
ADVANCES IN ELECTRONIC TIMING SYSTEMS: CONSIDERATIONS FOR SELECTING AN APPROPRIATE TIMING SYSTEM

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ABSTRACT

Earp, JE and Newton, RU. Advances in electronic timing systems: considerations for selecting an appropriate timing system. *J Strength Cond Res* 26(5): 1245–1248, 2012—The proper selection of equipment is vital to the ability to accurately measure and track changes in performance. When measuring sprint time, electronic timing systems are recommended but may contain significant errors when an arm or leg passes through a gate before the torso. Dual-photocell (DP) and signal processing systems have been developed to overcome these issues. Ten subjects performed 10× 10-m sprints during which split time was calculated using 3 timing systems: a single photocell (SP) and DP without processing and a no-reflector gate with signal processing. The DP had fewer false signals compared with the SP (7, 14); however, signal processing eliminated all false signals. The mean differences between the 3 timing systems ranged from 9 to 17 milliseconds; however, the *SD* ranged 12–42 milliseconds because of the occurrence of false signals. When performing repeated 10-m sprints, it is vital to have a system that reduces or eliminates the occurrence of false signals, or training adaptations are likely to be overlooked. Thus, for 10-m sprints or splits, a timing system that reduces the incidence of false signals is needed (either DP or gates signal processing), and the use of an SP system without internal processing is inappropriate. However, as the distance and the expected adaptations increase, a smaller proportion of the adaptation is likely to be confounded when using an SP system.

KEY WORDS timing gate, 10-m sprint, photocell, infrared timing

INTRODUCTION

In both competitive sprint running and sprint training, it is always the goal to move the body as quickly from one place to another. The ability to accurately and reliably measure sprint time is vital for athlete assessment and validation of training programs. Electronic photocells, commonly referred to as timing lights, are used in a range of tests measuring sprint speed, agility, and running pace. These systems have long been considered the gold standard for timing because they are more precise and eliminate human error and user bias when compared with manual timing (8,10). Most photocells work by using an infrared light beam sent from an emitter to a reflector 2 m away and records the instant the beam is broken using a high-resolution timer chip in a dedicated circuit board or computer, that is, the switch time (13). Although far more accurate than manual timing, photocell systems can suffer from significant errors because of false signals (3,11), that is, when a beam is broken by an outstretched arm or leg instead of the torso (Figure 1). This can be a major problem in competition sprinting (such as the Olympics) as finishing time or split time is recorded when the athlete's torso passes the plane of the finish line.

There are several factors that may give rise to greater timing errors occurring because of false signals. Athletes with longer limbs may encounter greater errors, whereas those who overstride or outstretch their arms toward the gates might increase the likelihood of false signals and record faster sprint times. Additionally, when timing short splits errors can be compounded when false signals may occur at some gates and not others.

In an effort to eliminate false signals, manufacturers have developed dual-photocell (DP) timing systems and timing systems with analog or digital postevent processing algorithms. The DP gates include 2 photocells aligned vertically and separated by approximately 30 cm (5), and switch time is considered the instant both beams are broken. In contrast, postprocessing involves internal software that examines the signal from a gate in its entirety, determines the frequency and duration that the beam is disrupted, and selects the beginning of the longest duration disruption as the switch time (5). Although both of these methods show promise in

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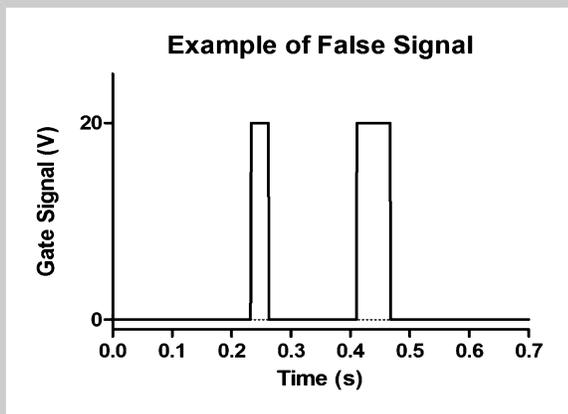


Figure 1. An example of a false signal taken during a 10-m sprint. The gate signal represents either an uninterrupted (0 V) or a broken infrared beam (20 V) from a single photocell. Under the assumptions of signal processing, Signal-A is believed to be a false signal as it represents the beam being broken by an appendage, whereas Signal-B represents the torso passing through the gate. Time-point zero was placement arbitrary for this illustration.

reducing the incidence of false signals and thus increase the reliability and validity of timing, there are limited data to support these claims. In the 2008 Olympics, multiple photocells and collecting at 1,000 Hz with internal processing were used and paired with video sampling at 3,000 Hz to determine finishing time and the winner of each race. However, such a setup is impractical for most training and even racing situations.

Additionally, a recent development in photocell technology negates the requirement for a reflector (no-reflector [NR]) as part of the timing gate pair (5). This may be attractive to practitioners as setup time, and equipment is reduced; however, validity has not been established.

Although the advances in technology may be able to decrease the incidence of false signals and increase the ease of equipment set up, there is also an increase in costs of research and development and manufacturing to produce such systems. Because of this, practitioners need to develop

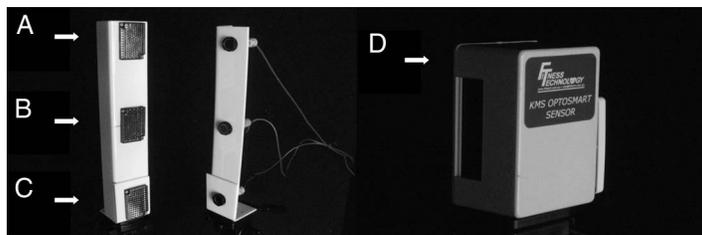


Figure 2. Photocell setup. Top (A) and bottom (C) photocells are reflectors used for dual photocell measurements and the middle photocell is a reflector used for single photocell measurements. Nonreflector photocell (D) was positioned adjacently 10 mm above to the middle photocell (data not shown).

TABLE 1. Frequency of false signals.*

Technique	One false signal	Two or more
Dual photocell	7 (5)	0 (0)
Single photocell no processing	14 (11)	1 (1)
No reflector no processing	17 (12)	3 (3)
No reflector with processing	0 (0)	0 (0)

*Out of 49 sprints. The first number indicates total false signals; the number in parentheses indicates false signals that altered gate switch time.

a cost-benefit rationale when selecting equipment for their individual needs. The factor most important when making this decision is the needed precision to accurately measure expected changes in timing duration. When measuring sprint time, repeated measurements such as those performed as preintervention and postintervention testing require greater accuracy than do cross-sectional tests (9). Additionally, in situations in which tests are repeated, the expected variance should be minimized to allow for a treatment affect to be observed or else the likelihood of a type-1 error increases (1,9). In sprint running, the treatment effect decreases as distance ran decreases (12). Previous research has reported training adaptations and treatment affects to 10-m sprint time of 0–300 milliseconds (2,6,7,12).

The purposes of this study were to first compare switch times and the incidence of false signals between SP, DP, and NR timing gates and determine if there is added benefit to signal processing. Second, to develop a cost-benefit rationale of using DP or signal processing when analyzing 10-m sprinting.

METHODS

Five healthy, physically active individuals (age: 27.4 ± 2.1 years) participated in this study. All the participants had undergone sprint training in the past, but none were competitive sprinters.

The participants gave their informed consent, and all testing met the standards set forth by a separate institutional ethical review board. Each participant performed 10, 10-m sprints during which switch time was recorded when the subject passed through a custom-designed gate containing 3 photocells with reflectors (Omron E3F20R2C4, Photoelectric switch, Nufringen, Germany) and 1 reflectorless photocell (Optosmart Sensor, Fitness

TABLE 2. Absolute time differences between techniques (seconds).*

Technique	Mean	SD	Coefficient of variation	Confidence interval
DP vs. SR	0.017	0.024	1.572	0.008–0.021
NR vs. SR	0.012	0.012	1.530	0.015–0.037
NR vs. DP	0.009	0.042	0.512	0.000–0.023

*DP = dual photocell; NR = no reflector.

Technologies, Skye, Australia) (Figure 2). In an effort to minimize runner bias, the participants were instructed to sprint 5 m beyond the gates and to run as though the gates were not present. Switch time and false signal incidence were determined for SG, DG, and NR timing gates and additionally postprocessing was performed for SG and NR timing gates and compared. The photocell setup and standardized heights were as follows:

1. Dual photocell lower with reflector (DG lower): 0.75 m.
2. Single photocell with reflector at midpoint (SG): 0.90 m.
3. Dual photocell upper with reflector (DG upper): 1.05 m.
4. Single photocell without reflector at midpoint (NR): 1.00 m.

One trial had to be discarded because of a recording error. Analog signals from the 4 photocells were converted to digital signals using a 12-bit AD converter (NI USB-6008) and recorded in a custom-built data collection program

(LabView 8.2.1, National Instruments, Austin, TX, USA) at a sampling rate of 1,000 Hz.

For NR, switch time was determined in 2 ways: (a) The first break in the infrared beam and (b) the start of the longest duration break in the infrared beam using postprocessing. All switch signals were analyzed using a time threshold of 30 milliseconds, that is, additional switch changes lasting <30 milliseconds were excluded in the processing.

The frequency of false signals was determined for each processing method. The mean, SD, and coefficient of variation of the differences between each processing method and the intraclass correlations (ICCs) were calculated using a statistical program (PASW 18, IBM, USA).

RESULTS

The frequency of false signals for DP, SR, and NR are presented in Table 1. Not all false signals recorded influenced the switch time because several occurred after the longer duration event. False signals were common for DP (7), SR (14), and NR (17); however, signal processing completely removed all false signals when performed. All photocell setup and processing techniques had a near perfect relationship to one another with all ICCs at 1.000 ($p < 0.000$). Differences between times measured by the various techniques are presented in Table 2.

DISCUSSION

The absolute differences between all timing systems were relatively small (5–17 milliseconds); however, the SD was much greater (12–42 milliseconds). This is reflective of the observation that differences between timing systems are negligible unless false signals occur, which then cause large timing disparities to occur. The DP method was able to reduce the incidence of false signals but did not completely remove such events. Both the SP and NR gates were prone to false signals; however, postprocessing eliminated false signals completely. However, signal processing works under the assumption that the longest break in the beam represents the torso, and further video analysis would be needed to prove such an assumption.

Because signal postprocessing eliminated all false signals, it is recommended that systems with false signal processing represent the best technique in relation to the true sprint time and should therefore be considered the gold standard for recording sprint time. However, there may be some added benefits to using both DP and signal processing.

When determining the appropriate timing system for use, the test being performed and the expected changes in duration need to be taken into account. A visual

Sensitivity of Gates to Anticipated Training Adaptations

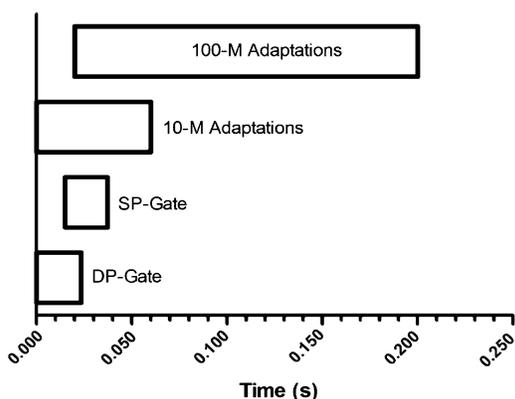


Figure 3. Confidence intervals between a timing gate with internal processing and single photocell (SP) and dual photocell (DP) gates without processing and the expected adaptations to sprint times (4). Adaptations that are less than the largest gate confidence intervals represent potential confounding values because of the insensitivity of the equipment used when compared with a gold standard.

representation of the expected variation based on the timing system used when compared with a processed signal (NR) along with the anticipated changes in sprint time based on previous research are featured in Figure 3 (2,4,6,7,12). When the anticipated changes in sprint time are lower than the differences in timing systems (the greatest value in the confidence interval), it is possible that any changes in sprint time will not be detectable in an individual and that an extremely large sample size would be needed to prove statistical significance in research.

All attempts to eliminate false signals should be taken into consideration when performing testing. Both DP and systems that use internal processing can decrease the impact of false signals on sprinting results. However, costs increase as the technology used increases; thus, a cost-benefit rationale needs to be determined in each situation. When timing repeated 10-m sprints or splits, it is inappropriate to use SP gates without processing because it is expected that over half of the anticipated adaptations may be overlooked because of the false signals recorded. In contrast, the relative variance of SP systems when compared with the anticipated changes in duration over longer distances (i.e., 50 or 100 m) decreases significantly. Thus, across longer distances, the added benefit of using DG or postprocessing decreases significantly.

PRACTICAL APPLICATIONS

The DP systems are less prone to false signals than SP, but computer signal processing totally overcomes this problem. In the 10-m sprinting, SP systems without processing are inappropriate because false signals occurred in 32% of trials and represented over half of the expected changes in performance; thus, either DP or photocells with processed signals should be used. If budget allows and accuracy is paramount, then dual beam may have an advantage, but single beam systems produce times within 5 milliseconds, which for most applications (100-m sprinting) is negligible. The latest NR photocells appear equally accurate as SP and greatly reduce setup time and equipment to be transported.

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