2024, Retos, 59, 658-665
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Vertical jump measurement results using the VJMeter and standing board: Observation of the VJMeter accuracy level

Resultados de la medición del salto vertical utilizando el VJMeter y la tabla de pie: observación del nivel de precisión del VJMeter

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Abstract. In various sports activities, tools are essential to facilitate the process, including vertical jump measurement, which is frequently performed across different sports. The necessity for practical, user-friendly, and highly accurate tools is paramount for measuring vertical jumps in diverse settings, each with unique constraints. This research aims to ascertain the accuracy level of the VJMeter device developed for vertical jump measurements. Employing a quantitative approach, the study compared vertical jump measurements obtained from a standing board and the VJMeter device. The study involved 10 students from the Physical Education program who participated in basketball. The research variable comprised vertical jump measurement results, categorized into two independent samples: measurements from the standing board and the VJMeter device. Data analysis was conducted using the Mann-Whitney test in SPSS version 25. The results indicated a p-value of 0.987, exceeding 0.05, signifying no significant difference between vertical jump measurements obtained from the standing board and the VJMeter device. Therefore, it can be concluded that the VJMeter device demonstrates a reliable level of accuracy for measuring vertical jumps.
Keywords: measurement accuracy; vjmeter; vertical jump; measurement tool

Resumen. En diversas actividades deportivas, las herramientas son fundamentales para facilitar el proceso, incluida la medición del salto vertical, que se realiza frecuentemente en diferentes deportes. La necesidad de herramientas prácticas, fáciles de usar y de alta precisión es primordial para medir saltos verticales en diversos entornos, cada uno con limitaciones únicas. Esta investigación tiene como objetivo conocer el nivel de precisión del dispositivo VJMeter desarrollado para mediciones de salto vertical. Empleando un enfoque cuantitativo, el estudio comparó las mediciones de salto vertical obtenidas desde una tabla de pie y el dispositivo VJMeter. En el estudio participaron 10 estudiantes del programa de Educación Física que participaron en la práctica de baloncesto. La variable de investigación comprendió los resultados de las mediciones del salto vertical, categorizados en dos muestras independientes: mediciones desde la tabla de pie y el dispositivo VJMeter. El análisis de los datos se realizó mediante la prueba de Mann-Whitney en SPSS versión 25. Los resultados indicaron un valor de p de 0,987, superior a 0,05, lo que significa que no hay diferencias significativas entre las mediciones del salto vertical obtenidas con la tabla de pie y el dispositivo VJMeter. Por lo tanto, se puede concluir que el dispositivo VJMeter demuestra un nivel confiable de precisión para medir saltos verticales.
Palabras clave: precisión de la medición; vjmeter; salto vertical; herramienta de medición

Fecha recepción: 23-06-24. Fecha de aceptación: 29-07-24
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Introduction

Jumping techniques constitute a crucial aspect of athlete performance across various sports, as highlighted by numerous studies (Delang, Hannon, Goto, Bothwell, & Garrison, 2021; Majid & Fauzi, 2021; Mancilla et al., 2023; Miller, Fry, Ciccone, & Poggio, 2022). Consequently, athletes often undergo specialized training programs aimed at improving their jumping abilities. To assess the efficacy of such training interventions, it is imperative to measure jumping performance, commonly achieved through vertical jump assessments, which serve as indicators of muscular strength and capacity (Fernández-Galván, Casado, & Domínguez, 2024; Hurr, 2021; Marković et al., 2021; Wilson et al., 2022). As a result, coaches frequently rely on vertical jump measurements to evaluate and enhance an athlete's jumping proficiency (Alawna & Mohamed, 2020; Giustino et al., 2022; Pagaduan & Pojskic, 2020; Soyal, Aksoy, Şengöl, & Kiliç, 2023).

Currently, Coaches have used various existing vertical jump measuring tools. Coaches are greatly helped by the use of vertical jump measuring tools that utilize electronic systems, sensors and intelligence systems. Coaches are always looking for new tools that have additional features that make the process of measuring vertical jumps easier. An illustrative example is the vertical jump measuring instrument employing a standing board, a conventional tool tailored for assessing vertical jumps. This instrument is frequently utilized due to its minimal error rate, as the underlying concept can be readily discerned visually (Harato, Morishige, Kobayashi, Niki, & Nagura, 2022; Köse, Akşit, Açıkgöz, & Ceyhan, 2023; Kozinc & Pleša, 2023; Mahar et al., 2022; Tan et al., 2022). However, a notable challenge arises from the complexity of determining the decimal value of measurement results. Specifically, when measurement point outcomes fall between two nominal measurement numbers, the recorded measurements are consistently rounded up. The process of measuring using a standing board entails two sequential steps: measuring the height of the arm's reach before jumping and repeating the measurement during the jump. Subsequently, the difference between the measurement results obtained during the jump and those acquired before the jump is calculated (Amanulla, Wakif, Boulahia, Fazuruddin, & Noor Mohammed, 2019; Gür, Soyal, & Doğan, 2022; Özaltaş & Serin, 2022; Zorba, 2021). Undoubtedly, this comprehensive procedure inevitably extends the time required for recording the measurement results. In addition to conventional measuring tools,

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a vertical jump assessment tool known as Smart Vertical Jump has been developed, featuring an electronic system capable of facilitating single-instance measurements. Smart Vertical Jump distinguishes itself by providing measurement outcomes in decimal values, enhancing precision and granularity in assessment (Oh, Choi, Shim, Park, & Lee, 2020). However, despite its technological advancements, Smart Vertical Jump exhibits limitations that impede its practicality. Notably, the tool relies on large-sized devices such as poles and various supplementary instruments to facilitate measurements. This reliance on additional equipment may hinder the tool's portability and ease of use, particularly in field settings where mobility is crucial. Moreover, the operational requirement of electric power further complicates its utility, necessitating the extension of lengthy cables to power the device during measurements conducted in expansive field environments. These constraints may restrict the applicability and convenience of Smart Vertical Jump in certain contexts, thus warranting consideration when selecting measurement tools for specific applications.

Previous research and development confirm that VJMP stands as the latest tool designed for evaluating vertical jump. Recognized for its practicality in vertical jump measurement tasks, VJMP is esteemed for its compact size, handheld operability, battery-powered functionality, capability for single measurements, and provision of decimal measurement outcomes (Fathoni, Mu'arifin, Hwa, & Mokmin, 2023). However, despite its merits, VJMP is not without its limitations. Notably, a significant drawback lies in its manual process for recording and summarizing measurement results. This entails either noting the data on paper or manually inputting it into a computer system. Consequently, this manual process prolongs the duration required to compile measurement results reports, thereby diminishing overall efficiency.

To overcome the various limitations identified, a vertical jump measuring tool called VJMeter was developed with the aim of overcoming and correcting these shortcomings. It adopts the strengths and advantages of current vertical jump measuring tools while improving certain shortcomings inherent in existing instruments. The VJMeter has a compact design, allowing for easy handheld operation, and is powered by three AA batteries, ensuring portability and ease of use in a variety of settings. In addition, VJMeter uses digital and electronic systems, thereby increasing accuracy and precision in measurement results. Unlike its predecessor, this tool only requires one measurement, thereby smoothing the measurement process and reducing time consumption. Although similar to features found in VJMP, VJMeter provides similar functionality to meet the demands of vertical jump measurement tasks. However, the advantage that differentiates VJMeter lies in its ability to capture measurement results directly via a smartphone application. This innovative feature allows for smooth and efficient recording of athlete measurements, eliminating the need for manual data entry. By automatically generating Microsoft Excel files, VJMeter simplifies data management and analysis, increasing the efficiency and effectiveness of the overall vertical jump measurement process.

Development of the VJMeter is ongoing, and the device must undergo comprehensive testing to ensure its ability to accurately measure vertical jump. The research and development of the VJMeter device involved a series of extensive processes over a fairly long period of time, including accuracy testing, validation testing, reliability testing, and usage testing to determine the practicality of the VJMeter. Each of these tests requires a different group of research participants. Due to time and cost limitations, this research was carried out in stages, with the current stage focusing on testing the accuracy of VJMeter measurements. Before assessing the potential benefits of using a VJMeter, it is important to conduct rigorous accuracy testing to determine its measurement capabilities. Ensuring the accuracy of measuring instruments is critical to their performance. After ensuring the accuracy of the instrument, it can then proceed to further stages, including validation testing, reliability testing and usage testing.

This research effort was specifically aimed at evaluating the accuracy of the VJMeter in measuring vertical jumps, serving as a basic step in assessing its suitability for practical applications. The main goal of this study was to determine whether the VJMeter could provide accurate vertical jump measurements. The accuracy testing protocol will involve carrying out a comparative analysis to evaluate the accuracy of measurement results obtained using the VJMeter. The findings of this study will contribute to establishing the credibility and usefulness of the VJMeter as a viable tool for assessing vertical jump performance. If VJMeter shows accuracy in measuring vertical jumps, then VJMeter has the potential to be used by coaches and physical fitness test organizers to assess the vertical jump ability of athletes they supervise. Accurate measurement data can inform and form the basis for developing training programs, performance evaluations, and athlete development strategies, thereby increasing the effectiveness of athletic training and performance monitoring practices.

Materials and methods

Procedures

Research and development efforts have yielded the creation of the VJMeter device, designed to measure vertical jumps accurately. Following its successful development, VJMeter requires thorough testing, particularly to assess its precision in measuring vertical jump performance. Evaluating the accuracy of the VJMeter device entails conducting comparative analyses between its measurement results and those obtained using a standing board measuring instrument, a conventional tool commonly employed for vertical jump assessments.

To ascertain the level of accuracy achieved by the VJMeter device, it is imperative to conduct measurements concurrently with both the VJMeter device and the standing

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board measuring instrument. This comparative approach enables a direct assessment of the measurement consistency and reliability between the two tools. Research participants are tasked with performing vertical jumps, with measurements being simultaneously captured using both the VJMeter device and the standing board.

In order to ensure robustness and reliability of the measurement data, each participant is instructed to perform vertical jumps a predetermined number of times, typically around 10 repetitions. This repetition helps to enhance the reliability of the measurement outcomes by providing a sufficient volume of data points for analysis. Subsequently, the measurement results obtained from both the VJMeter device and the standing board are systematically compared to identify any discrepancies or variations.

Differences observed in the measurement results between the VJMeter device and the standing board may indicate potential inaccuracies in the VJMeter's measurement capabilities. Conversely, consistent measurement outcomes across both devices suggest that the VJMeter device possesses the requisite accuracy for effectively measuring vertical jump performance. A thorough understanding of the measurement process and comparative analyses is provided in Figure 1, offering insights into the methodology employed for assessing the accuracy of the VJMeter device.

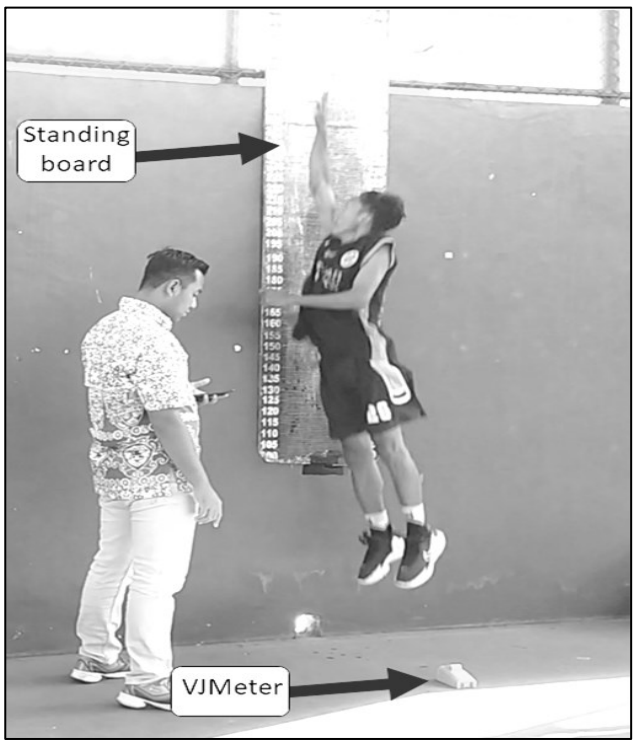

Figure 1. Vertical jump measurement using a Standing board and VJMeter

Participants

The research enlisted 10 participants enrolled in the Physical Education program, specifically chosen from students engaged in basketball activities, given their familiarity and proficiency in executing vertical jumps, thus minimizing the risk of potential injury. These participants volunteered to partake in the research, having expressed their willingness and provided formal consent to engage in the study procedures. Prior to their involvement, participants were duly informed about the study's objectives, procedures, and potential risks, with comprehensive details outlined in a consent form. This form ensured participants' understanding of the research protocol and affirmed their commitment to upholding ethical standards throughout the study.

Furthermore, the research protocol underwent rigorous ethical review and received approval from the Faculty of Medicine at Brawijaya University, Indonesia. The approval, granted under reference number 125/EC/KEPK-UM/04/2023, attests to the adherence of the study to established ethical guidelines and principles. This ethical oversight underscores the commitment to safeguarding the welfare and rights of the research participants throughout the duration of the study.

Variable

The primary focus of this research entails the examination of vertical jump measurement outcomes, which will be categorized into two distinct independent samples. These independent samples correspond to the vertical jump measurement results obtained through the utilization of a standing board and the VJMeter device, respectively. A comparative analysis will be conducted to assess the congruence or disparity between the measurement outcomes derived from these two measurement tools.

The comparison between the measurement results obtained from the standing board and the VJMeter device serves as a pivotal component of this research endeavor. Through this comparative approach, the research aims to ascertain the extent to which the measurement outcomes align or diverge between the two measurement tools. This comparative analysis will elucidate whether discrepancies exist in the measurement results or if they exhibit concordance across both measurement modalities.

By systematically evaluating measurement results from both the standing board and the VJMeter device, this research seeks to contribute insight into the accuracy of this measurement tool in assessing vertical jump performance. Through careful comparative analysis, this study seeks to elucidate the accuracy of the VJMeter device as a tool that can be used to measure vertical jump performance, thereby improving the understanding and practice of vertical jump assessment methodologies.

Instrument

The primary instruments employed for measuring vertical jumps in this study encompass the standing board and the VJMeter device. Standing boards represent a prevalent tool utilized for vertical jump assessment owing to their capacity for providing clear and observable measurement levels. Moreover, standing boards are renowned for their minimal propensity for errors when employed in the measurement of vertical jumps. Consequently, measurements conducted through the use of standing boards serve as a robust

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benchmark against which the measurement outcomes yielded by the VJMeter device can be assessed for accuracy.

Standing boards serve as an established reference point within the domain of vertical jump assessment due to their consistent performance and reliability in facilitating accurate measurements. Their widespread utilization underscores their utility as a standard measurement tool for vertical jump assessments across various research and practical settings. Consequently, standing boards are deemed well-suited for comparative analyses aimed at evaluating the accuracy and reliability of alternative measurement devices such as the VJMeter.

In contrast, the VJMeter device represents an innovative tool designed to simplify the vertical jump measurement process through digital and electronic functions. Despite the potential advantages and accuracy of the VJMeter device in capturing vertical jump measurements requires rigorous evaluation and comparison against established measurement standards. Therefore, the use of the standing board as a reference tool facilitates the systematic examination and comparison of measurement results obtained via the VJMeter device, thereby contributing to the continuous refinement of the vertical jump assessment methodology.

Statistic analysis

The collected data underwent normality testing utilizing the Kolmogorov-Smirnov test, a statistical procedure employed to assess whether a dataset conforms to a normal distribution. Following the normality assessment, the disparity between the measured variables was examined using the Mann-Whitney test, a non-parametric statistical test suitable for comparing two independent groups when the assumptions of normality and homogeneity of variances are not met. The significance level, or p-value, was set at 0.05, adhering to the conventional threshold for determining statistical significance. These statistical analyses were conducted utilizing SPSS version 25, a widely utilized software package for statistical analysis and data management in research settings.

Results

The evolution of vertical jump measurement techniques has led to the creation of a new device called the VJMeter. Designed with digital capabilities, VJMeter facilitates display of measurement data with precision down to the decimal point, increasing the detail of recorded results. Equipped with a proximity sensor, VJMeter efficiently detects the measured object, ensuring accurate data acquisition. Operated by three AA batteries, the VJMeter operates independently of an external power source, increasing its portability and flexibility. With compact dimensions measuring 15x7x9 cm, the VJMeter embodies practicality, facilitating easy handling during measurement procedures. VJMeter's advantage lies in its ability to capture measurement results directly via a smartphone application. This innovative feature enables smooth and efficient recording of athlete measurements, eliminating the need for manual data entry. By automatically generating Microsoft Excel files, VJMeter simplifies data management and analysis, increasing the efficiency and effectiveness of the overall vertical jump measurement process. A visual representation of the VJMeter device is depicted in Figure 2, providing a visual reference for its design and form factor.

Figure 2. VJMeter Device

This research involved the participation of 10 individuals who performed a series of vertical jumps, with measurements taken simultaneously using a standing board measuring instrument and a VJMeter device. Each participant completed 10 vertical jump repetitions. The purpose of this data collection process is to ensure average measurement results for each participant. The data obtained from measuring the vertical jump distances are presented in Table 1. In Table 1, it is evident that the standard deviation value is significantly different from the mean value. This indicates that data collection has been carried out with participants who exhibit a variety of vertical jump results. This diversity is crucial as it demonstrates the VJMeter's flexibility and suitability for users with varying vertical jump characteristics.

Table 1.
Descriptive statistics

		Standing board	VJMeter
N	Valid	10	10
	Missing	0	0
Mean		439.8000	439.7500
Std. Error of Mean		41.80399	41.89209
Median		385.0000	384.7750
Std. Deviation		132.19581	132.47443
Variance		17475.733	17549.474
Range		378.00	378.05
Minimum		306.00	305.70
Maximum		684.00	683.75
Sum		4398.00	4397.50

Subsequently, a comparative analysis of the data obtained from vertical jump measurements using both tools was conducted to determine any disparities in measurement outcomes. However, prior to conducting the comparative analysis, it was imperative to subject the data to a normality test. The process of normality testing is outlined and

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documented in Tables 2, 3, and 4. The results of the normality test, which utilized the Kolmogorov-Smirnov test for assessing the vertical jump measurement data, revealed a p-value of 0.000. This p-value, being less than the conventional significance threshold of 0.05, indicates that the tested data deviates from a normal distribution pattern. Detailed outcomes of the normality testing procedure are presented in Table 4 for reference and analysis.

Table 2.
Case Processing Summary

	Group	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
Vertical Jump measurement results	Standing board	100	100.0%	0	0.0%	100	100.0%
	VJMeter	100	100.0%	0	0.0%	100	100.0%

Table 3.
Data description

	Group		Statistic	Std. Error
Vertical Jump measurement results	Standing board	Mean	43.9800	1.27255
		95% Confidence Interval for Mean Lower Bound	41.4550	
		95% Confidence Interval for Mean Upper Bound	46.5050	
		5% Trimmed Mean	43.3333	
		Median	38.0000	
		Variance	161.939	
		Std. Deviation	12.72553	
		Minimum	28.00	
		Maximum	72.00	
		Range	44.00	
		Interquartile Range	21.00	
		Skewness	0.673	0.241
		Kurtosis	-0.886	0.478
	VJMeter	Mean	43.9750	1.27461
		95% Confidence Interval for Mean Lower Bound	41.4459	
		95% Confidence Interval for Mean Upper Bound	46.5041	
		5% Trimmed Mean	43.3417	
		Median	38.4750	
		Variance	162.464	
		Std. Deviation	12.74614	
		Minimum	27.85	
		Maximum	71.75	
		Range	43.90	
		Interquartile Range	21.48	
		Skewness	0.667	0.241
		Kurtosis	-0.901	0.478

Table 4.
Normality test

	Group	Kolmogorov-Smirnov		
		Statistic	df	Sig.
Vertical Jump measurement results	Standing board	0.213	100	0.000
	VJMeter	0.207	100	0.000

Given that the data has been determined to be non-normally distributed, there is no requirement to assess its homogeneity. Therefore, the research data can proceed directly to the Mann-Whitney test for further analysis. The Mann-Whitney test procedure is succinctly outlined in Tables 5 and 6, encapsulating the key steps and outcomes. The results of the Mann-Whitney test indicate a p-value of 0.987. With the p-value surpassing the conventional significance threshold of 0.05, it is inferred that there exists no significant disparity in the outcomes of vertical jump measurements obtained using the standing board and the VJMeter device. A comprehensive overview of the findings derived from the difference tests is presented in Table 6 for comprehensive reference and scrutiny.

Table 5.
Rank

	Group	N	Mean Rank	Sum of Ranks
Vertical Jump measurement results	Standing board	100	100.44	10043.50
	VJMeter	100	100.57	10056.50
	Total	200		

Table 6.
The difference test uses Mann-Whitney

	Vertical Jump measurement results
Mann-Whitney U	4993.500
Wilcoxon W	10043.500
Z	-0.016
Asymp. Sig. (2-tailed)	0.987

Discussion

The comparative analysis of vertical jump measurements conducted using a standing board and the VJMeter device revealed no statistically significant differences. This implies that when measuring the vertical jump of an individual using both tools, the outcomes were consistent. However, a closer examination of the raw data reveals distinctions between the measurement results obtained from the standing board and the VJMeter. Specifically, the standing board yielded measurements in whole numbers, while the VJMeter provided measurements in decimal numbers. Despite these numerical variations, the overall outcomes between the two measurement methods did not exhibit a significant discrepancy.

Conventional measuring tools like standing boards present a drawback in determining measurement results when the measurement point falls between two discrete values. In such cases, individuals conducting measurements often resort to rounding off the measurement values, introducing a high degree of subjectivity that compromises measurement reliability. In contrast, VJMeter employs Proximity sensor and digital technologies, enabling precise measurements even at minute distances, thereby discerning measurement results situated between two numerical points. Consequently, the reliability and accuracy of measurement outcomes obtained through VJMeter are significantly enhanced compared to conventional methods.

Research investigating the responses of participants in physical fitness tests, particularly regarding vertical jump measurements, revealed that participants expressed dissatisfaction with the prolonged process of determining measurement results, attributed to the use of conventional tools by the organizers. The challenges in determining these results stem from the need for additional time, as organizers often encounter difficulty when the measurement results fall between two numerical points, necessitating discussions to resolve discrepancies (Yu, Salisbury, & Mathiason, 2021). Consequently, the use of conventional tools like standing boards, while yielding whole number results, poses efficiency issues and contributes to inefficiencies in measurement processes.

Currently, digital technology is widely integrated into

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many measuring instruments (Arosha Senanayake & Naim, 2019). These digital measuring tools find extensive application across diverse domains including healthcare, construction, transportation, and others (Boriani et al., 2022; Kiss, Fitzpatrick, & Piko, 2020; Štefko, Bačík, Fedorko, Oleárová, & Rigelský, 2019; Williams, 2022). Despite their prevalence, tools or devices incorporating digital measuring instruments tend to be more expensive due to the high level of accuracy offered by digital technology, which significantly enhances usability (Castro Benavides, Tamayo Arias, Burgos, & Martens, 2022; Damaianti, Mulyati, & Abidin, 2023; Klebba, Adamczyk, Wąż, & Iwen, 2023; Rani, Hutagalung, & Dermawan, 2021; Štefko et al., 2019).

The incorporation of proximity sensor technology significantly enhances the functionality of VJMeter by augmenting the accuracy of vertical jump measurements through the synergistic integration of proximity and digital sensors. VJMeter's development is geared toward enhancing user experience and optimizing outcomes in vertical jump assessments. Given the critical role of measurement results in gauging athlete performance (Ivanović, Gajević, & Gajić, 2019; Podrigalo et al., 2019). VJMeter strives to deliver precise and reliable data. Furthermore, measurement outcomes play a pivotal role in shaping an athlete's training regimen to enhance competitive achievements (Boyarkina, 2021).

This study is restricted to assessing the accuracy of VJMeter in measuring vertical jumps, representing a limitation of the research endeavor. VJMeter, as a developmental product, seeks to streamline the process of vertical jump measurements for users. Nevertheless, this study does not delve into users' perceptions and experiences when utilizing VJMeter for vertical jump assessments. Consequently, future research avenues could explore user feedback regarding the usability and user experience associated with VJMeter, thereby providing valuable insights into its practical application and effectiveness.

Another weakness of this research is that the comparison tool to see the accuracy of the VJMeter uses a standing board. According to some experts, standing boards are still not suitable for viewing VJMeter accuracy. So that researchers can carry out further research, comparative tests can be carried out with more sophisticated, valid and reliable tools such as force plates or others.

Conclusion

The findings obtained from the VJMeter trial conducted for vertical jump measurements reveal no discernible variance in the measurement outcomes between the utilization of a standing board and VJMeter. Consequently, the research objective of ascertaining the precision of VJMeter in vertical jump assessments has been successfully attained, confirming the accuracy of VJMeter in measuring vertical jumps. These research outcomes serve as a foundational framework for the implementation of VJMeter in vertical jump measurement protocols. Recommendations are extended to coaches and physical fitness measurement organizers, advocating for the incorporation of VJMeter into their practices due to its demonstrated capability in accurately measuring vertical jumps.

Acknowledgements

Our gratitude is extended to the State University of Malang for its financial support of this research.

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