


Validity and reliability of a 10 and 20 m linear sprint protocol using a single-beam photocell system: An exploratory study with young male soccer players

João Pedro Araújo Morais^a, Paulo Roberto Pereira Santiago^b, Claudio Andre Barbosa de Lira^a, Carlos Alexandre Vieira^a, Ramon Ribeiro de Lima^a, Gustavo de Conti Teixeira Costa^c, Mário Hebling Campos^{a,*} 

^a Laboratório de Avaliação do Movimento Humano (LAMOVIH), Faculdade de Educação Física e Dança (FEFD), Universidade Federal de Goiás (UFG), Brazil

^b Biomechanics and Motor Control Laboratory, Ribeirão Preto Medical School, University of São Paulo, Brazil

^c Núcleo de Estudo e Pesquisa Avançada em Esporte (NEPAE), Faculdade de Educação Física e Dança (FEFD), Universidade Federal de Goiás (UFG), Brazil

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ABSTRACT

Single-beam photocell systems are the most cost-effective type of timing gates and are widely used to assess linear sprint performance. However, for short distances (<30 m), their validity may be compromised by early movement artifacts (e.g., arm swing, trunk lean, and foot motion), especially when the first timing gate is positioned very close to the athlete and at heights easily crossed by body segments. There is a need to develop low-cost standardized devices and protocols for timing short linear sprints. This exploratory study examined the validity and reliability of a single-beam photocell system applied to a short-distance linear sprint protocol with the initial timing gate positioned approximately below knee height (0.40 m) and a 0.5 m starting distance. Sixteen pre-professional young male soccer players [19.4 ± 1.4 years; 74.8 ± 6.8 kg; 1.79 ± 0.07 m] completed two 20 m linear sprints. Split (10 m) and total times were recorded simultaneously using a custom-built single-beam photocell system and a 240 fps (frames per second) panning camcorder (reference method). Results suggested good to excellent test-retest reliability [ICC ≥ 0.79; CV ≤ 1.26%], and good validity [ICC ≥ 0.84; CV ≤ 1.21%; Mean absolute error ≤ 0.040 s (1.40%)]. Systematic biases with small effect sizes between methods (p < 0.01; d < 0.5) indicated that photocell and video-based measurements are not fully interchangeable. This exploratory study suggests that the proposed photocell protocol is reliable for short-distance linear sprint assessment. The source code and hardware schematics are openly available, facilitating replication and adaptation.

1. Introduction

The development of short-distance linear sprint performance (<30 m) is a key determinant of athletic performance in several team sports, particularly in modern soccer [1–3]. Monitoring linear sprint performance provides relevant information to support coaching decisions [4] and to guide the design and adjustment of training programs [5].

Single-beam photocell systems are widely used in the assessment of linear sprint performance due to their relatively simple and practical implementation, ease of assembly, and capacity to provide immediate

feedback [6,7]. These systems consist of pairs of devices (light transmitter and receiver) that establish light beams at predefined points along the sprint track, such as the start, intermediate splits, and finish [7–9]. Sprint time is determined by the sequential interruption of these beams as the athlete passes through them [9].

Despite their widespread use, single-beam timing gates are generally recommended for linear sprints longer than 20 m or for protocols involving a flying start [7]. The system may be prematurely triggered by body segments such as the arms, trunk, or lower limbs, leading to measurement error [8], which is proportionally more important in short-distance assessments. Technological alternatives to mitigate these

* Corresponding author.

E-mail addresses: jpedro_am86@hotmail.com (J.P.A. Morais), paulosantiago@usp.br (P.R.P. Santiago), claudioandre@ufg.br (C.A.B. de Lira), vieiraca@ufg.br (C.A. Vieira), ramonribeirodelima@gmail.com (R.R. de Lima), conti02@ufg.br (G.C.T. Costa), mariohcampos@ufg.br (M.H. Campos).

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limitations include dual-beam and split-beam systems, post-processing approaches [10], and hybrid solutions integrating contact mats, force plates, or pressure-based triggering devices [11]. However, these solutions typically increase complexity, resource requirements, and operational complexity. Consequently, there remains a need for practical and accessible protocols that improve measurement validity in short-distance sprint assessments.

Among the protocol variables that can be adjusted without additional cost, the height of the timing gates plays a relevant role in measurement validity [12]. Knee height varies substantially among individuals, but individualized adjustments are often impractical in applied sports settings due to time constraints. Therefore, identifying a standardized height that provides acceptable validity across individuals is of practical interest. Altmann et al. [8] compared two configurations: one with all photocells positioned at 0.64 m (approximately knee height), and another with the first beam at 0.25 m (ankle height) and subsequent beams at 1.00 m (hip height). The latter configuration improved validity for 30 m sprints, but not for shorter distances (5 m and 10 m), leaving uncertainty regarding intermediate distances such as 20 m. Considering that foot displacement amplitude during running is greater than that of the knee [13], a beam positioned at 0.25 m may be more susceptible to premature triggering. This suggests that an intermediate height between the foot and the knee may improve the validity of measurements for short sprints using single-beam systems.

Another relevant protocol variable is the initial distance between the athlete and the first timing gate, which can also be manipulated without additional cost [12]. This distance is critical to avoid premature triggering caused by forward body movement prior to sprint initiation [14]. Altmann et al. [15] reported no significant differences in activation errors when varying the start distance (1.0 m, 0.5 m, and 0.3 m) with the first gate positioned at 1.0 m height, recommending 0.3 m as it minimizes the influence of prior acceleration. However, in subsequent work, Altmann et al. [8] modified the height of the initial gate while maintaining the start distance, limiting the transferability of those findings. In contrast, Simperingham et al. [16] highlighted that sprint protocols commonly adopt start distances of up to 0.5 m to reduce premature triggering due to forward lean.

Taken together, the findings from previous studies [8,15,16] suggest that a start distance of approximately 0.5 m, combined with a lower positioning of the first timing gate may improve the validity of measurements in short-distance sprint assessments. However, we found no previous studies that systematically evaluated these two factors together. Therefore, the present study aimed to analyze the validity and reliability of a 20 m sprint protocol using a single-beam photocell system, with a 0.5 m start distance and the initial timing gate positioned below knee height.

A single-beam photocell system was developed specifically for this study. In alignment with Open Science principles, the source code and hardware schematics are openly available to support replication and adaptation. Furthermore, if this protocol proves valid and reliable, it may contribute to the development of more accessible technologies for football coaches and other sports where short linear sprints are important.

2. Materials and methods

2.1. Participants

Eighteen pre-professional male soccer players from a club in the Midwest region of Brazil were invited and agreed to participate in the study. Anonymity was guaranteed. All participants signed a free and informed consent form to participate in the study protocol, which complied with the Declaration of Helsinki and was approved by the University Ethics Committee (CAAE 39910214.5.0000.5083) and the Club. Sixteen males (19.4 ± 1.4 years; 74.8 ± 6.8 kg; 1.79 ± 0.07 m; mean \pm standard deviation) completed all procedures described in the

experimental design and were included in the data analysis. Data from two participants were excluded from the analysis because they did not complete all procedures. This team was the champion of the state championship in the under-20 category during the season in which the data was collected.

2.2. Experimental design

Pre-professional soccer players performed test and retest trials of 20 m linear sprints, with five minutes of passive recovery. The first half (10 m) and the full sprint had their time simultaneously measured by a three-gate single-beam photocell system (100 Hz) and a panning 240 fps camcorder (reference method). The start distance behind the initial timing gate was 0.5 m. The initial timing gate was positioned approximately below knee height (0.4 m) and the remaining gates at approximately hip height (1.0 m).

2.3. Experimental protocol

A warm-up of approximately 7 min was carried out, structured with runs at moderate intensity with variations in technique and direction, followed by dynamic stretches, unilateral and bilateral jumps and short sprints with an emphasis on braking. After 3 min, two 20 m sprints were performed for familiarization, each followed by 5 min of passive recovery. This procedure was included to minimize potential habituation effects associated with repeated sprint testing. This warm-up protocol was chosen because all the athletes were familiar with it, as it was used during the competitive pre-season by the soccer club.

The main part of the experiment consisted of performing two explosive sprints of 20 m, in a straight sprint test track delimited with mini training cones, on a level natural grass (bahiagrass/ Batatais) soccer field (Fig. 1). The distance between the inner edges of the mini training cones used to delineate the width of the sprint lane was 0.8 m. Each athlete was instructed to start in a static standing position, similar to that described by Altmann et al. [8], without placing hands on the ground, without countermovement, with one foot in front of the other, with the tip of the front foot 0.5 m before the starting point (0.0 m) of the 20 m sprint track. The width of the support base, the foot that would be in front and the time of departure were self-selected. Verbal encouragement was provided to ensure maximal effort. A five-minute passive recovery was adopted between attempts. All tests took place in the morning (9h30 AM) before any training or game activity. No match had been played on the previous day.

2.4. Single-beam photocell system

A single-beam photocell system prototype was developed specifically for this study. It consisted of three infrared light-emitting devices (Fig. 2 A) and three receiving devices (Fig. 2B) each with a photoelectric sensor (50 ms time response). The total cost of the system was approximately 400 US dollars. The distance between each light-emitting device and its respective receiver was 2.2 m. Each device was powered by a lithium battery. One receiving device was defined as central command (Fig. 2 C) with: a) a central information processing module; b) LCD (Liquid Crystal Display) screen configured as a digital stopwatch (two decimal places), providing a temporal resolution of $1 \div 100 = 0.01$ s; c) buttons for system operation.

The ESP-NOW radio protocol [17] was used for communication between devices. For the electronic development of the system, the Proteus software (Version 8.3) was used. The algorithm for calculating the time of the first half of the sprint and the total sprint was written in the Arduino software (Version 1.8.1). The source code and hardware schematics for this study were provided as [supplementary material in Appendix A](#) - Code and hardware schematics.

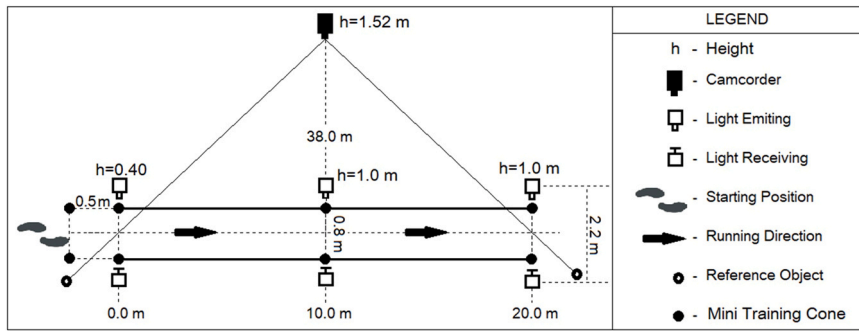


Fig. 1. Experimental scheme for the linear 20 m sprint test. Camcorder and photocell system layout for simultaneous sprint timing.

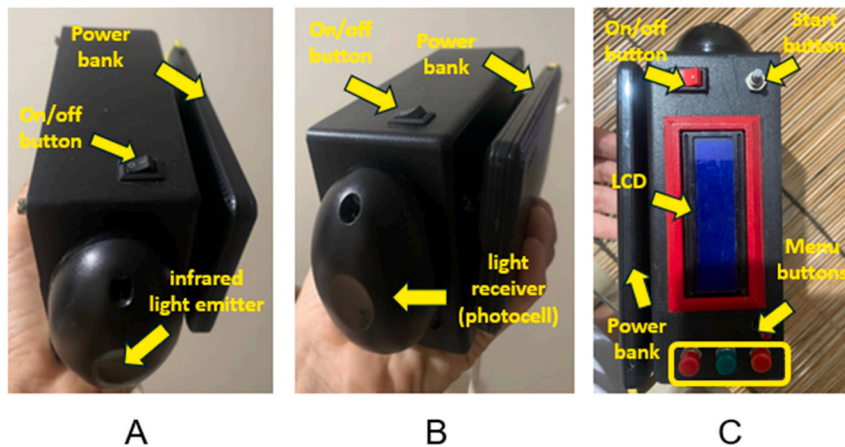


Fig. 2. Devices of the photocell system: A) Light Emitter; b) Receiver; C) Central command.

2.5. Panning 240 fps camcorder timing method

One 240 fps camcorder (Casio ExLim EX-Zr100; Casio America, Dover, NJ, USA) configured with autofocus and HS240 (Image resolution 432 × 320 pixels) was positioned on a tripod with 1.52 m height, 38 m away from the center of the sprint track (Fig. 1), with the optical axis perpendicular to the direction of the race in its half (10 m) providing images in the sagittal plane of the athletes (Fig. 3). The camera's zoom setting provided image coverage of approximately three meters horizontally, in the plane of the race. The vertical axis of the tripod allowed movement for the operator to rotate the tripod head, recording the athlete's movement during the 20 m sprint with a panning camera method.

To identify the passage of the athlete in the half (10 m) of the sprint track, photocells were used as references in the image (Fig. 3B). Two vertical white metal bars were driven into the lawn in a vertical position, behind the plane of the race, as a reference object for identifying the

starting point (Fig. 3 A) and end point (Fig. 3 C) of the sprint track. To correct the parallax, the position of each vertical bar was calculated so that its projection on the camcorder image would be exactly at the point of interest of the race route projected on the same image (Figs. 1, 3 A and 3 C) as exemplified by some previous works [6,9,11].

Video files were transferred to a laptop and analyzed by visual inspection, frame by frame, in free software KINOVEA (Version 0.9.5). The midpoint of the hips was defined as a reference to represent the athlete's position on the race course. The operator (rater) identified the frame in which the reference point passed the initial point (Fig. 3 A), in the half (Fig. 3B) and at the end (Fig. 3 C) of the sprint trajectory, that is, three events were identified in the race.

The number of the initial frame of the sprint (Fi), the final frame (Ff) of the split 10 m, and the final frame of the 20 m sprint were tabulated in the EXCEL software (Microsoft 365). The sprint times were calculated for 10 m and 20 m by the ratio between the number of frames elapsed in the section of interest (10 or 20 m) in the video register and the sample

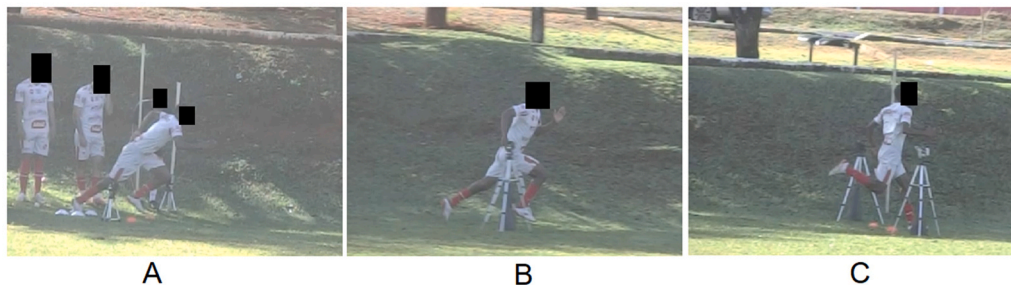


Fig. 3. Images from the 240 fps camcorder recording the passage of the average position of the hips by reference objects in the data collection environment. A: Metal bar at the starting point of the sprint track (0.0 m); B: Photocells at halfway (10.0 m); C: Metal bar at the end point (20.0 m).

frequency (FR) of the camcorder [Time = (Ff - Fi) ÷ FR]. The sample frequency was 240 frames in each second (240 fps), providing a temporal resolution of 1 ÷ 240 = 0.004 s.

The procedure for identifying frames with video was redone by another operator for the first ten (arbitrarily chosen number) sprints of the sample. This was used for inter-rater reliability analysis. One operator was a PhD student with 3 years of experience with this method and another was a master's student and had two years of experience with this method.

2.6. Statistical analysis

The data were analyzed [18–20] in the Matlab® system (The MathWorks, Natick, Massachusetts, USA), with a significance level of 5%. It was verified that the data sets showed normal distribution (*Shapiro-Wilk*) and homogeneous variances (*F-test*). Data were presented as mean ± standard deviation (SD).

Test-retest (intra-rater) reliability analysis: Intraclass Correlation Coefficient, ICC (3, 1), Two-way mixed effects, consistency, single measurement; Mean absolute error (MAE) and standard deviation (SDdiff) of the absolute differences between the scores of the repeated measures (trials); Typical Error (TE), calculated as the ratio between SDdiff and $\sqrt{2}$ (TE = SDdiff ÷ $\sqrt{2}$); Coefficient of variation (CV), calculated as the ratio between TE and the overall mean (\bar{M}) sprint time (CV = 100 x TE ÷ \bar{M}); Minimal Detectable Change (MDC), as the 95% confidence interval of the SDdiff (MDC = 1.96 x TE x $\sqrt{2}$).

Validity analysis: ICC (2, 1), Two-way random effects, absolute agreement, single measurement; Pearson's Linear Correlation Coefficient (*r*); MAE; Mean Absolute Percentage Error (MAPE) and *Bland & Altman's* 95% Limits of Agreement (LoA); The average scores of the methods were compared with a paired *t-test* and, when there was a significant difference, the magnitude of the effect (*Cohen d*) was evaluated, calculated by the difference between the means of the methods divided by their pooled standard deviation; TE; Coefficient of variation (CV), calculated as the ratio between TE and overall mean (\bar{M}) sprint time (CV = 100 x TE ÷ \bar{M}).

Inter-rater reliability analysis: ICC (2, 1); TE; CV; and paired *t-test*.

ICC was interpreted as: ICC < 0.5 – poor, 0.5 ≤ ICC < 0.75 – moderate, 0.75 ≤ ICC < 0.9 – good, ICC ≥ 0.9 – excellent [21]. Linear Correlation Coefficient was interpreted as: (*r*) < 0.1 – non-significant, 0.1 ≤ *r* < 0.3 – low, 0.3 ≤ *r* < 0.5 – moderate, 0.5 ≤ *r* < 0.7 – high, 0.7 ≤ *r* < 0.9 – very high, and *r* ≥ 0.9 – almost perfect [7]. The Effect size was interpreted as: *d* < 0.2 – trivial; 0.2 ≤ *d* < 0.5 – small; 0.5 ≤ *d* < 0.8 – medium; *d* ≥ 0.8 – large [20].

3. Results

The measured performance is presented in graphs for the half (Fig. 4 - A) and the full sprint distance (Fig. 4 - B). The individual sprint times were provided as [supplementary material \(Appendix B - Individual sprint times\)](#).

Results (Table 1) showed that the photocell system presented good test-retest reliability for 10 m and 20 m; and the video system presented good reliability for 10 m and excellent for 20 m.

The comparison between frame identification of the operators showed excellent video analysis inter-rater reliability for 10 m (ICC = 0.9794; TE = 0.008 s; CV = 0.50%), and 20 m (ICC = 0.9916; TE = 0.009 s; CV = 0.33%); with no biases for 10 m (*t*(9) = 0.688; *p* = 0.509), and 20 m sprint (*t*(9) = 0.099; *p* = 0.923).

Results (Table 2) suggested that the photocell system is valid (ICC > 0.75; *r* > 0.8; CV ≤ 1.21). However, paired *t-tests*, MAE, MAPE, and LoA showed systematic biases between methods of small magnitude (0.4 < *d* < 0.5) in the 10 m retest and in both 20 m tests.

4. Discussion

4.1. Main findings

The purpose of this study was to analyze the validity and reliability of a 20-meter linear sprint protocol using a single-beam photocell system, with a 0.5 m start distance and the initial timing gate below knee height. The 240 fps camcorder sprint timing-based method was the reference for the concurrent validation [9]. The photocell system appears to be valid (10 m: ICC = 0.8; *r* = 0.81 – 0.91; CV = 0.94% – 1.21% /

Table 1

Camcorder based method and photocell system timing reliability in 20 m sprint test-retest.

	10 m Video	10 m Photocell	20 m Video	20 m Photocell
ICC	0.8902 [good]	0.7881 [good]	0.9350 [excellent]	0.8876 [good]
MAE (s)	0.017 ± 0.023	0.023 ± 0.029	0.026 ± 0.032	0.029 ± 0.042
TE (s)	0.017	0.021	0.023	0.030
CV (%)	1.01	1.26	0.80	1.03
MDC (s)	0.046	0.058	0.063	0.083

ICC: Intraclass Correlation Coefficient (Two-way Mixed Effects, Consistency, Single Measurement); MAE: Mean absolute error - average of the absolute difference between sprint time for each subject; TE: Typical Error; CV: Coefficient of variation; MDC: Minimal Detectable Change.

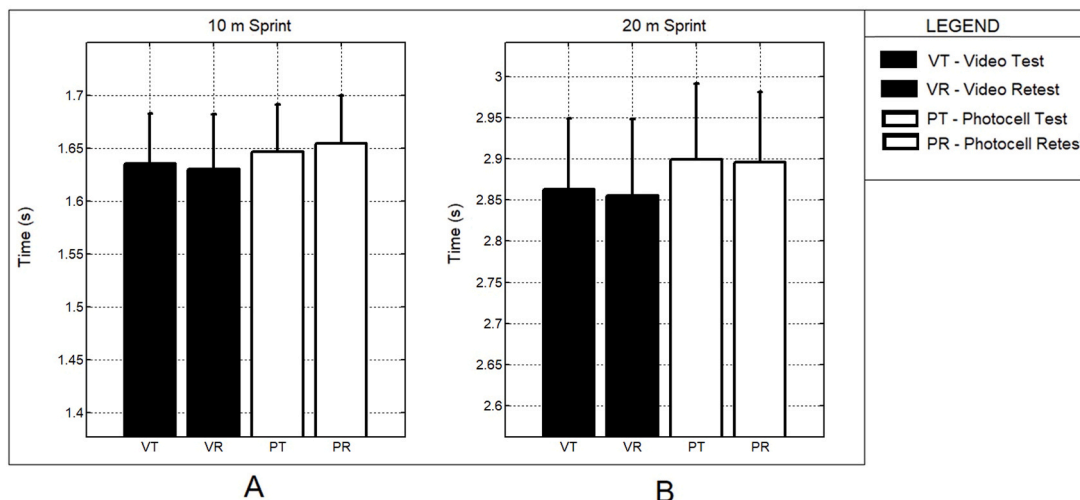


Fig. 4. Performance in sprint test-retest. A: Half of the sprint (10 m); B: Full sprint (20 m).

Table 2
Concurrent validity between the photocell system and the camcorder based method for sprint timing, for two independent trials.

	10 m		20 m	
	Test (n = 16)	Retest (n = 16)	Test (n = 16)	Retest (n = 16)
ICC	0.802	0.805	0.839	0.825
r	0.815*	0.909*	0.905*	0.905*
MAE (MAPE)	0.011	0.024**	0.036	0.040
[LoA] (s)	(0.66%) [-0.044 / 0.066]	(1.49%) [-0.019 / 0.067]	(1.25%) [-0.041 / 0.114]	(1.40%) [-0.037 / 0.118]
T-test	t(15) = 1.538 p = 0.145	t(15) = 4.453 p < 0.001	t(15) = 3.655 p = 0.002	t(15) = 4.055 p = 0.001
Cohen d	-	0.498	0.404	0.447
TE (s)	0.020	0.015	0.028	0.028
CV (%)	1.21	0.94	0.97	0.97

ICC: Intraclass Correlation Coefficient (Two-way random effects, absolute agreement, single measurement); r: Pearson's Linear Correlation Coefficient; MAE: Mean absolute error - average of the differences between the scores of the measures (Methods); MAPE: Mean absolute percentage error - the percentage with respect to the average time of the systems; LoA: Bland & Altman's 95% Limits of Agreement; T-test: paired t-test; Cohen d: Effect size magnitude; TE: Typical Error; CV: Coefficient of variation; *: $p < 0.001$; **: *Shapiro-Wilk* showed the differences between the scores are not normal distributed ($p = 0.033$).

20 m: ICC = 0.82–0.84; $r = 0.9$; CV = 0.97%) and reliable (10 m: ICC = 0.79; CV = 1.26% / 20 m: ICC = 0.89; CV = 1.03%) for both the 10 m and the 20 m sprint of young male soccer players. To the best of our knowledge, no previous concurrent validation study has reported an ICC above 0.75 in the comparison of single-beam photocell with video analysis as a reference method for timing linear sprints of 10 m or 20 m with the standing static start position. However there is uncertainty regarding whether timing methods produce interchangeable measurements as significant systematic biases were observed ($p < 0.05$), of small magnitude ($0.4 < d < 0.5$), with longer times recorded by the photocell system and MAE and MAPE values up to 0.024 s (1.49%) and 0.040 s (1.40%), respectively, for 10 m and 20 m.

4.2. Validity

Altman et al. [8] conducted a concurrent validity study of a single-beam photocell system proposing a sprint test protocol similar to the present study, with a 0.3 m starting distance, the initial timing gate at 0.25 m height and the remaining gates at 1.00 m height. They analyzed 5 m, 10 m and 30 m, finding good ICC (0.869) for 30 m but not acceptable validity ($ICC < 0.75$) for 5 m and 10 m. The present study found ICC values > 0.8 for 10 m and 20 m sprints with a single beam photocell system compared with video.

Using a 0.3 m start distance Bond et al. [9] compared a camcorder validated system with single beam photocell (0.99 m height) and single beam laser (0.91 m height) systems for timing 9.14 m (30 feet) and 18.29 m (60 feet) sprints, similar sprint distances to those used in the present study. They found 0.04 s and 0.05 s TE between photocell and video, respectively, for 9.14 m and 18.29 m, and 0.04 s between laser and video for both distances. The present study found lower TE that ranged from 0.015 s to 0.020 s for 10 m and 0.028 s for a 20 m sprint with a single beam photocell system compared with video.

The discrepancy between the present work and Altman et al. [8] and Bond et al. [9] results are in agreement with the literature, which has shown that different gate heights modify sprint measurement validity [22]. To obtain better measurements, ideally a measurement protocol would be implemented that allowed adjustments to the height of the photocells, so that all athletes, in all attempts, would activate all photocells with the same body part. However, this would require a significant amount of adjustment time for each athlete, making it impractical

in the sporting environment, where athletes have little time for assessments. For this reason, there is a search for protocols with fixed settings that can minimize errors. Possibly, 0.40 m height for the first photocell is a better option than 0.25 m, 0.64 m [8], 0.91 m and 0.99 m [9]. Another factor that may have influenced the results is the 0.5 m starting distance, which can avoid a false signal resulting in a premature timing start due to the forward lean of the subject [16].

Paired t-test showed significant ($p < 0.05$) systematic bias of small magnitude ($0.4 < d < 0.5$) in the 10 m retest and for both 20 m sprint trials, with a longer time in the photocell timing than in the camcorder method. Visual inspection of the graphs and average differences between the methods MAE (MAPE) present slight differences, ranging from 0.011 s (0.66%) to 0.024 s (1.49%) for a 10 m and 0.036 s (1.25%) to 0.040 s (1.40%) for a 20 m sprint. *Shapiro-Wilk* showed the differences between the scores are not normal distributed ($p = 0.0327$) for 10 m retest. The proposed single-beam protocol does not produce interchangeable measurements with a camcorder. This finding corroborates with prior work [9]. Altman et al. [8] also found bias but with longer time for video. Users should interpret results cautiously given these limitations.

4.3. Test-retest reliability

The photocell sprint protocol was reliable for 10 m (ICC = 0.79; CV = 1.26%) and 20 m (ICC = 0.89; CV = 1.03%). The Minimal Detectable Change (MDC) values were 0.058 s for 10 m distance and 0.083 s for 20 m, which reflect the sensitivity of the photocell system to detect performance changes over training periods. As an example to contextualize these results, the improvements in the sprint time of under-17 soccer athletes after 2-month contrast training intervention were 0.15 s for 10 m and 0.26 s for 20 m sprint test [23]. A second study, conducting a plyometric training program in 15-year-old athletes for 8 weeks, observed improvements of 0.11 s for 10 m and 0.15 s for 20 m sprint [24]. These results show that for an intervention of plyometric and contrast training, after 2 months of training, the photocell system is able to detect performance changes, being useful for these applications.

One way to apply the proposed test protocol is through the concept of smallest worthwhile change (SWC) and “likely limits” (observed change \pm TE) described by Hopkins [25]. These limits can be interpreted as beneficial, trivial, or harmful. Haugen et al. [26] stated that this SWC relates to approximately 0.02 s for elite athletes. If a soccer player has changed 20 m time from 2.9 s to 2.84 s (2%) between two periodic tests, this improvement can be represented as 0.06 ± 0.03 s and can be considered “beneficial” because the lower limit of the change 0.06 s - 0.03 s = 0.03 s was higher than 0.02 s (SWC).

Our findings are consistent with 2024 [27] evidence on the reliability of short-distance sprint assessments using dual-beam photocell systems that reported test-retest reliability for 10 m (ICC = 0.83; CV = 1.9%) and 20 m (ICC = 0.90; CV = 1.5%) sprint time. These values are closely aligned with those observed in the present study, indicating that the proposed single-beam photocell system provides reliability within the range reported in the literature, including studies using dual-beam systems.

From a practical perspective, coaches often aim to monitor changes in sprint performance over time, either for individual athletes or groups [9]. As suggested in previous research [9], repeated trials can be used to calculate an athlete's mean performance and its variability, allowing a more robust interpretation of changes. In the present study, the observed measurement error indicates that only performance improvements greater than 0.058 s (10 m) and 0.083 s (20 m) should be interpreted as real changes beyond measurement noise. Smaller differences are likely attributable to normal variability and should be interpreted with caution in applied settings.

4.4. Methodological considerations

Camcorders have been adopted as a reference method for sprint timing in concurrent validation studies [8,14,15,28]. Our study used a single camcorder that does not require synchronization between devices, thereby avoiding measurement errors inherent to synchronization procedures [29]. Dal Pupo et al. [30] employed a very similar single panning camcorder method, using athletics javelins as reference objects positioned behind the running trajectory (for parallax correction) to determine when the heads of young runners crossed predefined points along the sprint path, allowing calculation of average speed over 5 or 10 m intervals. Bond et al. [9] and Romero-Franco et al. [28] demonstrated the validity of applying geometric parallax correction by placing reference objects at adjusted positions along the sprint lane, ensuring that the athlete's reference point in the video coincided precisely with the true distances on the track.

When comparing our study and [30] with [9,28], the only difference lies in the camera motion, which causes the reference object to also move within the image. However, this difference should not affect measurement validity, provided that the reference objects remained fixed in the real-world environment and that the tripod remained stable throughout the experiment. This assumption is supported by the fact that event identification was performed manually, frame by frame, ensuring proper alignment among the camera position, the athlete's reference point, and the reference objects used for parallax correction. Additionally, compared with [9,28], the camera motion allowed framing a smaller region of interest, thereby increasing spatial resolution. This was reflected in the excellent inter-rater reliability of the video analysis ($ICC > 0.9794$; $TE < 0.01$ s; $CV \leq 0.50\%$), with no systematic bias ($p > 0.05$). Klous et al. [31] showed that classical kinematic measurement methods based on static cameras (typical of laboratory settings) can be adapted for field experiments using panning cameras, with accuracy comparable to that reported in laboratory studies. Finally, the present study, as well as [9,28,30], did not involve calibration procedures or 2D/3D reconstruction, making it less sensitive to sources of measurement error.

The hip was adopted as a reference point for sprint timing with camcorders in several studies [8,14,15,28], because it is close to the height of the body center of mass when the person is in the orthostatic position. These cited previous studies used a retroreflective marker attached to one of the hips to identify this anatomical reference point in the filming. In the present study, the midpoint between the hips was used as the anatomical reference point, visually estimated on the images, which tends to be more subjective. The positive aspect of this choice is the reduction in parallax error, since it tends to be closer to the center line of the sprint track than the marker positioned on the side of the hip. The comparison between two operators showed that the identification of the midpoint of the hips carried out in this study was reliable ($ICC > 0.97$). Even though there were small oscillations in the orientation and shakes of the camcorder, considering that the system proved to be reliable for 10 m ($ICC = 0.89$) and 20 m ($ICC = 0.93$), we considered the images adequate for the intended purpose.

This study was carried out with sixteen pre-professional (young) soccer players on the grassy field, so the generalization of the results should be considered with caution, considering that the photocell system for other modalities and types of surface should be tested. The findings are limited to young male pre-professional soccer players and may not be directly generalisable to athletes of different ages, performance levels, or sporting contexts.

The age, level of performance and the technique of running can influence the reliability and validity indicators [7]. The number of participants may limit the statistical power of the study, particularly regarding the precision of the estimated reliability metrics. However, it is important to note that studies assessing test-retest reliability in sprint performance commonly employ relatively small samples due to the controlled and repeated measures nature of the design. Previous

investigations in roughly similar contexts have used samples ranging from 12 to 15 participants (Altmann et al. [8] - 15 healthy and physically active male subjects; Bond et al. [9] - Fifteen athletes; Haugen et al. [14] - Fourteen female athletes; Altmann et al. [15] - 13 male sports students; Romero-Franco et al. [28] - 12 highly trained male sprinters), suggesting that the present sample size is consistent with the methodological standards typically adopted in this field. Nevertheless, the results should be interpreted with caution, particularly in terms of generalizability.

5. Conclusion

A single-beam photocell system was built for this study. In alignment with Open Science, the source code and hardware schematics of this study are openly available, encouraging replication and adaptation. This exploratory study suggests that the photocell protocol is valid and reliable, representing a potential contribution to the development of more financially accessible technologies for football (soccer) coaches and other sports where short sprints are important. However, small biases indicated that the methods are not fully interchangeable despite acceptable validity. These findings are limited to young male pre-professional soccer players and may not be directly generalisable to athletes of different ages, performance levels, or sporting contexts. From a practical perspective for users, only performance changes greater than the measurement error (0.058 s for 10 m and 0.083 s for 20 m) should be interpreted as meaningful improvements.

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CRedit authorship contribution statement

Ramon Ribeiro de Lima: Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Carlos Alexandre Vieira:** Writing – review & editing, Writing – original draft, Visualization. **Claudio Andre Barbosa de Lira:** Writing – review & editing, Writing – original draft, Visualization. **Paulo Roberto Pereira Santiago:** Writing – review & editing, Writing – original draft, Visualization. **João Pedro Araújo Morais:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mário Hebling Campos:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gustavo de Conti Teixeira Costa:** Writing – review & editing, Writing – original draft, Visualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

No AI tools were used at any stage of the conception or initial writing of the manuscript. During the revision stages, one of the authors used ChatGPT to help refine the formulation of some ideas, as well as to correct minor grammatical, spelling, and phrasing issues. After using this tool, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the published article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.footst.2026.100045](https://doi.org/10.1016/j.footst.2026.100045).

Data availability

I have shared the link to data.

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