

# THE ACCURACY OF DEVICES AND TECHNIQUES FOR MEASURING THE SPEED OF ATHLETES

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From gymnastics vaulting to pole vaulting, **football** to field hockey, how fast an athlete can run often determines his or her success in a sport. Coaches **are** thus interested in the *speed* of their athletes. Researchers have developed a variety of techniques for measuring running speed. These include electromagnetic timing devices (Hill, 1927). **photoelectric** timing devices (**Ikai, 1968**), mechanical timing devices (Volkov & Lapin, 1979). and cinematographic techniques (**Cavagna, Saibene, & Arcelli, 1965**). Most of these devices or techniques have not been used by coaches because they were expensive, complicated, measurement was not immediate, or they interfered with the athlete.

An inexpensive, easy to use, accurate, and non-intrusive method to measure the *speed* of athletes would be valuable for coaches. Several devices and techniques for measuring speed **are** presently used by coaches, but the accuracy of these devices or **techniques** has not been investigated. The purpose of this study was to investigate the accuracy of several devices and techniques for measuring the speed of athletes.

Four primary time measurement systems were investigated: a handheld **electronic** stopwatch, a custom built infrared timing light system, a commercially available timing system which used optical sensors to detect movement, and **videocamera** recordings.

Average *speed* was **determined** by using these systems to measure the time it **took** an **athlete** to move a specific distance. Average speed equals the distance moved divided by time. The effect of the length of this distance or timing interval upon the accuracy of the *speed* measurement was also investigated. Six intervals were investigated: 2.5 m, 5 m, 7.5 m, 10 m, 12.5 m, and 15 m.

How fast the athlete is moving may also influence the accuracy of the speed measurement. A timing error of 0.10 s over an elapsed time of 10.00 s would be much less of an error **than** a timing error of 0.10 s over an elapsed time of 1.00 s. The effect of movement speed upon the accuracy of the *speed* measurement was also investigated. Four general speeds were investigated: walking ( $-2$  m/s), jogging ( $-4$  m/s), running ( $-6$  m/s), and sprinting ( $-9$  m/s).

For the **videographic** techniques, the effect of sampling rate upon the accuracy of the *speed* measurement was also investigated. A **normal videocamera** records 60 fields per second or 30 frames per second. Two video fields are interlaced to produce a video

frame. Some research quality videocamera and recorder systems are capable of recording **200** video fields per second. By playing back a **videorecording** using the still frame and frame advance controls, one can count video fields ~~a~~ frames, and a measure of time can be **determined from** the **videorecording**. Some **videoplayback** units will show each video field (a sampling rate of 60 Hz) when operated in this manner, while others will only show every other field (a sampling rate of 30 Hz). Four video sampling rates were investigated: 30 Hz, 60 Hz, 100 Hz, and 200 Hz. For the 30 Hz and 60 Hz sampling rates, the difference between a shuttered (**1/1000** s exposure time) and unshuttered recording was also investigated.

The specific **purpose** of this study was to determine the accuracy of the following nine different systems for measuring the **speed** of an athlete over 2.5 m, 5 m, 7.5 m, 10 m, 12.5 m, and 15 m intervals:

1. Handheld electronic stopwatch (0.01 s precision)
2. Infrared timing light system (custom built by U.S. Olympic Committee engineering department, 0.001 s precision)
3. Commercial timing system (uses optical sensors to **detect** movement, 0.01 s precision)
4. Unshuttered videocamera recordings with 30 Hz sampling rate (0.033 s precision)
5. Shuttered videocamerarecordings with 30 Hz sampling rate (0.033 s precision)
6. Unshuttered **videocamera** recordings with 60 Hz sampling rate (0.017 s precision)
7. Shuttered **videocamera** recordings with 60 Hz sampling rate (0.017 s precision)
8. Shuttered videocamerarecordings with **100 Hz** sampling rate (**0.01** s precision)
9. Shuttered videocamera recordings with 200 Hz sampling rate (0.005 s **precision**)

## **METHODOLOGY**

One male athlete served as the subject for **all** timing trials. The custom built infrared timing lights and the optical sensors of the commercial system were positioned along a **straight** running track at 2.5 m intervals from **0** to 15 m. Seven trials were completed at each of the four movement speeds. Each trial yielded six samples of 2.5 m timing intervals, five samples of 5 m timing intervals, four samples of 7.5 m timing intervals, three samples of **10 m** timing intervals, two samples of 12.5 m timing intervals, and one sample of a 15 m timing interval.

Two **videocameras**, one shuttered and one unshuttered, recorded the trials at 60 Hz and one high speed videocamera recorded the **trials** at 200 Hz. These ~~cam~~ ~~ae~~ positioned **3 m above and 18 m horizontally** from the runway. The cameras were panned to follow the movement of the subject. The fields of view of these cameras were approximately 6 m. The person operating the handheld stopwatch was positioned near these cameras. The handheld stopwatch was capable of measuring split times, so it was

stopped/started at each 2.5 m mark. A fixed view high speed video camera operated at 200 Hz recorded a sagittal plane view of the subject's movement between the 5 and 10 m marks.

Times recorded by each system at each 2.5 m mark were used to determine velocities over each interval by dividing the interval distance by the difference in times. Times were determined from the videocamera recordings by counting frames (or fields) between the instances when the athlete was positioned at each 2.5 m mark.

The speeds between the 5 and 7.5 m and 7.5 and 10 m marks as determined from the digitized images of the 200 Hz fixed view movie were used as the criterion measures for an initial assessment of the accuracy of the devices. Accuracy was assessed by correlating the criterion measures with the experimental movies and by computing the standard deviations (standard error) between the criterion measures and the experimental measures. This standard error was expressed as a percent of the criterion measure. The higher the correlation coefficient and the lower the relative standard error, the more accurate the measurement. For the purposes of this study, a system was deemed to be accurate if its correlation coefficient was .90 or higher and its relative standard error was 5% or less. The most accurate device as determined in this comparison was then used as the criterion for the rest of the evaluations.

## RESULTS

The initial comparison of the speeds between the 5 and 10 m marks over all the trials as measured by each experimental system with the speeds as determined by the 200 Hz fixed view movie indicated that the speeds measured from the 200 Hz panning movie sampled at 200 Hz, the 200 Hz panning movie sampled at 100 Hz, and the infrared timing light system were most accurate. The correlations between the criterion measure and the experimental measures were 1.00 for the 200 Hz sampling rate, 1.00 for the 100 Hz sampling rate, and 0.999 for the infrared timing light system. All the other tested systems had correlations less than 0.999. The standard deviations between the criterion measure and the experimental measures were 0.076 m/s (1.33%), 0.077 m/s (1.35%), and 0.094 m/s (1.66%) for the 200 Hz sampling rate, the 100 Hz sampling rate, and the infrared timing light system respectively. The infrared timing light system was chosen as the criterion measure for evaluating the rest of the timing systems and intervals. It was not quite as accurate as the 200 Hz panning camera but the difference was insignificant. Theoretically, the accuracy of the 200 Hz panning movie would decrease as its angle of view deviated further from 90°.

A stop watch is the instrument most widely used by coaches for measuring velocity. Unfortunately, it was only useful for measuring walking and jogging speeds at timing intervals greater than or equal to 5.0 m. The inaccuracy of the stopwatch at the running and sprinting speeds was most likely due to the operator's errors in trying to stop start/stop the watch for split times at each 2.5 m mark. Only one stop watch was used. If seven watches were used and times to each 2.5 m mark were measured from the

watches, the accuracy of the stop watch for measuring running and sprinting speeds would have been improved.

The commercially available movement sensing timing system is marketed to coaches as a quick and easy system for measuring running speed. Unfortunately, its accuracy was not much higher than the stopwatch's. In fact at the walking and jogging speeds, the stopwatch was more accurate. The commercial system was accurate for measuring walking speeds if the timing interval was 7.5 m or larger. At speeds higher than walking speed, this system was only accurate at the largest measured timing interval of 15 m. It was not accurate for measuring sprinting speeds at any timing interval,

**Videocameras** are commonly used by coaches to evaluate techniques of their athletes. A **videocamera** may also be used to measure an athlete's speed if two or more **markers** are placed in the plane of motion or on either side of the plane of motion at known distances apart. The **normal** speed shuttered or **unshuttered** videocamera recordings sampled at 30 Hz were accurate for measuring walking and jogging speeds over every timing interval from 2.5 m to 15 m. The measured running speeds were accurate for 5 m timing intervals and larger. These timing systems did not provide accurate speed measurements for sprinting. Although the relative standard **errors** were less than 5% at this **speed** for **all** but the smallest timing interval, the correlations with the criterion were all less than .90.

The **normal** speed **shuttered** or **unshuttered** videocamera recording sampled at 60 Hz were **accurate** for measuring walking and jogging speeds over every timing interval from 2.5 m to 15 m. The measured running speeds were accurate for 5 m timing intervals and larger. These timing systems provided an accurate speed measurement of sprinting only for the timing intervals 10 m wide or larger for the **unshuttered** camera and 7.5 m wide or larger for the shuttered camera. At the smaller timing intervals, the relative standard **errors** were **all** less than 5% but the correlations with the criterion were **all** less than .90.

The high speed shuttered **videocamera** recordings sampled at 100 Hz or 200 Hz were accurate for measuring **all** tested speeds over every timing interval except for the 2.5 m interval at the sprinting speed. For the 100 Hz sampling rate, the relative standard error of the 2.5 m timing interval at the sprinting speed was only 1.96%. but the correlation with the criterion was .79. At the 200 Hz sampling rate, the relative standard error of the 2.5 m timing interval at the sprinting speed was only 1.48%, but the **correlation** with the criterion was .88.

## **CONCLUSION**

The custom built **infrared timing** light system, and the **videorecordings** produced by the high speed camera sampled at 100 Hz or 200 Hz proved to be the most accurate of the timing systems. But these are expensive and complicated systems which are unlikely to be used by coaches. **Unfortunately, the stop** watch and the **commercial** timing system which were the easiest to use, cheapest, and quickest with results were also the

least accurate and **inadequate** for measuring the faster speeds. That leaves the normal speed videocamera as the recommended system to use to measure the running speed of an athlete. Most coaches have access to **videocameras** and **are** familiar with their operation. Placing **marks known distances apart** on either **side of** the running track **is easy** to do. If a **proper** playback unit is used, a 60 Hz sampling rate is possible. This can provide accurate speed measurements for speeds up to 10 **m/s** if the timing interval is not less than 5 m. The use of a shutter improves the accuracy slightly.

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