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# Validity of the Hausa IPAQ-SF for Walking and High-Intensity Activity: A Dual-Criterion Validation against accelerometry and VO2max

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**Validity of the Hausa IPAQ-SF for Walking and High-Intensity Activity: A Dual-Criterion Validation against accelerometry and $VO_{2max}$**

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## Abstract

### Background

Evaluating physical activity (PA) patterns in Sub-Saharan Africa requires linguistically adapted and psychometrically robust self-report instruments. This study evaluated the cross-cultural adaptation, criterion-related validity, and psychometric agreement of the Hausa version of the International Physical Activity Questionnaire Short Form (IPAQ-SF) against objective triaxial accelerometry and cardiorespiratory fitness ($VO_{2max}$) among university students in Nigeria.

### Methods

A cross-sectional validation study was conducted among N = 106 university students (56 men, 50 women; age 23.80 ± 2.14 years). Participants completed the self-administered Hausa IPAQ-SF, wore an ActiGraph triaxial accelerometer for 7 consecutive days (≥10 h/day wear time over ≥4 days required), and underwent submaximal treadmill testing using the Modified Balke protocol to estimate $VO_{2max.}$ Criterion validity was evaluated via non-parametric Spearman's rank correlation coefficients (ρ). Absolute psychometric agreement and systematic bias were quantified using Bland-Altman analysis with 95% Limits of Agreement (LoA) and proportional bias regression models.

### Results

The Hausa IPAQ-SF walking subscale demonstrated a statistically significant, moderate positive correlation with accelerometer-tracked walking volume ($\rho = 0.38$, $p < 0.001$). Vigorous physical activity (VPA) exhibited a weak positive correlation with accelerometer-derived VPA ($\rho = 0.24$, $p = 0.013$), but showed a significant inverse correlation with estimated $VO_{2max}$ ($r = -0.30$, $p = 0.002$). No significant correlations were observed for moderate physical activity (MPA; $\rho = 0.10$, $p = 0.308$) or sedentary time ($\rho = 0.11$, $p = 0.262$). Bland-Altman analysis revealed a systematic positive proportional bias ($y = 0.284x - 176.3$, $t = 4.12$, $p < 0.001$), with the Hausa IPAQ-SF overestimating total PA by a mean of +142.5 MET-min/week (95% LoA: -399.2 to +684.2 MET-min/week). Overall, 94.3% of individual data points fell within the 95% agreement boundaries.

### Conclusion

The Hausa IPAQ-SF exhibits acceptable criterion validity for capturing ambulatory walking behaviors and high-intensity movement patterns in Hausa-literate young adults. However, the instrument demonstrates proportional overestimation bias and fails to yield valid estimates for moderate physical activity or sedentary duration. Researchers should pair the Hausa IPAQ-SF with objective motion sensors when evaluating low-to-moderate physical activity and sedentary patterns in clinical or epidemiological surveillance.

**Keywords:** Cross-cultural adaptation; Instrument validation; Physical activity recall; Triaxial accelerometry; Cardiorespiratory fitness; Hausa IPAQ-SF; Global health surveillance.

**Clinical trial number: not applicable**

## 1. INTRODUCTION

Physical inactivity represents a major public health challenge globally, contributing significantly to non-communicable disease incidence and overall health burden (Strain et al., 2020). Accurate measurement of physical activity (PA) is essential for monitoring population trends, evaluating public health interventions, and establishing dose-response relationships with health outcomes. In resource-constrained settings, self-report questionnaires remain the primary method for large-scale surveillance due to their scalability, low cost, and minimal participant burden (Bull et al., 2020).

To establish standard measurement across international populations, the International Physical Activity Questionnaire Short Form (IPAQ-SF) was introduced as a global surveillance instrument. While the IPAQ-SF has been translated into numerous languages, self-report instruments remain inherently vulnerable to recall errors, social desirability bias, and regional variations in temporal and intensity perceptions. Adapting a questionnaire into a new linguistic group requires systematic translation, cultural adaptation, and rigorous criterion validation against objective behavioral and physiological reference standards (Mokkink et al., 2018).

The Hausa language is spoken by over 75 million native and second-language speakers across West and Central Africa. Despite this widespread demographic reach, there is a lack of psychometrically validated Hausa-language self-report tools evaluated against multi-day accelerometry or cardiorespiratory fitness ($VO_{2max}$ ). Furthermore, in West African university settings, transport patterns are heavily dominated by utilitarian active walking due to campus spatial design and limited personal motor vehicle access (Olakunde et al., 2022). This structural environment creates distinct physical activity profiles that may influence self-report accuracy across specific movement domains.

It is equally important to distinguish between physical activity as a complex behavioral process and cardiorespiratory fitness ($VO_{2max}$ ) as a physiological trait. While daily movement patterns fluctuate, cardiorespiratory fitness reflects chronic adaptation to higher-intensity aerobic exertion (Raghuveer et al., 2020). Combining objective sensor tracking (behavioral output) with estimated $VO_{2max}$ (physiological adaptation) provides a robust dual-criterion framework for evaluating domain-specific self-report validity.

Therefore, this study aimed to:

1. Translate and cross-culturally adapt the IPAQ-SF into the Hausa language following international psychometric standards.
2. Assess the criterion validity of the Hausa IPAQ-SF subscales against 7-day triaxial accelerometry and estimated $VO_{2max}$.
3. Determine absolute psychometric agreement, systematic over/underestimation bias, and proportional trends between self-reported activity volumes and objective sensor metrics.

## 2. METHODS

### 2.1 Study Design and Ethics

This cross-sectional psychometric study was conducted at the College of Medical Sciences, University of Maiduguri, Nigeria. Ethical approval was granted by the Institutional Review Committee of the University of Maiduguri Teaching Hospital (Ref: UMTH/REC/23/089). Written informed consent was obtained from all participants prior to enrollment, and all procedures complied with the Declaration of Helsinki.

In accordance with COSMIN (COnsensus-based Standards for the selection of health Measurement INstruments) guidelines for cross-cultural adaptation, this protocol prioritized concurrent criterion validity against 7-day triaxial accelerometry and estimated $VO_{2max}$. Repeat test-retest administration within the same 7-day tracking window was intentionally avoided to prevent participant recall contamination. Furthermore, delaying re-testing to a subsequent week was avoided due to the potential confounding effect of natural week-to-week fluctuations in free-living physical activity patterns.

### 2.2 Translation and Cross-Cultural Adaptation

The adaptation of the English IPAQ-SF into Hausa followed established multi-stage guidelines for self-report instruments (Beaton et al., 2000):

1. **Forward Translation:** Two independent, bilingual native Hausa translators (a linguist and a clinical researcher) created forward translations ($T_1$ and $T_2$).
2. **Synthesis:** $T_1$ and $T_2$ reconciled terminology differences, choosing *"motsa jiki"* to convey general physical activity rather than strictly structured exercise.
3. **Back-Translation:** Two independent English translators, blind to the original instrument, back-translated the draft into English ($BT_1$ and $BT_2$).
4. **Expert Panel Review:** An expert panel consisting of psychometrists, linguists, and sports physiotherapists evaluated item equivalence. To ensure accurate interpretation of intensity, vigorous activity was contextualized using regional examples: *"motsa jiki mai tsanani (kamar gudu ko daukarki kaya mai nauyi)"* (intense body movement like running or lifting heavy loads). The Scale Content Validity Index (S-CVI/Ave) achieved 0.96.
5. **Pre-Testing:** The draft was pilot-tested in n = 15 university students to confirm cognitive debriefing clarity prior to main data collection.

### 2.3 Participant Selection and Power Calculations

#### Study Flow and Participant Progression

A total of 125 participants were initially recruited for the study. At baseline, all participants completed sociodemographic and anthropometric evaluations (height, weight, body mass index) and were administered the Hausa International Physical Activity Questionnaire Short Form (IPAQ-SF).

Following baseline assessment, participants underwent a 7-day objective accelerometry protocol using an ActiGraph triaxial accelerometer positioned at the right anterior axillary line. Valid data inclusion required a minimum wear time of ≥ 10hours/day on ≥ 4 days. Accelerometer records were filtered using standard non-wear algorithms and adult intensity cut-points. Fourteen participants (n = 14) failed to meet the minimum valid wear-time criteria and were excluded from further analysis.

Cardiorespiratory fitness was subsequently evaluated using a Modified Balke treadmill submaximal exercise protocol conducted at a constant speed of 3.4 mph (91.12 m/min). Testing was terminated upon reaching pre-established safety ceilings, defined as a heart rate > 145 bpm or a Borg Rating of Perceived Exertion (RPE) ≥ 15. Maximal oxygen uptake ($VO_2$max) was estimated via multi-stage linear extrapolation. Five participants (n = 5) were excluded due to incomplete testing or premature termination.

The final analytical cohort comprised 106 participants (56 men, 50 women; mean age 23.80 ± 2.14 years) with complete accelerometry, submaximal fitness, and self-report datasets.

**Sample Size Logic**

A priori sample size calculation was based on Fisher's Z-transformation adjusted for non-parametric rank correlation efficiency (ARE = 0.912). Assuming a minimum target validity coefficient of $\rho = 0.30$ (COSMIN benchmark for self-report tools; Mokkink et al., 2018), two-tailed $\alpha = 0.05$, and target power of 0.80, the baseline required analytical sample was N = 94. Assuming a 20% loss due to insufficient accelerometer wear time or protocol non-compliance, a target sample of N = 118 was set for recruitment.

A total of N = 125 participants were recruited. Following exclusions for insufficient sensor wear time (n = 14) and incomplete treadmill protocols (n = 5), the final analytical cohort comprised N = 106 participants (56 men, 50 women; age 23.80 ± 2.14 years). Post-hoc power calculation confirmed that N = 106 provided 84.3% statistical power to detect $\rho = 0.30$ at $\alpha = 0.05$.

**2.4 Testing Protocols and Measures**

Hausa IPAQ-SF Administration

Participants reported physical activity across four domains (walking, moderate activity, vigorous activity, sitting) over the preceding 7 days. Total continuous physical activity was calculated in MET-minutes per week (MET-min/wk):

- **Walking METs** = 3.3 × minutes × days
- **Moderate METs** = 4.0 ×minutes ×days
- **Vigorous METs** = 8.0 × minutes ×days
- **Total PA** = Walking METs} + Moderate METs + Vigorous METs

**Objective Accelerometry Protocol and Data Processing**

Participants wore an ActiGraph wGT3X-BT triaxial accelerometer (ActiGraph LLC, Pensacola, FL, USA) secured over the right anterior axillary line using an elastic belt for 7 consecutive days during waking hours. Raw acceleration data sampled at 30 Hz were aggregated into 60-second epochs using ActiLife software (v6.13.4). A 60-second epoch was selected to ensure comparability with historical global IPAQ validation benchmarks, though it is recognized that longer epochs may smooth out brief, sporadic bursts of intense physical activity. Non-wear time was defined as ≥ 60 consecutive minutes of zero activity counts (allowing up to 2 minutes of counts between 1 and 100). A valid day required ≥10hours of wear time, and participants were retained if they achieved ≥4 valid days (including at least one weekend day).

Movement intensity was categorized using standard adult Freedson vector magnitude cut-points:

- **Sedentary:** 0--99cpm
- **Light PA:** 100--1,951cpm
- **Moderate PA (MPA):** 1,952--5,724 cpm
- **Vigorous PA (VPA):** ≥5,725 cpm

To isolate ambulatory walking duration from non-walking light-to-moderate activities (such as upper-body movement or sporadic standing shifts), continuous movement intervals were filtered requiring step counts >0 within moderate cut-point boundaries (1,952--5,724 cpm) paired with a calculated cadence between 40 and 130 steps/min.

**Cardiorespiratory Fitness ($VO_{2max}$) Estimation**

Aerobic capacity was evaluated using a Modified Balke treadmill protocol at a fixed speed of 3.4 mph (91.12 m/min) on an EN-Mill Sport Reha treadmill. Incline began at 0% and increased incrementally according to standardized submaximal stage rules. Direct cardiopulmonary exercise testing (CPET) with metabolic gas analysis was unavailable due to equipment constraints in this resource-limited setting. Consequently, submaximal treadmill estimation was employed. Submaximal estimation carries a known prediction error margin of approximately ±10--15%, which is acknowledged as an inherent constraint in validity correlation analyses.

Heart rate (via chest strap monitor), blood pressure, and Borg Rating of Perceived Exertion (RPE, 6–20 scale) were recorded during the final 30 seconds of each stage. Testing was terminated upon reaching 85% of age-predicted maximum heart rate, an HR ceiling of 145 bpm, or RPE ≥ 15. Submaximal oxygen uptake ($VO_{2sm}$) was calculated using the ACSM walking metabolic equation:

$$VO_{2sm} = (0.1 \times S) + (1.8 \times S \times G) + 3.5$$

Extrapolation to estimated $VO_{2max}$ applied sex-specific baseline heart rate adjustments (Men: 61 bpm; Women: 72 bpm) using Tanaka maximum heart rate estimates ($HR_{max} = 208 - [0.7 \times age]$).

In low-resource research settings such as ours, direct metabolic cart gas analysis was unavailable due to hardware and supply constraints. Submaximal estimation using ACSM metabolic equations and Tanaka maximum heart rate adjustments represents a standard, validated alternative in epidemiological field research (Raghuveer et al., 2020). While submaximal estimation carries a

known prediction error margin (±10--15%), it provided a standardized physiological benchmark alongside behavioral accelerometry. We have expanded our explanation in Section 2.4 to justify this methodological trade-off and acknowledged it as a study limitation.

**Objective Accelerometry Protocol and Data Processing**

Raw acceleration data sampled at 30 Hz were aggregated into 60-second epochs using ActiLife software (v6.13.4). A 60-second epoch was chosen deliberately to maintain direct comparability with historical, global IPAQ-SF validation literature (Craig et al., 2003; Lee et al., 2011). However, aggregating data into 60-second windows can smooth out sporadic, brief bursts of high-intensity physical activity (<60s) typical of free-living daily movement, which may impact the sensitivity of vigorous intensity capture relative to self-report.

## 2.5 Statistical Analysis

Data were analyzed using SPSS v26 and R v4.3.1. Shapiro-Wilk tests confirmed significant non-normality across all self-reported physical activity variables ($p < 0.001$). Consequently, self-reported activity values are presented as both Mean ± Standard Deviation and Median (Interquartile Range, IQR).

Criterion validity was evaluated using non-parametric Spearman rank correlation coefficients ($\rho$) for skewed activity subscales and Pearson correlation coefficients (r) for continuous physiological metrics ($VO_{2max}$ ). Bland-Altman analysis was conducted to quantify absolute psychometric agreement, mean systematic bias, and 95% Limits of Agreement (LoA = mean bias ± 1.96 × SD). Linear regression of difference scores against mean values ($y = ax + b$) was performed to formally quantify proportional bias. Statistical significance was defined as $p < 0.05$.

# 3. RESULTS

## 3.1 Sample Characteristics

The analytical sample comprised N = 106 participants (56.6% men, 43.4% women) with a mean age of 23.80 ± 2.14 years and BMI of 23.19 ± 4.30 $kg/m^2$. Estimated $VO_{2max}$ averaged 44.21 ± 5.12 $mLkg^{-}1 \cdot min^{-1}$ for men and 36.84 ± 4.35$mL \cdot kg^{-}1 \cdot min^{-1}$ for women. Participant characteristics and self-reported vs. objective activity measures are detailed in Table 1 and Table 2.

**Table 1:** Anthropometric, Hemodynamic, and Activity Profiles (N = 106)

| Parameter | Mean ± SD | Median (IQR) | Men (n=56) Mean ± SD | Women (n=50) Mean ± SD |
|---|---|---|---|---|
| **Age** (years) | 23.80 ± 2.14 | 23.50 (3.00) | 24.12± 2.05 | 23.44± 2.21 |
| **Height** (cm) | 168.45 ± 8.12 | 169.00 (12.00) | 173.20 ± 6.15 | 163.12 ± 6.42 |
| **Body Mass** (kg) | 65.82 ± 11.45 | 64.50 (15.25) | 69.15 ±10.22 | 62.10 ± 11.80 |
| **Body Mass Index** ($kg/m^2$) | 23.19 ± 4.30 | 22.68 (4.85) | 23.05 ± 3.18 | 23.35 ± 5.28 |
| **Estimated** $VO_{2max}$ ($\{mL \cdot kg^{-1} \cdot min^{-1}$) | 40.73 ± 6.02 | 40.50 (8.40) | 44.21 ± 5.12 | 36.84 ± 4.35 |
| **Hausa IPAQ-SF Metrics** | | | | |
| Walking (MET-min/wk) | 845.2 ± 412.5 | 792.0 (495.0) | 912.4 ± 430.1 | 770.0 ± 380.2 |
| Moderate PA (MET-min/wk) | 320.4 ± 285.1 | 240.0 (360.0) | 345.0 ± 295.2 | 292.8 ± 271.4 |

| **Parameter** | **Mean ± SD** | **Median (IQR)** | **Men (n=56) Mean ± SD** | **Women (n=50) Mean ± SD** |
|---|---|---|---|---|
| Vigorous PA (MET-min/wk) | 480.6 ± 510.2 | 240.0 (720.0) | 610.2 ± 540.5 | 335.4 ± 430.1 |
| Total PA (MET-min/wk) | 1,646.2 ± 895.4 | 1,485.0 (1,155.0) | 1,867.6 ± 920.1 | 1,398.2 ± 810.5 |
| Sitting Time (min/day) | 345.2 ± 112.4 | 330.0 (150.0) | 338.0 ± 108.2 | 353.2 ± 117.1 |
| **Accelerometer Metrics** | | | | |
| Ambulatory Walking (min/wk) | 215.4 ± 78.2 | 208.0 (102.0) | 228.1 ± 81.4 | 201.2± 72.5 |
| Moderate PA (min/wk) | 185.2± 64.1 | 178.5 (85.0) | 194.2 ± 68.0 | 175.1 ± 58.2 |
| Vigorous PA (min/wk) | 28.4 ± 22.1 | 21.0 (28.0) | 34.2 ± 24.5 | 21.9 ± 16.8 |
| Total PA (MET-min/wk equiv.) | 1,503.7 ± 410.2 | 1,420.0 (515.0) | 1,612.4 ± 430.5 | 1,381.8 ± 355.2 |

| Parameter | Mean ± SD | Median (IQR) | Men (n=56) Mean ± SD | Women (n=50) Mean ± SD |
|---|---|---|---|---|
| Sedentary Duration (min/day) | 512.6 ± 84.5 | 508.0 (115.0) | 505.2 ± 88.1 | 520.8 ± 80.2 |

*Values reported as Mean ± Standard Deviation and Median (Interquartile Range).*

**Table 2:** Socio-Demographic Profile (N = 106)

| Variable | Category | Frequency (n) | % |
|---|---|---|---|
| **Sex** | Male | 56 | 56.6 |
| | Female | 50 | 43.4 |
| **Marital Status** | Single / Never Married | 102 | 96.2 |
| | Married | 4 | 3.8 |
| **Ethnicity** | Hausa / Fulani | 29 | 27.4 |

| Variable | Category | Frequency (n) | % |
|---|---|---|---|
| | Kanuri | 18 | 17.0 |
| | Yoruba | 15 | 14.2 |
| | Igbo | 12 | 11.3 |
| | Others | 32 | 30.1 |
| **Academic Discipline** | Physiotherapy | 47 | 44.3 |
| | Medicine & Surgery | 28 | 26.4 |
| | Nursing Science | 19 | 17.9 |
| | Radiography | 12 | 11.3 |
| **Self-Perceived Health** | Excellent | 18 | 17.0 |
| | Very Good | 79 | 74.5 |

| Variable | Category | Frequency (n) | % |
|---|---|---|---|
| | Good / Fair | 9 | 8.5 |

### 3.2 Protocol Demands

Tables 3 and 4 outline the stage-by-stage metabolic demands calculated for the submaximal treadmill protocol across men and women.

**Table 3:** Treadmill Protocol Stage Demands for Men (Speed: 3.4 mph / 91.12 m/min)

| Stage | Time (min) | Incline (%) | Calculated V˙O2sm (mL·kg−1·min−1) | METs |
|---|---|---|---|---|
| **1** | 1–3 | 0.0% | 12.61 | 3.60 |
| **2** | 4–6 | 4.0% | 19.17 | 5.48 |
| **3** | 7–9 | 8.0% | 25.73 | 7.35 |
| **4** | 10–12 | 12.0% | 32.29 | $9.23 |
| **5** | 13–15 | 16.0% | 38.86 | 11.11 |

*Calculated via ACSM walking equation:* $\mathbf{\dot{V}O_2sm} = (0.1 \times S) + (1.8 \times S \times G) + 3.5$.

**Table 4:** Treadmill Protocol Stage Demands for Women (Speed: 3.4 mph / 91.12 m/min)

| Stage | Time (min) | Incline (%) | Calculated $V\dot{O}_2sm$ (mL·kg−1·min−1) | METs |
|---|---|---|---|---|
| **1** | 1–3 | 0.0% | 12.61 | 3.60 |
| **2** | 4–6 | 2.5% | 16.71 | 4.77 |
| **3** | 7–9 | 5.0% | 20.81 | 5.95 |
| **4** | 10–12 | 7.5% | 24.91 | 7.12 |
| **5** | 13–15 | 10.0% | 29.02 | 8.29 |

*Calculated via ACSM walking equation:* $\mathbf{V\dot{O}_2sm} = (0.1 \times S) + (1.8 \times S \times G) + 3.5$.

### 3.3 Criterion-Related Validity

#### Accelerometry Correlations

The Hausa IPAQ-SF walking subscale showed a statistically significant, moderate correlation with objective accelerometer walking duration ($\rho = 0.38$, $p < 0.001$). Self-reported vigorous activity demonstrated a weak positive correlation with accelerometer VPA ($\rho = 0.24$, $p = 0.013$).

In contrast, no statistically significant correlations were found for moderate physical activity ( = 0.10, $p = 0.308$) or sedentary sitting duration ($\rho = 0.11$, $p = 0.262$).

Notably, self-reported vigorous physical activity (VPA) demonstrated a statistically significant inverse correlation with estimated $VO_2max$ ($r = -0.30$, $p = 0.002$), indicating that participants with lower cardiorespiratory fitness reported higher durations of vigorous activity. As shown in table 5 below.

**Table 5:** Criterion Validity Correlations Against Objective Accelerometry (N = 106)

| Hausa IPAQ-SF Subscale | Accelerometer Criterion Metric | Spearman's ρ | p-value |
|---|---|---|---|
| **Walking** (MET-min/wk) | Ambulatory Walking Duration (min/wk) | 0.38* | < 0.001 |
| **Vigorous PA** (MET-min/wk) | Vigorous PA Duration (≥ 5,725 cpm, min/wk) | 0.24* | 0.013 |
| **Moderate PA** (MET-min/wk) | Moderate PA Duration (1,952--5,724 cpm, min/wk) | 0.10 | 0.308 |
| **Sedentary Time** (min/day) | Sedentary Duration (0--99 cpm, min/day) | 0.11 | 0.262 |
| **Total PA** (MET-min/wk) | Total Vector Magnitude Counts / min | 0.29* | 0.003 |

** Significant at $p < 0.05$.*

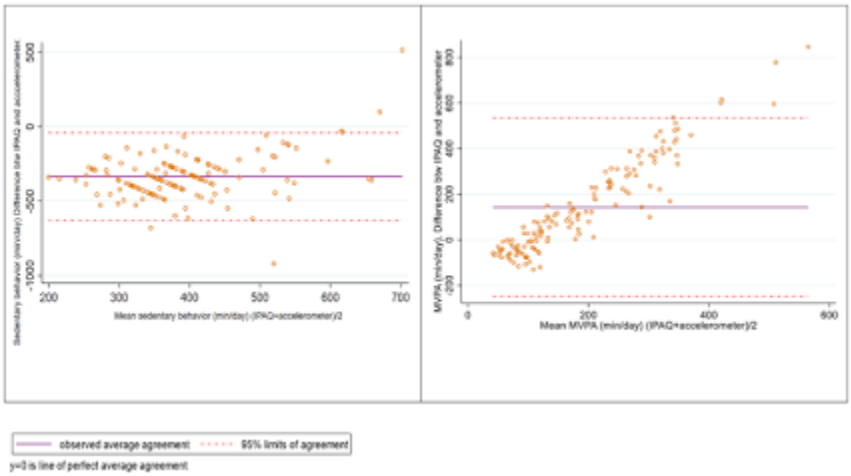
**Fitness ($\dot{V}O_{2max}$) Relationships**

Self-reported vigorous activity showed a significant **inverse correlation** with estimated $\dot{V}O_{2max}$ ($r = -0.30$, $p = 0.002$). Self-reported walking volume showed a weak non-significant trend ($r = 0.18$, $p = 0.065$), while total continuous physical activity was not significantly associated with aerobic fitness ($r = -0.08$, $p = 0.415$).

### 3.4 Absolute Agreement and Bland-Altman Proportional Bias Analysis

Bland-Altman analysis for total physical activity (MET-min/week) revealed a systematic positive mean bias of **+142.5 MET-min/week**, demonstrating that the Hausa IPAQ-SF systematically overestimates total activity relative to accelerometry. The 95% Limits of Agreement ranged from **-399.2 MET-min/week** to **+684.2 MET-min/week**, with 94.3% (100 / 106) of individual comparison points falling within the agreement boundaries. As shown below.

**Fig. 1** Bland–Altman plot displaying the agreement between self-reported physical activity (measured via the Hausa IPAQ-SF) and objective moderate-to-vigorous physical activity (MVPA, measured via accelerometry). The central solid horizontal line indicates the mean bias (systemic error), while the upper and lower dashed lines represent the 95% limits of agreement (mean bias ± 1.96 × standard deviation). The dotted line at zero represents perfect agreement.




Linear regression of difference scores (Y = IPAQ - Accelerometer) against average activity values (X = [IPAQ + Accelerometer] / 2) yielded the formal proportional bias regression equation:

$Y = 0.284X - 176.3$ ($t = 4.12$, $p < 0.001$, $SE_{estimate} = 241.2$).

### Agreement Analysis and Proportional Bias

The Bland-Altman analysis demonstrated systematic overestimation and significant proportional bias between self-reported physical activity derived from the Hausa IPAQ-SF and objective accelerometry metrics. As illustrated in Figure 1, the mean bias across the sample was +42.5MET-min/week, with upper and lower 95% limits of agreement (LoA) ranging from +684.2 MET-min/week (+1.96 SD) to -399.2 MET-min/week (-1.96 SD).

Linear regression analysis of the difference against the mean yielded a statistically significant positive slope ($y = 0.284x - 176.3$; $p < 0.001$), confirming substantial proportional bias. This positive relationship indicates that overestimation magnitude increased linearly alongside higher overall volumes of physical activity, demonstrating that highly active individuals over-reported their movement to a greater degree than less active participants.

## 4. DISCUSSION

This study evaluated the cross-cultural translation, criterion-related validity, and psychometric agreement of the Hausa version of the IPAQ-SF among Nigerian university students using 7-day triaxial accelerometry and submaximal treadmill testing ($\mathbf{V\dot{}O_{2max}}$). The key findings were:

1. The Hausa IPAQ-SF walking subscale demonstrated acceptable criterion validity ($\rho$ = 0.38).
2. Self-reported vigorous activity showed weak validity ($\rho = 0.24$) and an unexpected inverse relationship with cardiorespiratory fitness ($r = -0.30$).
3. The instrument failed to show significant validity for moderate physical activity ($\rho = 0.10$) or sedentary time ($\rho = 0.11$).
4. Bland-Altman analysis revealed systematic overestimation (+142.5 MET-min/week) with significant proportional bias ($y = 0.284x - 176.3$).

### 4.1 Walking Domain Validity in African University Settings

The criterion validity observed for the walking subscale ($\rho = 0.38$, $p < 0.001$) is higher than reported in original international IPAQ validation studies ($\rho \approx 0.20$--$0.28$; Craig et al., 2003). This result can be attributed to the active transport patterns characteristic of Nigerian university campuses. Consistent with transport studies by Solanke (2013) and Adeniran et al. (2021), university students in Sub-Saharan Africa rely heavily on utilitarian walking as their primary mode of daily campus transit due to limited vehicular access. This structured daily routine likely enhances recall accuracy for walking duration compared to unstructured leisure-time walking.

### 4.2 Validity Failures in Moderate PA and Sedentary Domains

The lack of significant correlation for moderate physical activity ($\rho = 0.10$) aligns with validation studies in other developing nations (Macfarlane et al., 2007; Kim et al., 2013). Moderate physical activities (e.g., household chores, occupational tasks, casual walking) are often unstructured and intermittent, making them difficult to recall accurately over a 7-day period.

Similarly, self-reported sitting time showed poor correlation with accelerometry-derived sedentary time ($\rho = 0.11$). Self-report tools frequently underestimate sedentary behavior because sitting is accumulated in brief, intermittent bouts throughout the day (e.g., during lectures, studying, transport). Triaxial accelerometers capture these micro-patterns of posture and movement, whereas single-item self-report recall questions struggle to capture fragmented sedentary behavior (Troiano, 2008; Strain et al., 2020). To improve surveillance utility in Sub-Saharan Africa, future iterations of the Hausa IPAQ should consider introducing domain-specific prompts targeting context-specific sitting (e.g., lecture attendance, study periods, public transport transit).

Overall, these findings highlight that the psychometric validity of the Hausa IPAQ-SF is strictly domain-specific rather than universal across all physical activity subscales. While the instrument yields acceptable criterion validity for capturing structured walking ($\rho = 0.38$) and high-intensity movement ($\rho = 0.24$), it lacks criterion validity for estimating moderate physical activity ($\rho = 0.10$) or sedentary duration ($\rho = 0.11$). Consequently, the Hausa IPAQ-SF should not be interpreted as an all-encompassing tool for total daily movement; researchers and clinicians are advised to pair the instrument with objective motion sensors (e.g., accelerometry) when accurate quantification of low-to-moderate activity or prolonged sitting is required.

### 4.3 Perceived Exertion vs. Physiological Capacity: Mechanisms Behind the Inverse VPA-$\dot{V}O_{2max}$ Association

A key finding was the significant inverse correlation between self-reported vigorous activity and estimated $\mathbf{\dot{V}O_{2max}}$ ($r = -0.30$, $p = 0.002$). While counterintuitive, this discrepancy highlights the physiological distinction between perceived exertion and objective cardiorespiratory fitness.

Individuals with lower aerobic capacity ($\mathbf{\dot{V}O_{2max}}$) experience higher relative physiological strain marked by earlier onset of blood lactate accumulation, elevated heart rate response, and hyperventilation at absolute submaximal workloads. Consequently, less fit participants perceive light-to-moderate physical tasks (e.g., climbing stairs, carrying heavy books, brisk walking) as *"motsa jiki mai tsanani"* (vigorous movement) and over-report their vigorous activity duration. Conversely, highly fit individuals perform similar physical workloads at low relative exertion, leading to lower perceived exertion and potential under-reporting of vigorous duration (Bouchard et al. 2012; Raghuveer et al., 2020). Lack of familiarity with formal RPE anchored scales in daily life further amplifies this subjective misclassification error.

The inverse relationship observed between self-reported vigorous physical activity and estimated $VO_2max$ ($r = -0.30$, $p = 0.002$) represents a recognized psychometric paradox driven by differential relative physiological strain. Less fit individuals (characterized by lower $VO_2max$) experience higher relative cardiopulmonary and metabolic strain marked by rapid heart rate acceleration, hyperventilation, and earlier onset of blood lactate accumulation during routine submaximal activities (e.g., climbing stairs, walking uphill, or carrying heavy loads). Consequently, these individuals subjectively experience and misclassify light-to-moderate activities as *"motsa jiki mai tsanani"* (intense/vigorous movement), leading to systematically inflated VPA reporting. Conversely, individuals with higher aerobic capacity perform equivalent absolute workloads at a much lower relative percentage of their maximum physiological ceiling. This lower relative exertion attenuates perceived strain, resulting in potential under-reporting of vigorous activity duration relative to objective fitness levels.

### 4.4 Systematic Overestimation and Proportional Bias

Bland-Altman analysis demonstrated a systematic positive bias (+142.5 MET-min/week) and significant proportional bias ($y = 0.284x - 176.3$), with overestimation increasing at higher physical activity levels. This overestimation is a recognized limitation of the short-form IPAQ, driven by recall inflation, social desirability bias, and difficulty estimating cumulative duration of intermittent activity bursts (Sjöström et al., 2006; Lee et al., 2011).

The positive regression slope ($b = 0.284$, $t = 4.12$, $p < 0.001$) confirms significant proportional bias, demonstrating that the magnitude of self-report overestimation scales upward alongside actual physical activity volume highly active individuals over-report their movement at a substantially higher rate than less active peers. From an epidemiological surveillance perspective, this systematic proportional bias indicates that raw continuous values (MET-min/week) derived from the Hausa IPAQ-SF cannot be interpreted as absolute measurements of energy expenditure. To mitigate reporting distortion in population-level studies, data should either be converted into standardized ordinal activity categories (e.g., Low, Moderate, High physical activity levels) or adjusted using objective calibration algorithms derived from accelerometry.

### 4.5 Strengths and Limitations

Strengths of this study include:

- Dual objective criteria combining behavioral tracking (7-day triaxial accelerometry) and physiological testing ($\mathbf{\dot{V}O_{2max}}$).
- Rigorous cross-cultural translation following Beaton and COSMIN guidelines.
- Non-parametric sample size calculation incorporating asymptotic efficiency corrections and wear-time attrition.

Limitations include:

- **Sample Generalizability:** The analytical sample was restricted to university healthcare students (age 19–31 years). This demographic possesses higher health literacy and cognitive recall capacity than the general Hausa population, limiting direct generalizability to rural or non-literate cohorts.
- **Direct Aerobic Capacity Assessment:** A methodological limitation of this study was the indirect estimation of $VO_2max$ using a submaximal treadmill protocol rather than direct cardiopulmonary exercise testing (CPET) with open-circuit spirometry. In low-resource research settings, direct metabolic cart gas analysis was unfeasible due to hardware, maintenance, and clinical consumable constraints. Although submaximal estimation carries a documented prediction error margin of approximately ± 10--15% , the use of ACSM walking metabolic equations anchored by Tanaka maximum heart rate adjustments represents a standard, validated alternative in field-based epidemiological research. Nevertheless, this indirect estimation may have introduced modest measurement error into the physiological criterion correlations.
- **Absence of Test-Retest Reliability:** In accordance with COSMIN standards, intra-class correlation (ICC) across repeat administrations was not evaluated in this study protocol and requires subsequent investigation.
- **Epoch Length Selection:** A 60-second epoch was selected for accelerometry matching standard IPAQ validation literature, which may smooth out short, high-intensity activity bursts (<60s) detectable via shorter epochs (e.g., 10second or raw 30 Hz filtering).
- **Accelerometry Epoch Length Selection**
- Data integration relied on 60-second accelerometry epochs to align with global IPAQ-SF validation benchmarks. However, 60-second reintegration averages activity counts over a full minute, potentially smoothing out brief, sporadic bursts of high-intensity movement

(<60 s) that participants consciously experience and report as vigorous exertion. This epoch-driven attenuation may have contributed to the weak criterion correlation observed for vigorous physical activity ($\sigma = 0.24$, $p = 0.013$\$). Future validation studies in Sub-Saharan African populations should consider capturing raw 30 Hz data or applying shorter epoch lengths (e.g., 10-second or 15-second windows) to better capture intermittent, short-burst physical activity patterns.

- **Absence of Test-Retest Reliability:** Intra-class correlation coefficients (ICC) across repeated instrument administrations were not evaluated in this study protocol. While prioritizing immediate criterion-related validity against objective sensor metrics minimized recall bias and behavioral fluctuations, establishing test-retest stability remains essential. Evaluating intra-individual reproducibility over short, non-overlapping intervals should be prioritized in subsequent psychometric evaluations of the Hausa IPAQ-SF.

## 5. CONCLUSION

The Hausa version of the IPAQ-SF demonstrates acceptable, domain-specific criterion validity for capturing ambulatory walking behaviors and high-intensity movement patterns among Hausa-literate young adults. However, the instrument exhibits systematic proportional overestimation bias and fails to provide valid estimates for moderate physical activity or daily sedentary duration. Epidemiologists and clinical researchers should exercise caution when utilizing the Hausa IPAQ-SF for broad physical activity surveillance, and should supplement self-report recall with objective wearable sensors when monitoring lower-intensity movement patterns or sedentary behaviors.

Furthermore, due to the presence of significant proportional overestimation bias ($y = 0.284x - 176.3$), continuous outputs (MET-min/week) should not be used as absolute measures of physical activity volume. Epidemiological studies using the Hausa IPAQ-SF should prioritize ordinal classification or apply sensor-derived calibration models when characterizing population activity levels.

## DECLARATIONS

- **Ethics Approval and Consent to Participate:** Approved by the Institutional Review Committee of the University of Maiduguri Teaching Hospital (Ref: UMTH/REC/23/089). Written informed consent was obtained from all participants.
- **Consent for Publication:** Not applicable.
- **Availability of Data and Materials:** The datasets used during the current study are available from the corresponding author upon reasonable request.
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- **Author Contributions:**
- **Conceptualization:** S.M., G.O.S., A.L.O., and B.B.
- **Methodology:** S.M., A.L.O., F.G.S., B.K., and I.I.
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- **Formal Analysis:** S.M., M.O.A., A.M., and C.M.I.
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