Development and Validation of a Sensor-Based Standing Board Jump System for Measuring Lower-Limb Explosive Power

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Abstract. This study aimed to develop and validate a sensor-based standing board jump instrument designed to measure lower-limb explosive power with improved accuracy and digital integration. The research employed a Research and Development (R&D) approach based on the Borg and Gall model, consisting of nine systematic stages: (1) needs analysis and information gathering, (2) planning, (3) prototype development, (4) preliminary field testing, (5) product revision, (6) main field testing, (7) operational revision, (8) operational field testing, and (9) final product refinement. The study population comprised students from the Faculty of Sport Science, Universitas Negeri Medan. A purposive sampling technique was applied, involving two testing phases: Phase I included 20 students, while Phase II involved 30 students specializing in soccer. The evaluation criteria focused on feasibility, usability, and measurement effectiveness of the developed instrument. The results indicated that the prototype demonstrated high feasibility and reliability, achieving a 96% validity score in Phase I and 91% in Phase II, both categorized as very feasible. These findings suggest that the sensor-based standing board jump tool provides a valid and efficient method for assessing explosive leg power, with enhanced precision compared to conventional manual measurement techniques. From a sport science perspective, the integration of sensor technology and digital data acquisition systems enables real-time performance monitoring and minimizes human error, aligning with current trends in technology-driven athletic assessment and training optimization [1], [2]. The developed instrument also supports objective data recording, which is essential for performance analysis, coaching evaluation, and athlete development programs. In conclusion, the sensor-based standing board jump device is scientifically valid, practically applicable, and suitable for broader implementation in sport performance testing environments. Future studies are recommended to examine its comparative accuracy against gold-standard biomechanical instruments and expand its application across different athletic populations.

Keywords: Sensor-based system; standing board jump; lower-limb explosive power; sport technology; performance measurement; digital assessment; wearable sensors.

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1 Introduction

Recent advancements in sport technology and digital innovation have significantly influenced the development of modern training, testing, and performance evaluation systems. The integration of sensor-based technologies into sport science is increasingly essential to enhance the accuracy, efficiency, and objectivity of measurement procedures, particularly in athlete performance assessment [1]–[3]. In this context, the development of digital tools for evaluating physical performance represents a critical step toward evidence-based coaching and data-driven training strategies.

One key component of athletic performance is lower-limb explosive power, which plays a fundamental role in various sport activities such as sprinting, jumping, and rapid directional changes. Explosive power is commonly assessed using tests such as the standing broad jump and vertical jump, which provide indirect indicators of neuromuscular performance [4], [5]. However, conventional measurement methods—typically relying on manual tools such as measuring tapes—are prone to human error, limited precision, and low reproducibility, thereby reducing their effectiveness for high-performance monitoring [6]–[8].

Field observations conducted during physical testing sessions at the Universitas Negeri Medan stadium, particularly in preparation for regional athletic events, revealed that standing broad jump assessments are still predominantly conducted using manual measurement techniques . These approaches involve measuring jump distance from the take-off point to the nearest landing mark, which may introduce inconsistencies due to subjective interpretation and measurement inaccuracies. Such limitations highlight the urgent need for innovative and technology-driven solutions to improve the reliability and validity of performance testing instruments.

Previous studies have explored the application of sensor-based and digital measurement systems to enhance sport performance evaluation. For instance, wearable sensors and embedded measurement devices have demonstrated the capability to provide real-time data acquisition and higher measurement precision, thereby supporting more effective training interventions and athlete monitoring [2], [9]. Despite these advancements, the availability of affordable, practical, and field-applicable tools for measuring standing jump performance remains limited, particularly in developing sport environments.

To further substantiate this need, a preliminary needs analysis was conducted involving athletes who regularly perform jump-based performance tests. The findings indicated that all participants (100%) had experience using conventional standing board jump measurements and expressed a strong preference for technology-assisted testing systems . This result underscores the demand for modernized testing instruments that can provide accurate, efficient, and user-friendly measurement solutions.

Based on these considerations, this study aims to develop a sensor-based standing board jump system designed to improve the precision and reliability of lower-limb explosive power assessment. The proposed system integrates multiple sensors to capture jump performance data digitally, thereby minimizing measurement error and enabling more objective evaluation. This innovation aligns with current trends in sport science, digital transformation, and performance analytics, contributing to the advancement of technology-supported athletic assessment tools.

2 Method

2.1 Research Design

This study employed a Research and Development (R&D) approach aimed at designing, developing, and validating a sensor-based standing board jump instrument for measuring lower-limb explosive power. The research framework was adapted from the Borg and Gall development model, which is widely used in educational and sport technology research due to its systematic and iterative structure [1].

The development process consisted of sequential stages, including needs analysis, prototype design, preliminary testing, revision, and large-scale validation. This approach ensures that the resulting product is not only theoretically grounded but also empirically validated in real-world sport performance contexts. The selection of the R&D method aligns with the objective of producing a practical, valid, and reliable measurement tool to address limitations in conventional testing systems.

2.2 Participants

The participants in this study were students from the Faculty of Sport Science, Universitas Negeri Medan, who regularly engaged in physical performance testing. A non-probability sampling technique, specifically purposive sampling, was employed to select participants based on their relevance to the research objectives [2].

The study was conducted in two phases of field testing to evaluate the feasibility and functionality of the developed instrument:

- Phase I (small-group trial): 20 students participated to assess initial usability, clarity, and technical performance of the prototype.
- Phase II (large-group trial): 30 students, primarily specializing in soccer, were involved to evaluate the effectiveness, consistency, and broader applicability of the instrument under more realistic conditions.

This staged testing design enabled progressive refinement of the tool while ensuring that the final product meets user needs and performance standards.

2.3 Instruments

Data were collected using a structured questionnaire designed to evaluate the usability, clarity, accuracy, and practicality of the sensor-based standing board jump instrument. The questionnaire employed a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), which is commonly used to quantify user perceptions and system performance in applied research [3].

The instrument consisted of 20 items categorized into two main dimensions:

1. Clarity and Usability of the Instrument
   This dimension assessed the ease of use, clarity of instructions, technological relevance, portability, and efficiency of the developed tool.
2. Material and Measurement Aspects
   This dimension evaluated the conceptual clarity, accuracy of measurement results, appropriateness of the tool design, and overall effectiveness in measuring standing jump performance.

The questionnaire was designed to ensure content validity by aligning each item with the research objectives and key performance indicators of sport measurement tools. Prior to implementation, the instrument was reviewed to ensure clarity, relevance, and consistency with sport science terminology.

Table 1. Triel Sample Instrument Grid

No	Statement	Rating Scale				
		1	2	3	4	5
	Clarity of Material					
1	Clarity of the intended use of the instrument-standing *board jump* sensor-based					
2	Clarity of test result indicators carried out					
3	In accordance with the development of technology and its use					
4	Makes it easier to measure the distance of the jump					
5	Test and measurement instruments *standing board jump* sensor-based developed easy to use and carry					
6	Test and measurement instruments *standing board jump* economically developed sensor-based					
7	More accurate, efficient, and easy to carry					
8	Data can be processed easily					
9	Instructions for use of the tool are clear					
10	Easy to operate by yourself					
	Material Aspect					
11	Easy to understand material					
12	The truth of the content of the material presented					
13	Clarity of material description					
14	Suitability of material character with tools					
15	Suitability of examples to material					
16	The material presents the concept of test and measurement instruments. *standing board jump* sensor-based					
17	Extensive material to achieve the goal of measuring long jumps					
18	Accuracy of measurement results					

19	Can be used alone or with the help of an assistant
20	The use of words in the tool is easy to understand

2.4 Data Analysis Techniques

The data obtained from the questionnaire were analyzed using descriptive quantitative analysis, expressed in the form of percentages. This approach allows for systematic interpretation of participant responses regarding the feasibility and effectiveness of the developed instrument.

The percentage score for each evaluation component was calculated using the following formula:

$$P = X/Xi \times 100\%$$

where:

P = Percentage of evaluation results;
X = Total score obtained from respondents;
Xi = Maximum possible score
100% = Constant value

The resulting percentages were then interpreted using predefined feasibility criteria to determine the level of validity and practicality of the instrument. This method is widely applied in development research to assess product quality and user acceptance [4].

3 Results and Discussion

3.1 Result

Phase I: Small-Group Trial

The initial trial was conducted with 20 students from the Faculty of Sport Science to evaluate the usability, functionality, and preliminary feasibility of the sensor-based standing board jump instrument. The results indicated that the developed system operated effectively, with the integrated sensor successfully detecting and recording jump distance (in centimeters) through an Android-based interface .

Quantitative analysis of the questionnaire responses yielded a total score of 1,938 out of a maximum possible score of 2,000, corresponding to a feasibility percentage of 96%, which falls within the very feasible category. This high score suggests that the prototype demonstrates strong initial acceptance in terms of clarity, usability, and measurement functionality.

However, several technical and operational issues were identified during this phase. These included minor instability of the device due to its lightweight structure, reduced sensor sensitivity under direct sunlight, and delays in data transmission to the Android interface. These findings informed subsequent revisions to improve structural stability, sensor positioning, and system responsiveness.

Table 2. Research Findings.

No	Research Findings
1	Sample frequently shifting the test tool *standing board jump* in the form of a box that is hit by the back leg of the sample
2	Tool in the form of a box *standing board jump* too light so that it is often shifted by the feet of the sample that will jump
3	Sensor attached to the box *standing board jump* not perfect in capturing sample jumps
4	Sunlight affects the capture of jumps through the sensor
5	It is better to make a mat for the jump mat so that the sensor can more easily capture the distance of the jump.
6	Jump meter via sensor connected via android iop takes too long to output jump results

Phase II: Large-Group Trial

Following product refinement, a second trial was conducted involving 30 students specializing in soccer to assess the effectiveness and broader applicability of the instrument under more realistic conditions.

The results showed a total score of 2,743 out of 3,000, equivalent to a 91% feasibility rating, which also falls within the very feasible category . Although slightly lower than the Phase I result, this outcome reflects consistent performance and confirms the tool's practicality for field-based applications.

The slight decrease in the feasibility percentage may be attributed to more varied user interactions and environmental conditions during large-group testing, which typically introduce greater variability in performance evaluation. Nevertheless, the results indicate that the developed system maintains a high level of reliability and user acceptance across different testing scenarios.

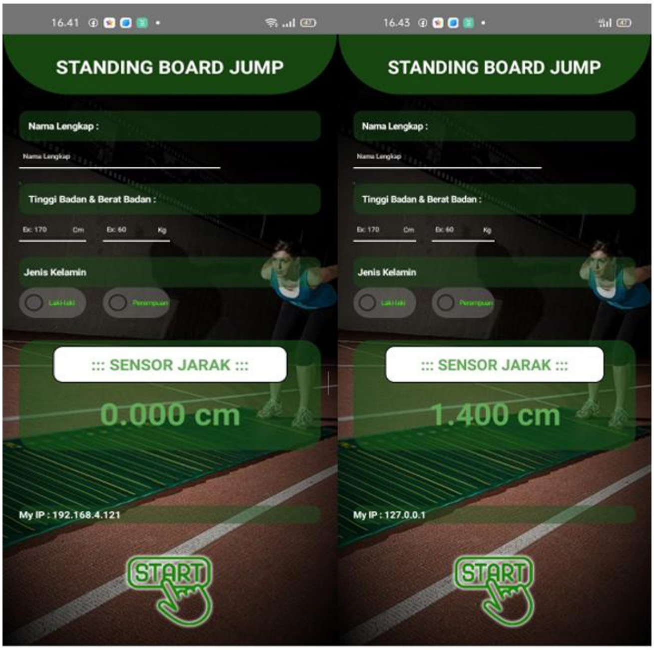

Fig 1. Sensor-Based Jump Board Product

3.2 Discussion

The findings of this study demonstrate that the sensor-based standing board jump instrument provides a viable alternative to conventional manual measurement methods. By integrating digital sensors with an Android-based data acquisition system, the tool enhances the precision, objectivity, and efficiency of lower-limb explosive power assessment. These advantages are consistent with recent developments in sport technology, where sensor-based systems have been shown to significantly improve measurement accuracy and real-time performance monitoring [1], [2].

From a sport science perspective, the accurate measurement of explosive power is critical for evaluating neuromuscular performance and optimizing training interventions. Traditional methods, which rely on manual distance measurement, are often limited by observer bias and measurement inconsistency. In contrast, the developed system minimizes human error and provides standardized and reproducible data, thereby supporting evidence-based coaching practices [3], [4].

The iterative development process, guided by the Borg and Gall model, ensured that the product underwent systematic refinement through expert validation and field testing. Expert evaluation confirmed the content validity and functional suitability of the instrument, indicating that it meets the required standards for use in sport performance testing. This aligns with established principles of instrument development, where validation by domain experts is essential to ensure measurement accuracy and relevance [5].

Despite its strengths, several limitations were identified. The sensor performance was influenced by environmental factors, particularly lighting conditions, indicating the need for improved sensor calibration or shielding. Additionally, the system's response time and physical stability require further optimization to enhance user experience and operational reliability. These limitations are consistent with challenges reported in previous studies on wearable and sensor-based sport technologies, where environmental interference and hardware constraints can affect data accuracy [2], [6].

Overall, the developed instrument demonstrates significant potential for application in sport science, coaching, and physical education contexts. Its portability and digital integration make it suitable for both laboratory and field environments, supporting broader implementation in athlete performance evaluation. Furthermore, the transition from manual to digital measurement systems reflects the ongoing digital transformation in sport performance analysis, emphasizing the importance of technology-driven assessment tools.

Future research should focus on comparative validation against gold-standard measurement systems, such as force plates or motion capture technologies, to further establish the accuracy and reliability of the instrument. In addition, expanding the sample to include athletes from diverse sports and performance levels would enhance the generalizability of the findings.

4 Conclusion

This study successfully developed and validated a sensor-based standing board jump instrument designed to measure lower-limb explosive power with improved accuracy and efficiency. The findings from both small-group and large-group trials demonstrated that the instrument achieved high feasibility ratings (96% and 91%, respectively), indicating that it is valid, practical, and suitable for use in sport performance testing contexts.

The integration of sensor technology with an Android-based data acquisition system enables objective, real-time measurement of jump performance, thereby reducing human error associated with conventional manual methods. From a sport science perspective, this advancement supports more reliable assessment of neuromuscular performance, which is essential for monitoring athlete development and optimizing training programs [1], [2].

Furthermore, the developed instrument offers practical advantages, including ease of use, portability, and efficient data processing, making it applicable for coaches, educators, and sport practitioners in both training and evaluation settings. The transition from traditional measurement techniques to technology-assisted assessment tools reflects current trends in digital transformation within sport science and performance analytics [2], [3].

Despite its promising performance, several technical limitations were identified, particularly related to environmental sensitivity and system responsiveness. Therefore, future research should focus on enhancing sensor robustness, improving system stability, and conducting comparative validation against established gold-standard instruments, such as force plates or motion capture systems.

In conclusion, the sensor-based standing board jump tool represents a reliable and innovative solution for measuring explosive leg power and has strong potential for broader implementation in sport science, coaching, and physical education domains.

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