ORIGINAL ARTICLE

Validity and reliability of MATS integrated with sensors and IoT to measure locomotor skills of 3-6 year old children

Anton Komaini . *Padang State University. Indonesia.*
Qorry Armen Gemael. *Singaperbangsa University Karawang. Indonesia.*
Eka Sahputra. *Muhammadiyah University of Bengkulu. Indonesia.*
Krismadinata. *Padang State University. Indonesia.*
Asrul Huda. *Padang State University. Indonesia.*
Heru Andika. *Padang State University. Indonesia.*

ABSTRACT

Considering that traditional musical instruments are subjective and ineffective in developing the locomotor skills of children aged 3-6 years. The main objective of this study is to develop a Motor Assessment Test Station (MATS) that uses sensors and the Internet of Things (IoT) to measure children's locomotor movements automatically and in real-time. Using the Borg & Gall model, the research and development (R&D) approach includes needs analysis, design, expert validation, limited trials, and field tests. Three experts were involved (motor, Media/IT, measurement) and thirty early childhood participants. MATS is an appropriate and reliable measurement tool, based on the results of the study, which also revealed that the instrument has excellent reliability (r = 0.95 – 0.96) and high validity (V = .886). A unique feature of MATS is its ability to integrate sensors and IoT, which allows it to efficiently and objectively process, process, and display children's movement data. By offering a digital assessment model that follows technological developments, this research empowerment makes a substantial contribution to the field of early childhood education. Socially, this technique can help researchers, parents, and educators identify children's motor development reliably and sustainably. The development of comparable systems for manipulative and non-locomotor skills, as well as validation testing with larger and more diverse samples, are the primary goals of this research recommendation. The development of technology-based evaluation tools that enhance the integration of science, technology, and early childhood education toward data-driven and sustainable physical education is a key contribution of this research.

Keywords: Physical education, Measuring instruments, Locomotor, Early childhood, Sensors, IoT.

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Corresponding author. *Padang State University. Indonesia.*
E-mail: antonkomaini@fik.unp.ac.id
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INTRODUCTION

Motor skills are the basic foundation of a child's life (Brons et al. 2021). Locomotor movements are an essential element in early childhood development (Sutapa et al. 2021; Szeszulski et al. 2022). In early childhood, children begin to demonstrate various forms of movement, such as walking, running, jumping, hopping, and crawling (Biino, Pesce, and Martins 2025; Grillner et al. 2021; O'Hagan et al. 2022). These movements not only help improve physical skills but also encourage balance, coordination, and confidence in interacting with their environment (Logan et al. 2018; Madu et al. 2025). Mastering locomotor skills is one solution for developing more complex motor skills at a later stage, such as sports and physical activities (Chen et al. 2023). However, a lack of attention to early detection has a negative impact on children throughout their lives. Detecting children's motor skills as early as possible is essential to support achievement in sports, physical activity, and daily activities (Roscoe et al. 2024). Therefore, in physical education and health during early childhood, the ability to accurately observe and monitor the development of locomotor movements in children is crucial.

Several previous studies have attempted to develop measurement tools to evaluate children's motor skills, both in educational contexts and in child development research. In various countries, many tools have been widely used, such as the Test of Gross Motor Development (TGMD) to measure gross motor skills in children aged 3–10 years (Ezzelle and Moutoux 1993; Valentini 2012), the Movement Assessment Battery for Children (MABC) (Staples, MacDonald, and Zimmer 2012), and the Pre-School Motor Assessment. These tools evaluate children's basic motor skills through direct observation of motor performance. Although proven effective, most measurements still rely on manual observations made by the examiner, which introduces the possibility of subjectivity in the assessment. In addition, the results of the measurements are often time-consuming to analyse, making them less effective when applied to large populations of children or in long-term studies.

Although various traditional measurement tools are widely used, most still have limitations in terms of objectivity, efficiency, and the ability to display data in real time. Measurement processes that rely on human observation have a high potential for error, as assessors can have differing perceptions (Viswanathan et al. 2017). Furthermore, the lack of technological integration makes it impossible to directly process or analyse data collected in digital format. This presents a barrier when accurate, comparable, and rapid results are required over time. In an increasingly digital world, to ensure that child development assessment processes are sustainable and measurable, the need for more modern and automated measurement systems is increasingly urgent. Therefore, the manual calculation system needs to be updated with technology-based calculations in order to achieve better and more efficient calculations (Frevel, Beiderbeck, and Schmidt 2022). Advances in digital technology bring changes in the scope of education and sports; technological innovation has a significant impact on life (Timotheou et al. 2022). Such is the use of sensor technology in obtaining hand-eye coordination test data that produces precise and accurate calculations (Irawan et al. 2024).

Developing a technology-based measurement system in response to these limitations is a strategic step. One proposed solution is the Model Evaluation Tool System (MATS), which focuses on measuring the locomotor skills of children aged 3-6 years, connected to sensors and the Internet of Things (IoT) (Swain et al. 2023). This system is designed to automatically and objectively identify, record, and analyse children's movements. Sensor integration allows for highly accurate recording of each child's locomotor activity (Fischer et al. 2021), while Internet of Things (IoT) technology facilitates the direct transmission and monitoring of data via electronic devices (Swain et al. 2023). This methodology not only optimizes measurement efficiency but also reduces the possibility of observer bias. Measurements involving technological assistance are

becoming easier, and it can be said that technology plays an important role in supporting the improvement of the quality and efficiency of measuring instruments. Utilizing technology in sports is an important part of innovation (Alnedral et al. 2023; Handayani et al. 2023) to reduce calculation errors in measurements (Komaini et al. 2022). Therefore, MATS is expected to become a new innovation for evaluating children's motor skills with greater relevance in the digital era.

The purpose of this study is to develop a measurement tool for the locomotor skills of children aged 3-6 years. This measurement tool is specifically designed for early childhood with varying levels of ability and background. This tool not only evaluates locomotor skills but also integrates locomotor activities into children's daily activities. It is hoped that with this method, empirical evidence can be obtained regarding the precision and consistency of the system in objectively measuring children's motor skills. In addition, this study also aims to introduce a new measurement model that can help teachers, researchers, and physical education professionals in monitoring children's motor development on an ongoing basis. It is hoped that the findings of this study can provide an important contribution to the development of more standardized and modern assessment tools that are appropriate to the needs of today's technology-based learning.

MATERIALS AND METHODS

Research design and participant

This research is a research and development (R&D) process, this development process adopts the Brog and Gall model which has several stages, such as needs analysis, design and development, testing and revision of the instrument. Participants involved in this study were children aged 3-6 years. A total of 15 children were involved in the needs analysis stage, 9 children in the initial testing stage, and 30 children in the final testing stage of the tool testing stage. And This study involved 3 experts, such as 1 motor expert, 1 media/IT expert and 1 measurement expert.

Procedures

The needs analysis phase began with a comprehensive literature review covering all aspects of research on children's motor skill development, developmental movement theory, and locomotor standards. Additionally, a survey was conducted with early childhood education teachers and students to determine the extent to which existing research methods align with the goals of fundamental motor education. The results showed that most teachers lacked standards for assessing children's motor skills, and 90% of respondents agreed that assessments should be conducted using technology-based systems. More specifically, 51% of respondents stated that these methods did not fully evaluate children's learning experiences. Variations in assessments across educators also highlighted the need for objective and reliable assessment tools.

Motor Assessment Test Stations (MATS), integrated with sensors and the Internet of Things (IoT), were developed during the design and development phase. This tool is designed to improve three key locomotor aspects: running, jumping, gliding, and long jump. The initial design was visualized using a digital presentation application that displayed the tool layout, implementation process, and scoring system. The initial draft was validated by child development and technology experts to ensure validity, practicality, and feasibility.

An initial trial was then conducted with 15 children aged 3 to 6 years to evaluate the tool's reliability and ability to differentiate ability levels. A further 15 children were used for further trials to ensure consistency of results and identify technical improvements. After the refinement phase, an operational trial was conducted with 60

children. The collected data was analysed using descriptive and inferential methods to evaluate implementation time, score distribution, and the stability of the IoT-based system.

This revision phase of the tool focused on improving usability and accuracy. Adjustments were made to the sensor sensitivity for recording children's movements, as well as to the detection threshold, to better reflect the characteristics of childhood. The track layout was expanded to better reflect real-world conditions, while movement accuracy, rather than just speed, became the focus of the implementation instructions. The scoring system was also improved by balancing movement time and accuracy, resulting in a fair and comprehensive evaluation.

Analysis

The sensor- and IoT-enabled Motor Assessment Test System (MATS), developed and implemented in the 2019 ACM, has undergone a refinement phase based on quantitative data analysis, participant feedback, and expert recommendations. The system focuses on reliability and validity to evaluate the effectiveness of the measurement tool, providing an accurate picture of the appropriateness of MATS for measuring motor skills in children aged 3 to 6 years. To verify validity, a product-moment correlation test was used, which aims to observe the consistency of each measurement element with the locomotor skill construct being evaluated. Furthermore, internal reliability was evaluated using the r-correlation method, which is used to assess the stability of MATS measurement results when repeatedly applied to different groups of children. All statistical analyses were performed using SPSS V24 software.

RESULTS

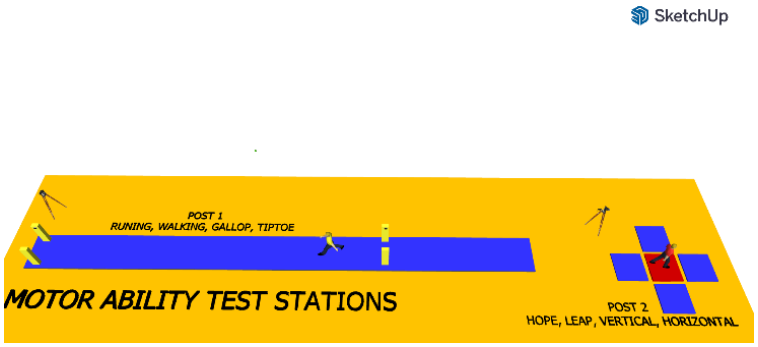

Figure 1. Locomotor skills test series.

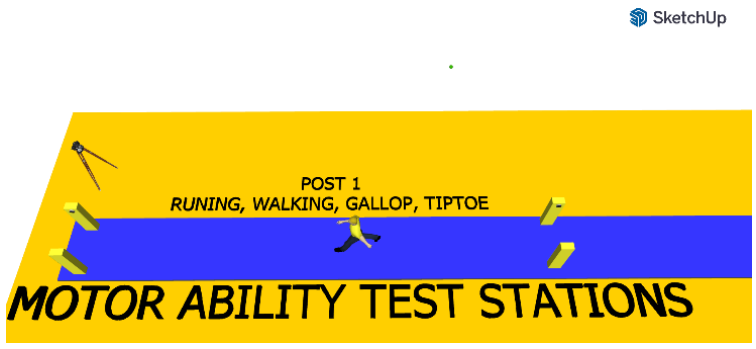

Figure 2. Locomotor test (running, walking, gallop, tiptoe).

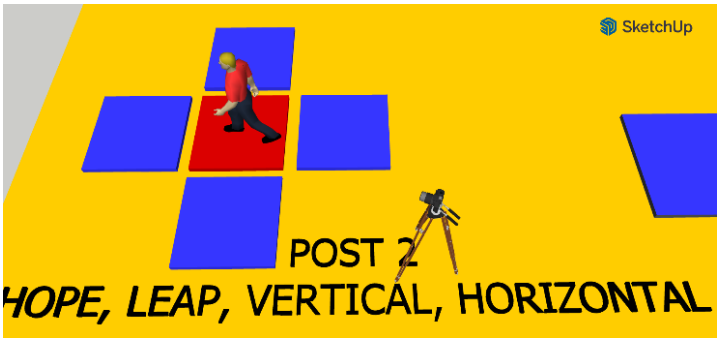

Figure 3. Locomotor test (hope, leap, vertical, horizontal).

The research results show that the Motor Ability Test Stations design, consisting of two test stations, successfully provides a comprehensive overview of children's basic motor abilities. At Station 1, activities such as running, walking, galloping, and tiptoeing focus on locomotor skills, assessing coordination, balance, and the ability to transition from fast to slow motion. Meanwhile, Station 2, which includes hop, leap, vertical, and horizontal jump activities, functions to measure leg muscle strength, explosive power, and body control when changing direction.

Validity

Research and development of sensor- and technology-based motor skill measurement tools have gone through seven stages according to the Borg & Gall model. The results of the study indicate that the developed product has gone through a validation process, limited trials, and field trials and is declared feasible, practical, and reliable for use in measuring locomotor skills. Product validity is based on three experts, namely motor experts, media/IT experts, and measurement experts. Expert assessment of sensor- and IoT-based locomotor skill instruments obtained (V = .886) or in the high category. For suitability in the aspects of Suitability (V = .950), Accuracy (V = .875), Ease (V = .896), and Practicality (V = .833), which can be seen in Table 1. Internal validity was used with a sample of 30 children aged 3-6 years.

Table 1. Validity index.

Aspect	**Raters**				**∑**	**n(c-1)**	**V Index**	**M ± SD**
	Items	S1	S2	S3				
Suitability	1	4	4	3	11	12	.917	.950 ± 0.075
	2	4	4	4	12	12	1.000	
	3	4	4	4	12	12	1.000	
	4	4	4	4	12	12	1.000	
	5	3	4	3	10	12	.833	
Accuracy	1	4	3	4	11	12	.917	.875 ± 0.046
	2	4	3	3	10	12	.833	
	3	4	3	3	10	12	.833	
	4	4	3	3	10	12	.833	
	5	3	4	4	11	12	.917	
	6	4	3	4	11	12	.917	
Ease	1	4	4	3	11	12	.917	.896 ± 0.42
	2	4	3	4	11	12	.917	
	3	4	3	3	10	12	.833	
	4	4	4	3	11	12	.917	

Practicality	1	4	4	4	12	12	1.000	.833 ± 0.102
	2	2	3	4	9	12	.750	
	3	3	3	4	10	12	.833	
	4	4	3	3	10	12	.833	
	5	2	3	4	9	12	.750	
All aspect		73	69	71	213	12		.886 ± 0.078

Note. "V" is the rater agreement index, and "S" is the score given to each rater minus the lowest score in the category.

From the calculation results of three experts, a value of .886 was obtained or a high level of validity, meaning that the sensor-based and IoT locomotor skill measurement instrument can be continued to the next stage, namely field trials. For reliability, it is carried out after the tool is valid and continued with field tests on samples involving 30 children with an age range of 3-6 years.

Table 2. Reliability results with test and retest method.

Day	n	Correlation coefficient	Reliability
First day	30	.96	Very high
Second day	30	.95	Very high

Based on the results of the correlation coefficient test of the reliability test, the sensor-based and IoT locomotor skill measurement instrument is said to be reliable and consistent in collecting research data. This study obtained positive results in the development of motor skill instruments, such as making it easier for researchers to collect data, minimizing bias in researcher observations.

DISCUSSION

Numerous studies have proven that sensors and IoT have the potential to be highly effective in assisting in research measurement. Based on validity and reliability tests, the next step was a small-group trial. This study found effective and efficient results in measuring children's locomotor skills. The results indicate that sensor- and IoT-based MATS has the potential to be highly effective in measuring children's locomotor skills.

Based on the results of the research conducted, it was found that the sensor- and IoT-based children's locomotor skills measurement tool obtained a high level of validity with a "*good*" categorization. The results of this validation measurement were obtained from three experts: motor experts, media/IT experts, and measurement experts. The resulting tool is feasible and valid, so it can be applied to children according to age. Absolute assessment in developing an instrument/measuring tool must have a level of validity and reliability. Validity is the accuracy of what is to be measured on the instrument (Rifki et al. 2022; Susiono et al. 2024), while reliability indicates how well the items correlate and are consistent in producing scores (Belita et al. 2022). Validity and Reliability in the instrument are parts that must be fulfilled in the measurement that ensures the accuracy and usefulness of feedback to participants in knowing the training they are doing (Amirzadeh, Rasouli, and Dargahi 2024).

The main results in this study conveyed in the small group and large group testing high alpha coefficients, so that the Sensor and IoT-based locomotor skill measurement tool is consistent and reliable in measurement. The researcher's validity measurement involved three experts in their fields such as 1 motor expert, 1 media/IT expert and 1 measurement expert, in order to obtain optimal content (García-Ceberino et al. 2020), from three experts said that the resulting product had a very good category (Phillips et al. 2021). The results of the study found positive things in conducting research and encouraging the application of technology in

sports, which means that the use of technology can minimize bias in manual observation, seen in the study (Almohanna et al. 2022) that reliable and valid instruments are very important for measuring accurately, measurement accuracy has a positive impact on research (Abdelrasoul et al. 2015), such as collecting SMAS ability data using sensors that produce accurate research data (Rifki et al. 2022), and collecting hand-eye coordination data based on sensors can make it easier for researchers to calculate and data can be seen directly by research samples (Irawan et al. 2024), as stated in previous research that technological advances provide convenience and accuracy in data collection and become more complex, easy to manage and easier to understand (Dellaserra, Gao, and Ransdell 2014; Measurement, Control, and Tracking Technologies Used in Soccer Players' Training: A Review 2023; Sandbakk 2020).

The results of the study that combined technology and sports successfully created a modern measuring instrument that was able to reduce bias in observation, the results of this study when compared to manual or conventional calculation methods, were able to provide new solutions and breakthroughs in collecting data and developments that researchers had carefully collected. This is a unique design for measuring locomotor capabilities based on sensor technology and IoT which is used to advance measurement and enable real-time data collection. This measurement was successfully provided in order to enable measurable evaluation combined with analytical data to provide direct evaluation and feedback to children.

The advanced technology design of this locomotor measuring instrument creates a more creative method, offering much greater efficacy in producing research calculations. The creation of a locomotor skill measuring instrument that can specifically make this research innovative, effective and evidential in measurement. It is clear that technological advances in the field of sensors and IoT have a positive impact on researchers, teachers and other stakeholders, with the implementation of this research we hope that it can be a guideline, reference, and can realize the instruments/ measuring instruments that we design according to the age that researchers recommend. Although this study found positive things in the study, we have limitations such as the sample that researchers use is not yet extensive and the categorization of children's ages is limited, we provide recommendations for future research such as focusing more on object control skills, age categorization and involving sensor technology and IoT.

CONCLUSIONS

The research that has been conducted shows that the use of sensor technology and IoT has succeeded in creating an effective and efficient measurement tool for locomotor skills in producing data on locomotor skills in children aged 3-6 years. The resulting measurement tool has been validated by three experts and continued with field tests on children, which obtained high reliability. With the creation of this tool, it is expected to be able to help teachers, researchers and stakeholders in evaluating the locomotor skills of children aged 3-6 years, with a younger and more accurate measurement process.

To expand the scope of research and increase validity, it is recommended that future research be conducted on a wider and more varied sample. The creation of a sensor and IoT-based locomotor skills assessment tool is a substantial advance in the fields of education and research, which offers instruments that can be trusted and useful for assessing children's locomotor abilities more effectively and efficiently. In addition to being used for locomotor skills, sensor technology and IoT serve as a basis for future advances in motor learning, including other motor skills that require real-time assessment and measurement.

AUTHOR CONTRIBUTIONS

Anton Komaini and Qorry Armen Gemael designed and reviewed the investigation, analysed and interpreted the data, and drafted the manuscript; Eka Sahputra and Krismadinata, methodology and validation; Asrul Huda and Heru Andika collected and interpreted the data. All authors participated in the review and approval of the final manuscript, as well as in ensuring the integrity and accuracy of the content presented.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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