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ORIGINAL SCIENTIFIC PAPER

Test-Retest Reliability of the EUFITMOS Battery for Assessing Health-Related Physical Fitness in Low-Income Young People

Duarte Henriques-Neto[1], Adilson Marques[2], Miguel Peralta[2,3], Marta Ferreira[4,5], Alex Barreto de Lima[6]

[1]University of Maia, Research Center in Sports Sciences, Health Sciences and Human Development, Maia, Portugal, [2]Universidade de Lisboa, CIPER, Faculdade de Motricidade Humana, Cruz Quebrada, Portugal, [3]Universidade de Lisboa, ISAMB, Faculdade de Medicina, Lisboa, Portugal, [4]Instituto Politécnico do Porto, inED, Centro de Investigação e Inovação em Educação, Escola Superior de Educação, Porto, Portugal, [5]Universidade de Aveiro, Departamento de Educação e Psicologia, Aveiro, Portugal, [6]Universidade Nilton Lins, Curso de Educação Física, Amazonas, Brasil

Abstract

Assessing the reliability of physical fitness measures in middle- and low-income contexts is considered a research priority. This study aimed to analyse the test-retest reliability of field-based physical fitness tests in low-income young people from Amazonas, Brazil. Participants were 152 adolescents (75 boys) aged 11 to 16, living in Jutaí, Amazonas. Physical fitness, including cardiorespiratory fitness, upper- and lower-body strength, flexibility, and speed, was assessed using the EUFITMOS battery across two trials conducted one week apart. Test-retest reliability was assessed using the intra-class correlation coefficient (ICC). The agreement was estimated using the Bland-Altman approach with a 95% confidence interval (CI). Every physical fitness test showed good to excellent reproducibility with ICC ranging from 0.81 to 1.00 between trials 1 and 2. Agreement analysis presented limited evidence of systematic bias with mean difference lines close to 0 and without any specific positive or negative trend. In each physical fitness test, most observations were within the 95%CI limits, except for the standing broad jump in boys. The EUFITMOS battery is appropriate for use in low-income contexts such as the Amazonas, providing field-based physical fitness measures that can be used to collect important data and inform decision-making on young people's health from low-income contexts.

Keywords: *fitness testing, public health, reproducibility, surveillance*

Introduction

Physical fitness translates the combined result of genetic and biological characteristics with the influence of the social environment in which young people live (Burgos-Postigo et al., 2021; Caspersen et al., 1985). Body composition, cardiorespiratory fitness, and muscular fitness are the main components of physical fitness, where attributes such as height, body weight, waist circumference, lean mass, fat mass, VO2 peak, flexibility, agility, upper, middle and lower body strength are often assessed (Campbell et al., 2013). It is widely recognized that physical fitness is a biomarker of health, used not only in epidemiological studies but also in different types of scientific studies (e.g. clinical, experimental) (García-Hermoso et al., 2022; Murphy et al., 2016; Ortega et al., 2023). Thus, assessing physical fitness in youth is important for monitoring health and well-being, and can contribute to a better understanding of young people's health status and to developing tailored physical activity-promoting strategies.

Physical fitness tests are properly structured protocols designed to stimulate certain biological systems. The response of biological systems to these specific stimuli varies according to individual characteristics and adolescents' exposure to physical activity, exercise, or sports participation (Henriques-Neto et al., 2021; Ibáñez et al., 2023). Therefore, different batteries of physical fitness tests have been developed worldwide, mainly to monitor young people's health (Marques, Henriques-Neto, et al., 2021). The EUFITMOS battery is a field-based physi-

Correspondence:

Duarte Henriques-Neto
University of Maia (UMaia), Research Center in Sports Sciences, Health Sciences, and Human Development (CIDESD), Av. Carlos Oliveira Campos - Castelo da Maia -4475-690- Portugal
E-mail: dhneto@umaia.pt

cal fitness battery developed using scientifically validated test protocols for young people between 10 and 18 years old with minimal instrument requirements. It was designed to assess and monitor the health of young people in Europe at the lowest possible cost and with a high level of validity and reproducibility (Marques, Peralta et al., 2021).

A recent twin-panel Delphi study defined the top 10 international priorities for physical fitness research and surveillance (Lang et al., 2022). Priority 7 assesses the reliability and validity of fitness measures, with a special focus on middle- and low-income countries, as research in these contexts is scarce. Young people from Amazonas in Brazil are considered a low-income population with difficulties in accessing health monitoring services. Given the needs of young people from Amazonas and the research gap among low-income countries, it can be beneficial to assess the adequacy of the EUFITMOS battery in this population, allowing for the use of physical fitness as a health indicator and providing reliable fitness data. Therefore, this study aimed to analyse the test-retest reliability of the different physical fitness test protocols composing the EUFITMOS battery in low-income young people from Amazonas.

Methods

Participants, study design and procedures

This test-retest study comprises 152 adolescents aged between 11 and 16 (75 boys and 77 girls) living in the municipality of Jutaí (Amazonas). Participants were recruited between September and October 2023 in public schools. All participants were informed about the project's aim and written consent was obtained from their legal guardians before participating in the research. The authors did not have access to information that could identify participants during or after data collection. This study was approved by the Ethics and Research Committee of the Amazonas State University - Manaus following the Declaration of Helsinki (WMA, 2013) and Resolution 466/12 of the National Health Council and is part of the research project:"EFEJU - Educação Física nas Escolas de Jutaí, Amazonas" (CAAE 56791822.8.0000.5016 / opinion 5.621.338).

Physical fitness assessment was carried out in schools by trained staff. Each participant performed eight physical fitness tests from the EUFITMOS battery in four different sessions with a 48-hour interval in between (trial 1). Researchers repeated assessmentsfollowing week with a 7-day interval (trial 2). Each session lasted approximately 60 minutes. Before performing the physical fitness tests, the participants underwent a standardised 10-minute warm-up. To minimise the effects of circadian rhythm variability, all the tests were carried out in the same order and at the same time of day.

Measures

Physical fitness was assessed using the EUFITMOS fitness battery (Marques et al., 2023). The manual and videos of the physical fitness tests, including procedures and protocols, are available on the EUFITMOS website (https://eufitmos.eu/fitness-testing-protocol/). Eight fitness tests were performed including body mass index (BMI), grip strength, push-up test, standing broad jump (SBJ), back-saver sit and reach, 20m run, Progressive Aerobic Cardiovascular Endurance Run (PACER), and 1-mile run.

Body mass index. Weight (kg) and height (cm) were determined using a mechanical scale with an attached stadiometer (Welmy, São Paulo City, Brazil) to the nearest decimal place. Participants were wearing shorts and a T-shirt but without shoes. BMI was calculated as weight (kg)/height2(m). Anthropometric assessments were only carried out in trial 1.

Grip strength. Grip strength (kg) was assessed using a JAMAR® hydraulic dynamometer. Participants were instructed to stand upright, feet shoulder-width apart, hold the dynamometer with the elbow in full extension and the arm slightly abducted, and then squeeze as hard as possible for at least two seconds. This procedure was carried out twice on each hand with 1-minute rest between attempts. The best result was recorded.

Push-up test. Upper-body strength (muscular endurance) was assessed with the push-up test. The number of push-ups performed (until the arm and forearm formed a 90º angle) was recorded at a cadence of 20 push-ups per minute.

Standing broad jump. Lower-body strength (power) was assessed with the SBJ. Participants stood with their feet parallel, shoulder-width apart and immediately behind a line. Then, they were instructed to slightly bend their knees, swing their arms and jump forward as far as possible, landing in a standing position with both feet simultaneously. The distance (cm) covered in the jump, considering the heel of the rear foot, was measured using a measuring tape. The best result from two attempts was recorded.

Back-saver sit and reach. It is used to assess the flexibility of the lower back and posterior thigh. Participants flexed their torso with both arms outstretched, one hand on top of the other with the palms facing downwards, one leg stretched out with the sole touching the measuring box and the other bent with the foot on the floor. The best score (in cm) of the two attempts was recorded.

20m run. The 20-meter run was used to assess speed. Time (s) was recorded using a stopwatch. Two attempts, with a minimum rest period of 3 minutes, were performed, and the best time was recorded.

Progressive Aerobic Cardiovascular Endurance Run. PACER examines cardiorespiratory fitness. Participants run back and forth between two parallel lines 20m apart at a pre-defined increasing cadence (starting at 8.5 km/h and increasing by 0.5 km/h each minute). The number of laps performed before exhaustion or two fouls (e.g. not reaching the line on time) is recorded. An audible signal was used to help participants control their running speed during the test.

1-mile run. The 1-mile run is also used to assess cardiorespiratory fitness. Participants must complete a 1-mile course on a flat surface (e.g. running track) at a steady running pace (walking at a fast pace is allowed) and time is recorded.

Sociodemographic

Sex and age were self-reported. Decimal age was calculated as the difference between the date of birth and the date of data collection in months. Socioeconomic status was assessed with a questionnaire from the Brazilian Association of Research Companies (ABEP, 2021). This questionnaire allows us to identify five social classes, ranging from class A (highest purchasing power) to class E (lowest purchasing power), based on the possession of certain consumer goods, the education level of the head of the family and access to public services.

Statistical Analyses

Descriptive statistics (including mean, standard deviation and frequencies) were calculated for anthropometric and sociodemographic variables. Differences between sexes were examined using the independent sample t-test and chi-square. For each physical fitness test, differences between trials (one week apart) were assessed using paired sample t-tests. Test-retest reliability was assessed using the intra-class correlation coefficient (ICC) by one-way random effects, absolute agreement, multiple measurements and categorised as ICC<0.50 - poor; 0.50≤ICC<0.75 - moderate; 0.75≤ICC<0.90- good; and ICC ≥0.90– excellent (Koo & Li, 2016). The 95% confidence interval (CI) for the ICC was calculated. The agreement was estimated using the Bland-Altman approach on the between-trial difference for each test (T2-T1). Data analysis was performed using IBM SPSS Statistics version 28.0 (SPSS Inc., an IBM Company, Chicago, Illinois, USA). Statistical significance was set at p≤0.05.

Results

Anthropometric and socioeconomic characteristics are presented in Table 1. Notably, most participants (90.1%) had a low socioeconomic status.

Test-retest reliability analysis showed that every physical fitness test had a good or excellent ICC (ranging from 0.81 to

Table 1. Anthropometric and sociodemographic characteristics

	Mean±SD or n (%)			p-value
	Total (n=152)	Boys (n=75)	Girls (n=77)	
Age, years	13.29±1.00	13.32±1.07	13.25±0.94	0.344
Weight, kg	47.96±10.78	49.49±11.50	46.48±9.88	0.043
Height, m	1.53±0.08	1.55±0.09	1.50±0.06	<0.001
BMI, kg/m2	20.34±3.56	20.31±3.51	20.37±3.63	0.460
Socioeconomic status				0.290
Low	137 (90.1)	65 (86.7)	72 (93.5)	
Average	14 (9.2)	9 (12)	5 (6.5)	
High	1 (0.7)	1 (1.3)	0	

Legend: BMI - Body mass index; SD - Standard deviation.

Table 2. Test-retest reliability of each physical fitness test for the total sample and by sex.

	Mean±SD		p-value	T2-T1 (%T1)	ICC	ICC 95%CI
	T1	T2				
Total (n=152)						
Grip strength (kg)	25.9±7.5	26.5±7.5	<0.001	0.64 (2.5)	0.99	0.96, 0.99
Push-up test (reps)	3.8±5.1	4.3±5.3	<0.001	0.43 (11.3)	0.98	0.96, 0.99
Back-saver sit and reach (cm)	26.7±6.6	27.5±6.3	<0.001	0.82 (3.1)	0.86	0.80, 0.90
SBJ (cm)	133.8±26.8	134.6±26.6	<0.001	0.84 (0.6)	0.99	0.99, 1.00
The 20m run (s)	4.6±2.5	4.6±2.5	<0.001	-0.05 (1.1)	0.99	0.99, 0.99
PACER (VO2Peak – ml/Kg/min)	37.8±4.5	37.8±4.5	0.082	0.01 (0.0)	1.00	1.00, 1.00
1-mile run (minutes)	12.0±2.5	12.0±2.5	<0.001	-0.05 (0.4)	0.99	0.99, 0.99
Boys (n=75)						
Grip strength (kg)	28.3±8.9	28.8±8.9	<0.001	0.02 (0.1)	0.99	0.98, 0.99
Push-up test (reps)	6.3±6.0	7.0±6.2	<0.001	0.68 (10.8)	0.98	0.94, 0.99
Back-saver sit and reach (cm)	25.1±6.7	26.5±6.6	0.001	1.39 (5.5)	0.81	0.70, 0.88
SBJ (cm)	144.6±26.8	145.1±26.7	<0.001	0.44 (0.3)	0.99	0.99, 1.00
The 20m run (s)	4.6±3.5	4.5±3.5	<0.001	-0.05 (1.1)	1.00	0.99, 1.00
PACER (VO2Peak – ml/Kg/min)	39.4±5.1	39.5±5.1	0.057	0.02 (0.1)	1.00	1.00, 1.00
1-mile run (minutes)	11.3±2.9	11.2±2.9	<0.001	-0.09 (0.8)	0.99	0.99, 0.99
Girls (n=77)						
Grip strength (kg)	23.5±4.7	24.2±4.8	<0.001	0.67 (2.9)	0.97	0.83, 0.99
Push-up test (reps)	1.4±2.1	1.6±2.3	0.017	0.18 (12.9)	0.94	0.91, 0.96
Back-saver sit and reach (cm)	28.2±6.0	28.5±6.0	0.192	0.27 (1.0)	0.90	0.84, 0.93
SBJ (cm)	123.2±22.2	124.5±22.3	<0.001	1.22 (1.0)	0.99	0.94, 0.99
The 20m run (s)	4.6±0.6	4.6±0.6	<0.001	-0.05 (1.1)	0.98	0.96, 0.99
PACER (VO2Peak – ml/Kg/min)	36.2±3.0	36.2±2.9	0.396	0.01 (0.0)	0.99	0.99, 1.00
1-mile run (minutes)	12.6±1.8	12.6±1.8	<0.001	-0.03 (0.2)	1.00	0.99, 1.00

Legend: CI, confidence interval; ICC, intraclass correlation coefficient; PACER, Progressive Aerobic Cardiovascular Endurance Run; SBJ, standing broad jump; SD, standard deviation; T1, trial 1; T2, trial 2.P-value is for paired sample t-test.

1.00) between trials 1 and 2 for the whole sample, boys and girls (Table 2). Mean differences between trials (T2-T1) were minimal. However, a slight but statistically significant improvement in the physical fitness tests' results was observed for all tests, except the PACER and the back-saver sit and reach (only for girls). The total sample relative improvements (compared to trial 1) ranged from a 0.4% decrease in the 1-mile run time to an 11.3% increase in repetitions for the push-ups test. Apart from the push-ups test, all tests presented a single-digit relative improvement from trial 1 to trial 2.

Bland-Altman plots for the difference between trials 1 and 2 for each physical fitness test are presented in Figures 1 (boys) and 2 (girls). All tests presented a mean difference line close to 0 without any specific positive or negative trend, suggesting low systematic bias. Furthermore, most differences were within the 95%CI limits of agreement for all tests except for the SBJ for boys.

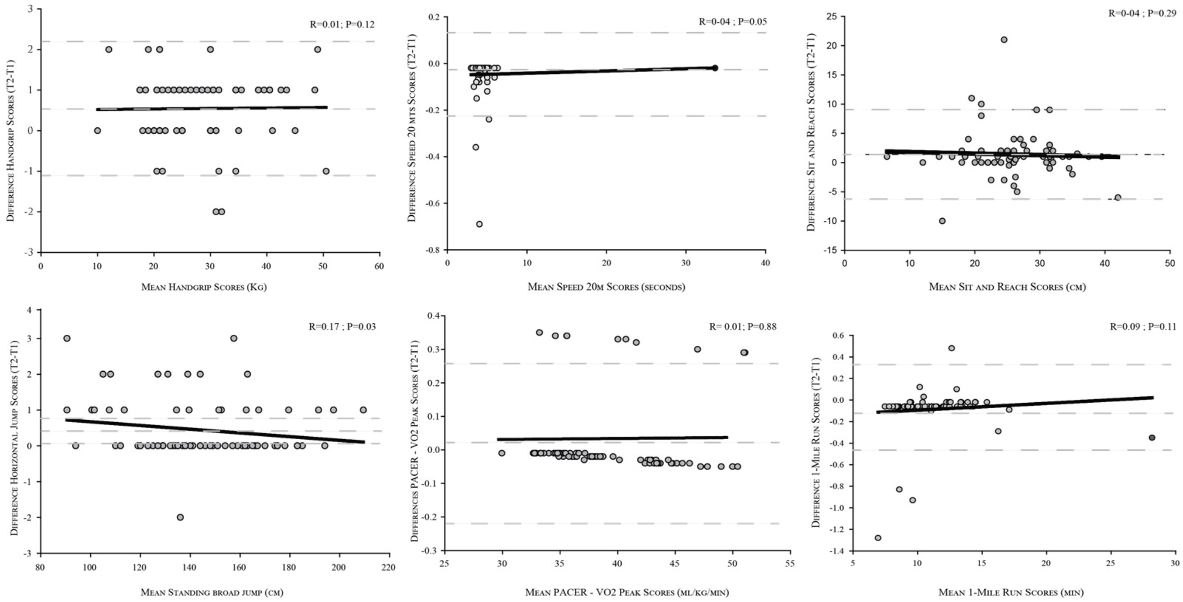

FIGURE 1. Bland-Altman of the difference between trials 1 and 2 for each physical fitness test with 95% confidence interval lines among boys.

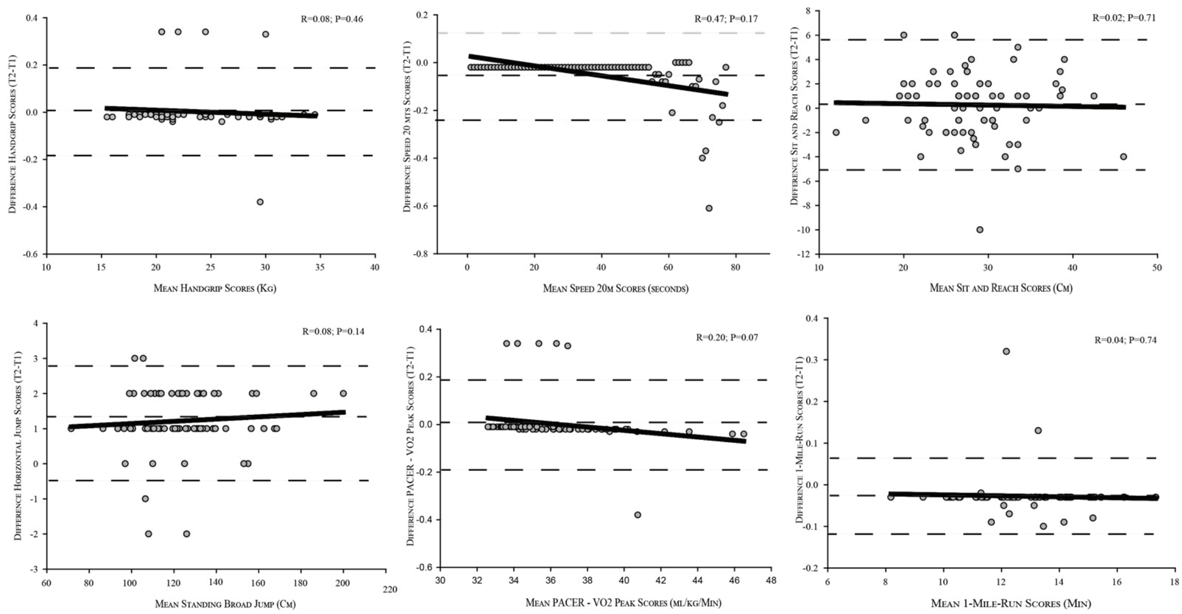

FIGURE 1. Bland-Altman of the difference between trials 1 and 2 for each physical fitness test with 95% confidence interval lines among boys.

Discussion

This investigation examined the test-retest reliability of the physical fitness tests composing the EUFITMOS battery in low-income young people from Amazonas. Every physical fitness test, including grip strength, push-up test, SBJ, back-saver sit and reach, 20m run, PACER and 1-mile run, presented good to excellent reproducibility between two trials one week apart. Moreover, agreement analysis showed no risk of serious systematic bias. These findings suggest that the EUFITMOS battery is appropriate for use in low-income contexts such as the Amazonas when assessing physical fitness.

Physical fitness is intimately associated with present and future health in youth. For example, cardiorespiratory fitness is an indicator and predictor of cardiovascular, metabolic and mental health (Altermann & Gröpel, 2024; Roldão da Silva et al., 2020; Sánchez-Delgado et al., 2022; Wheatley et al., 2020). Muscular fitness attributes such as speed and upper- and lower-body strength are associated with better bone mineral density (Henriques-Neto et al., 2020). Therefore, field-based physical fitness assessment is a non-invasive, easy-to-apply and inexpensive methodology that allows to monitoring of young people's health and plans tailored health promotion strategies focused on physical activity. While physical fitness laboratory protocols are more precise, they are more expensive and require specific technical support (e.g. instrumental and personal) (Tabacchi et al., 2019). When considering low-income contexts, having an inexpensive but reliable tool is key (Brazo-Sayavera et al., 2024). In this sense, the EUFITMOS battery provides field-based physical fitness measures that can be used to collect important data and inform decision-making on young people's health from low-income contexts.

Assessing the reliability and validity of physical fitness tests, especially among school-aged young people from low- and middle-income countries, is considered a research and surveillance priority (Lang et al., 2022). To the best of our knowledge, this is the first study examining the test-retest reliability of physical fitness tests in young people from Amazonas. On the one hand, the EUFITMOS battery comprises field-based physical fitness tests that showed good to excellent test-retest reliability (with ICC ranging from 0.81 to 1.00) and no evidence of systematic bias. On the other hand, physical fitness measurements slightly improved from trial 1 to trial 2. Notwithstanding, these improvements were small and can be attributed to a learning effect since this was the first time performing the tests. Previous research in middle- and low-income countries has found similar results. For example, in the FUPRECOL study from Colombia, several filed-based physical fitness tests, including some that are also used in the EUFITMOS battery such as grip strength, SBJ, sit-and-reach and PACER, were reliable for measuring health-related components of fitness (Ruiz et al., 2015). These findings support the use of field-based physical fitness assessments, such as those comprising the EUFITMOS battery, as reliable measures to monitor health in young people from low- and middle-income contexts.

Strengths and limitations

The conceptualization and results of this research were developed based on the three main objectives of the European Union Global Health Strategy (Plasència et al., 2024), namely, strengthening health systems to prevent disease and promote well-being, with special attention to populations with low economic resources and a geographical location known as tropical.

There is extensive evidence on the reliability of different physical fitness tests in young people. However, very few studies have been conducted in middle- and low-income settings (Lang et al., 2022). Thus, to the best of our knowledge, the major strength of this study is the first to examine the test-retest reliability of a field-based physical fitness battery in Amazonas, a low-income context and with a mostly low-income population (90.1%). Despite recent strides in this direction, future research should still be focused on providing data on the validity and reliability of field-based physical fitness measurements in different middle- and low-income countries. Other strengths include using already validated physical fitness tests incorporated in a standardised fitness battery (EUFITMOS battery) implemented in different European countries. Some limitations must also be acknowledged, such as the relatively small and non-representative sample and the lack of confounding variables that could influence physical fitness levels (e.g. regular physical activity, diet, maturation), and the tests were not familiarized before the first assessment.

Conclusion

The EUFITMOS battery comprises scientifically validated field-based physical fitness tests that are simple to apply and low-cost. For the first time, these tests were reliable for assessing physical fitness among young people from a low-income context in Amazonas. In addition, the EUFITMOS online platform allows education, sport and health professionals to learn all the protocols through educational resources (e.g. video tutorials, images, descriptions of the protocols and scientific articles). These resources have been developed to reduce errors between assessors. Thus, the EUFITMOS battery can be useful for monitoring health-related fitness and inform decision-making on creating health promotion strategies focused on physical activity tailored to low-income young people.

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Conflict of interest

The authors declare that there is no conflict of interest.

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