYCD6235

28. Faul F, Erdfelder E, Buchner A, Lang A-G. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav Res Methods.* 2009;41(4):1149-1160. https://doi.org/10.3758/BRM.41.4.1149

29. Bureau of Nutrition, Department of Health. *A guide to using growth reference data for children aged 6-19 years.* Bureau of Nutrition, Department of Health, Ministry of Public Health; 2021.

30. WHO Child Growth Standards based on length/height, weight and age. *Acta Paediatr.* 2006;450:76-85. https://doi.org/10.1111/j.1651-2227.2006.tb02378.x

31. Warburton D, Jamnik V, Bredin SSD, Shephard RJ, Gledhill N. The 2023 Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and electronic Physical Activity Readiness Medical Examination (ePARmed-X+). *Health Fit J Can.* 2023;16(1):3-17. https://doi.org/10.14288/hfjc.v4i2.103

32. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med.* 2020;54(24):1451-1462. https://doi.org/10.1136/bjsports-2020-102955

33. Lyden K, Keadle SK, Staudenmayer J, Freedson P, Alhassan S. Energy cost of common activities in children and adolescents. *J Phys Act Health.* 2013;10(1):62-9. https://doi.org/10.1123/jpah.10.1.62

34. Butte NF, Watson KB, Ridley K, et al. A youth compendium of physical activities: activity codes and metabolic intensities. *Med Sci Sports Exerc.* 2018;50(2):246-256. https://doi.org/10.1249/mss.0000000000001430

35. Edwardson CL, Gorely T. Epoch length and its effect on physical activity intensity. Med Sci Sports Exerc. 2010;42(5):928-34. https://doi.org/10.1249/MSS.0b013e3181c301f5

36. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ.* 2007;85(9):660-7. https://doi.org/10.2471/blt.07.043497

37. Shechtman O. The coefficient of variation as an index of measurement reliability. In: Doi SAR, Williams GM, eds. *Methods of Clinical Epidemiology*. Springer Berlin Heidelberg; 2013:39-49.

38. Tütüneken YE, Van Der Veer P, Kardeş K, Buran Çırak Y. Reliability and validity of the Turkish version of the state mindfulness scale for physical activity in young adult athletes. *Meas Phys Educ Exerc Sci.* 2024;28(4):309-315. https://doi.org/10.1080/1091367X.2024.2339807

39. Taber KS. The use of Cronbach's Alpha when developing and reporting research instruments in science education. *Res Sci Educ.* 2018;48(6):1273-1296. https://doi.org/10.1007/s11165-016-9602-2

40. Martin Bland J, Altman D. Statistical methods for assessing agreement between two methods of clinical measurement. *The Lancet.* 1986;327(8476):307-310. https://doi.org/10.1016/S0140-6736(86)90837-8

41. Karchynskaya V, Kopcakova J, Madarasova Geckova A, de Winter AF, Reijneveld SA. Does it fit better? measures of physical activity among adolescents in relation to health indicators. *Eur J Public Health.* 2022;32(6):900-904. https://doi.org/10.1093/eurpub/ckac138

42. Crouter SE, Kuffel E, Haas JD, Frongillo EA, Bassett DR, Jr. Refined two-regression model for the ActiGraph accelerometer. *Med Sci Sports Exerc.* 2010;42(5):1029-37. https://doi.org/10.1249/MSS.0b013e3181c37458

43. Wijndaele K, Westgate K, Stephens SK, et al. Utilization and harmonization of adult accelerometry data: review and expert consensus. *Med Sci Sports Exerc.* 2015;47(10):2129-39. https://doi.org/10.1249/mss.0000000000000661

44. Arumugam A, Alsaafin N, Shalash RJ, et al. Concurrent validity between self-reported International Physical Activity Questionnaire Short Form and Fibion accelerometer data among young adults in the UAE. *Eur J Med Res.* 2024;29(1):426. https://doi.org/10.1186/s40001-024-01975-5

45. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci.* 2008;26(14):1557-65. https://doi.org/10.1080/02640410802334196

46. Freedson P, Pober D, Janz KF. Calibration of accelerometer output for children. *Med Sci Sports Exerc.* 2005;37(11 Suppl):S523-30. https://doi.org/10.1249/01.mss.0000185658.28284.ba

47. Breau B, Coyle-Asbil HJ, Haines J, Ma DWL, Vallis LA. ActiGraph cutpoints impact physical activity and sedentary behavior outcomes in young children. *J Meas Phys Behav.* 2022;5(2):85-96. https://doi.org/10.1123/jmpb.2021-0042

48. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. *Med Sci Sports Exerc.* 1998;30(5):777-781. https://doi.org/10.1097/00005768-199805000-00021

49. Lee EY, Shih AC, Tremblay MS. Exploring the world of active play: a comprehensive review of global surveillance and monitoring of active play based on the global matrix data. *J Exerc Sci Fit.* 2024;22(3):254-265. https://doi.org/10.1016/j.jesf.2024.03.008

50. Lubans DR, Plotnikoff RC, Miller A, Scott JJ, Thompson D, Tudor-Locke C. Using pedometers for measuring and increasing physical activity in children and adolescents:the next step. *Am J Lifestyle Med.* 2015;9(6):418-427. https://doi.org/10.1177/1559827614537774

51. Nettlefold L, Naylor PJ, Warburton DE, Bredin SS, Race D, McKay HA. The influence of epoch length on physical activity patterns varies by child's activity level. *Res Q Exerc Sport.* 2016;87(1):110-23. https://doi.org/10.1080/02701367.2015.1129046

52. Haapala EA, Gao Y, Vanhala A, Rantalainen T, Finni T. Validity of traditional physical activity intensity calibration methods and the feasibility of self-paced walking and running on individualised calibration of physical activity intensity in children. *Sci Rep.* 2020;10(1):11031. https://doi.org/10.1038/s41598-020-67983-7

53. Ibrahim ST, Hammami N, Katapally TR. Traditional surveys versus ecological momentary assessments: digital citizen science approaches to improve ethical physical activity surveillance among youth. *PLOS Digit Health.* 2023;2(9):e0000294. https://doi.org/10.1371/journal.pdig.0000294

54. Christiansen LB, Koch S, Bauman A, Toftager M, Bjørk Petersen C, Schipperijn J. Device-based physical activity measures for population surveillance—issues of selection bias and reactivity. Brief Research Report. *Front Sports Act Living*. 2023;5. https://doi.org/10.3389/fspor.2023.1236870

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