EVALUATION OF TIME MEASUREMENT METHODS – A REVIEW

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Abstract:
Accurate sprint time measurement is essential for assessing athletes' speed capabilities and informing training decisions. This review paper examines the characteristics of various timing methods, including electronic timing systems (such as photocells and digital setups) and manual methods (like stopwatches), with a focus on their validity, reliability, accuracy, and practicality across different sports contexts. The analysis includes ten scientific papers published between 2020 and 2025 that compared measurement methods in both laboratory and field settings. The findings indicate that electronic systems significantly reduce human error, providing greater accuracy and consistency in measurements compared to stopwatches. Nevertheless, manual methods remain valuable in resource-limited environments, particularly when standardised protocols are followed. Additionally, mobile applications emerge as a promising alternative, especially when complemented by software analysis. In conclusion, the choice of measurement method should be guided by the test objectives, the level of expertise, and the available resources. For situations requiring high precision, the use of electronic systems is recommended.

Keywords:
Sprint, Photocells, Stopwatch, Reliability, Validity.

INTRODUCTION

Accurate and reliable measurement of running time is crucial in sports, particularly when assessing, selecting, and enhancing athletes' performance. Time measurement in various disciplines, such as sprints, agility tests, and specific sports evaluations, serves as the foundation for making important decisions for coaches, researchers, and athletes alike. Traditionally, stopwatches have been the primary tool for timing because of their practicality, affordability, and ease of use. However, with advancements in technology, photocells are becoming more common and are favoured for their higher accuracy and reliability [1]. Despite this trend, stopwatches are still frequently used, especially in circumstances where cost, availability, or practicality are significant concerns.

To better understand the importance of timing in sports, it is essential to define several key terms: validity, accuracy, and precision. Validity refers to the degree to which a particular measurement method accurately measures what it claims to measure.

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In the context of sports performance, validity is critical because it directly impacts the interpretation of results and decision-making, which can have significant consequences for athlete training, selection, or readiness assessment [2]. Accuracy indicates how close a measured result is to the actual value of a performance, such as running time. High accuracy is crucial, as even minor deviations can affect the evaluation of athletic abilities and the effectiveness of training programs. Reliability refers to the consistency of repeated measurements taken under identical conditions and indicates the dependability of the measurement instrument or method [3].

Understanding these terms is essential for effectively evaluating sports performance. In practice, stopwatches that require manual activation and stopping often have limitations regarding accuracy and reliability, as their results are significantly influenced by the reaction time of the person operating them [4]. As a result, stopwatches are susceptible to both systematic and random errors, which can lead to significant variations in the measurement of the same event by different individuals or even by the same person at different times. Photocells work by cutting infrared light beams, providing automated start and stop times without requiring human intervention. This dramatically reduces the impact of human error, enhancing the accuracy and precision of measurements [1].

In recent years, numerous studies have compared these two methods to identify apparent differences in their metric characteristics. Understanding these differences is crucial because selecting the appropriate measurement method can significantly impact the quality of the information obtained, which in turn affects the decisions made based on that information. Aside from scientific research, the choice of method also depends on practical factors, such as the cost of the device, its market availability, the technical complexity of operating the device, and the specific conditions under which the measurements are taken [5].

New technologies and systems, including mobile applications, video analysis, and GPS-based systems, have been developed to enhance timing capabilities. [6, 7, 8]. These innovations aim to combine the convenience of stopwatches with the precision and accuracy of photocells. Despite these advancements, photocells are still considered the gold standard in most research studies where high precision and reliable results are essential [9].

This paper offers a comprehensive overview of research findings from the past five years, providing valuable insights into the advantages and disadvantages, as well as the practical implications, of using photocells and stopwatches. By analysing previous studies, we can offer clear recommendations for the application of these tools in various sports contexts. Additionally, this review aims to benefit the research community by consolidating existing knowledge and identifying areas where further research is needed, particularly in the introduction of new technologies.

Given the complexity and significance of this topic, this review aims to provide a thorough, systematic, and detailed overview of the current state of time measurement techniques using photocells and stopwatches. This paper is intended for coaches and researchers who need guidance in selecting the most effective and reliable methods for measuring sports performance. A clear understanding of these methods and their characteristics will enhance the training process, improve athlete selection, and increase the validity of conclusions drawn from test results.

2. METHODS

This review utilised a systematic analysis of relevant scientific literature published in the last five years (2020-2025) to provide a comprehensive and reliable overview of current knowledge. This analysis aimed to identify and compare the metric characteristics of running time measurement using photocells and stopwatches, with a specific focus on the validity, accuracy, and precision of the instruments employed.

The literature search was conducted using the following Google Scholar electronic database. The keywords employed in the search included *stopwatch reliability, photocell accuracy* and *sprint time measurement*.

Only peer-reviewed scientific papers that contained empirical research on sprint timing or similar movements in athletes were considered. Papers focused solely on laboratory testing without applications in a sports context were excluded, as were review papers that did not provide specific data on the metric characteristics of the instruments.

Several papers were selected that met all the inclusion criteria. Each paper was analysed in terms of:

types of measuring instrument (stopwatch, photocell, application),

sizes and characteristics of the respondents (gender, age, sport),

measurement method and start position (reactive or automated),

displayed values for reliability (e.g. ICC, CV%),

statistical validation and level of precision.

Special attention is paid to the differences in validity between methods involving the human factor (stopwatches) and automated systems (photocells, applications), as well as the effects of variability between measurement repetitions. Potential measurement biases, including the meter's *learning effect* and the influence of ambient conditions on the measurement, were also analysed.

This methodology enabled an objective and structured analysis of contemporary literature, laying the foundations for the following sections of the paper, where the results and implications of the findings will be presented and compared in detail.

3. RESULTS AND DISCUSSION

An analysis of contemporary research published between 2020 and 2025 enabled the identification of key differences in metric characteristics between running time measurements using stopwatches, apps and photocells. The papers focused on parameters such as accuracy, precision, and validity of measurements in different sports contexts (Table 1).

3.1. VALIDITY AND RELIABILITY OF MOBILE APPS

Chen et al. [1] investigated the validity and reliability of the mobile app *COD Time*r in comparison to handheld stopwatches for measuring direction change performance (Figure 1). Their findings indicated that the *COD Timer* application demonstrated high validity and reliability, whereas the manual stopwatches exhibited greater measurement errors, highlighting their limited effectiveness for precise measurements.

Table 1. Comparison of the metrics of stopwatches and photocells

Characteristic	Stopwatch	Photocells
Accuracy	Low	High
Precision	Variable	High
Reliability - ICC	0.70-0.85	>0.95
Human error influence	High	Low
Practicality	High	Medium
Equipment price	Low	High

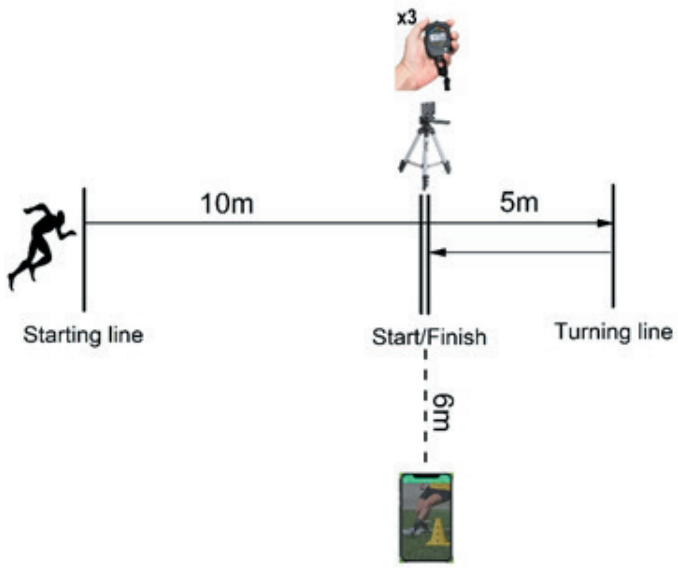

Figure 1. Different ways of measuring time [1]

Uysal et al. [5] assessed the validity, reliability, and sensitivity of mobile applications for estimating turn speed. Thirty students participated in the tests using six different devices, which included apps and handheld stopwatches. The study found that some apps delivered results comparable to professional systems, while the handheld stopwatches were less reliable.

It can be concluded that while mobile applications and stopwatch-based time measurements are feasible, using mobile applications is preferable for ensuring the validity and reliability of results.

3.2. COMPARISON OF DIFFERENT MEASURING DEVICES

Altmann et al. [9] studied the criterion validity of various devices used to assess maximum sprint speed in soccer players. Thirty elite young soccer players participated in 30-meter sprint tests utilising radar, photocells, a magnetic timing system, and GNSS devices. The results indicated that photocells and magnetic systems delivered the most accurate measurements, whereas GNSS devices showed greater variability.

Zajac et al. [10] assessed the validity and inter-examiner reliability of manual measurements for maximum sprint speed. The study involved 18 amateur runners, and the results revealed significant discrepancies between manual measurements and electronic systems. This highlights the need for caution when relying on manual stopwatches.

Based on previous statements, we recommend using electronic systems, specifically photocells, for timing running tests, especially when measuring athletes' maximum speed. While all the other measuring devices mentioned are effective, electronic systems offer the highest level of accuracy.

3.3. APPLICATION OF NEW TECHNOLOGIES IN SPRINT MEASUREMENT

Skujytė et al. [11] investigated the reliability and validity of the *Alex7* device for measuring sprint performance under conditions with added load and assistance. The results showed that *Alex7* provides reliable measurements but consistently overestimates run times compared to standard devices, indicating the need for calibration when using this device.

Dewanti and Hermawan [2] compared the measurement of running speed using photocells and manual stopwatches to reduce human error. The study showed that photocells provided more accurate results compared to manual stopwatches, which were more prone to measurement errors.

Integrating stopwatches into the testing process is the most feasible and straightforward approach; however, it is essential to consider that measurement error, resulting from the human factor, is present. To what extent it will depend on various conditions. Indeed, once again, a commitment to electronic devices, but with the caution of monitoring the calibration of the given instruments.

3.4. COMBINING DIFFERENT MEASUREMENT METHODS

Van den Tillaar et al. [12] compared the mechanical parameters of sprinting measured by photocells and a laser device. Thirty-four female handball players performed 30-meter sprints, with the results showing that both devices provide similar measures, but with certain differences that can be significant depending on the context of the application.

Mamo [3] highlighted the superiority of photocells in measuring sprint performance compared to manual stopwatches, emphasising that even minimal measurement errors can significantly affect the evaluation of athletes.

Marco-Contreras et al. [13] analysed the validity and reliability of the *Photo Finish*® mobile app for measuring sprint times. The study showed that the application provides accurate and reliable results, with an error of 0.09 seconds compared to photocells, which makes it suitable for use in various sports contexts.

Moreno-Azze et al. [4] evaluated the validity and reliability of the iOS mobile application *Fitnessmeter* for measuring change of direction performance. Forty-six adolescent soccer players participated in the study, and the results showed a strong correlation between the app and standard photocells, with no significant differences in times, suggesting that the app is a valid performance measurement tool.

These findings indicate that, although photocells are superior in terms of accuracy and reliability, manual stopwatches may still have their applications in situations where resources are limited or when a quick assessment of performance is required. However, it is necessary to be aware of their limitations and interpret the results with caution.

4. CONCLUSION

Analysis of these studies reveals that photocells and certain mobile applications are more reliable for sprint timing than manual stopwatches. Manual stopwatches are prone to human error and are less accurate, particularly in situations that require high precision. Mobile applications, such as *COD Timer* and *Photo Finish*®, have proven to be effective alternatives, offering accurate results with greater convenience and accessibility.

However, using mobile applications necessitates clearly defined measurement protocols and a certain level of technical training for users to ensure accuracy and reliability. Additionally, variations in smartphone models and the recording speed of cameras can affect the quality of the results, indicating that these applications cannot yet fully replace standardised systems, such as photocells or laser timing devices.

It's important to recognise that the effectiveness of these technologies depends on the specific context and available resources. While photocells are commonly used in professional sports environments, mobile applications can be beneficial in school or recreational settings where resources may be limited. Furthermore, factors such as user experience, test conditions, and the technical specifications of the equipment should be considered when selecting a measurement method.

In addition, several studies suggest that combining multiple methods, such as using a mobile application with parallel photocell measurement, can contribute to validation and facilitate a more accurate interpretation of the results. The introduction of automated data analysis and processing through software platforms also opens up space for more precise monitoring of athletes' progress over time.

The choice of sprint timing method should be guided by a balance between required precision and available resources, taking into account the specific demands of the sporting context and performance evaluation objectives. The potential for further development lies in standardising the use of applications and integrating digital systems that offer both measurement and analysis within the same ecosystem. However, it is important to note that the application of these technologies depends on the specific context and resources. While photocells are standard in professional sports environments, mobile applications can be useful in school or recreational settings where resources are limited. Additionally, factors such as user experience, test conditions, and technical specifications of the equipment should be considered when selecting a measurement method.

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