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Original research

Design and validation of a portable, inexpensive and multi-beam timing light system using the Nintendo Wii hand controllers

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Abstract

Objectives: Commercial timing light systems (CTLS) provide precise measurement of athletes running velocity, however they are often expensive and difficult to transport. In this study an inexpensive, wireless and portable timing light system was created using the infrared camera in Nintendo Wii hand controllers (NWHC). *Design*: System creation with gold-standard validation. *Method*: A Windows-based software program using NWHC to replicate a dual-beam timing gate was created. Firstly, data collected during 2 m walking and running trials were validated against a 3D kinematic system. Secondly, data recorded during 5 m running trials at various intensities from standing or flying starts were compared to a single beam CTLS and the independent and average scores of three handheld stopwatch (HS) operators. Intraclass correlation coefficient and Bland–Altman plots were used to assess validity. Absolute error quartiles and percentage of trials in absolute error threshold ranges were used to determine accuracy. *Results*: The NWHC system was valid when compared against the 3D kinematic system (ICC = 0.99, median absolute error (MAR) = 2.95%). For the flying 5 m trials the NWHC system possessed excellent validity and precision (ICC = 0.97, MAR < 3%) when compared with the CTLS. In contrast, the NWHC system and the HS values during standing start trials possessed only modest validity (ICC < 0.75) and accuracy (MAR > 8%). *Conclusions*: A NWHC timing light system is inexpensive, portable and valid for assessing running velocity. Errors in the 5 m standing start trials may have been due to erroneous event detection by either the commercial or NWHC-based timing light systems.

Keywords: Run; Sprint; Speed; Gait; Athlete; Talent identification

1. Introduction

The accurate measurement of running velocity is a vital component in the evaluation of athletic performance for a number of sports.[1,2] The two most common methods for assessing sprinting speeds are the use of handheld stopwatches (HS) and instrumented timing light systems. Handheld stopwatches have been shown to produce times with acceptable *mean* error, but poor *absolute* error, and therefore they are unsuitable for accurate timing in many instances.[3] In contrast, the superior accuracy of the timing light systems, particularly as running velocity increases and/or distance decreases, has been well established.[3,4] A typical timing light system works by monitoring an infrared light source which is transmitted perpendicular to the athlete's running direction, commonly with a light emitter and sensor on one side of the running path and a reflector on the other side. This forms a timing light gate, and when the athlete passes through this gate the light source is broken, providing the signal to commence or terminate timing. While highly accurate, these systems are expensive, difficult to transport and time intensive to setup, which precludes their more widespread use.

Recent advancements in computer gaming technology have resulted in the mass production of the low-cost Nintendo Wii hand controllers (NWHC), which incorporate a small infrared camera capable of tracking multiple light sources and transferring their pixel position via Bluetooth to a Nintendo Wii console or computer. The NWHC are small and

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lightweight and therefore, when incorporated with an LED light source such as the Nintendo Sensor Bar, it is feasible that they could be setup to create a timing light gate. Previous research suggests that a similar computer game controller, the Nintendo Wii Balance Board, provides valid balance assessment data.[5] This supports the notion that the NWHC may also be suitable for research purposes. Given that in excess of 70 million Nintendo Wii consoles have been sold as of March 2010, and that each of these systems includes at least one NWHC and infrared light source, the widespread availability of these controllers would make them an ideal performance assessment device. The aim of this project was to create a low-cost, portable and simple to use timing light system incorporating the hardware associated with the NWHC and then validate it against a 3D kinematic system, a commercial timing light system (CTLS) and multiple operators of HS.

2. Methods

The NWHC-based timing light system utilised in this study possessed one NWHC and one infrared LED light source per timing gate, with two gates created – an initial and end timing point. The software program was designed so that the end of the first break recorded at each timing light gate was the signal to either commence or stop timing the run. This corresponded to the last instant at which both light beams were not visible to the NWHC, and represents the posterior aspect of the athlete's body passing through the light beam. Consequently, the end of the first break at the initial timing point commenced timing, and the end of the first break at the end timing point stopped timing.

A commercially available Wireless Sensor Bar (PowerWave Accessories, Australia) LED light source designed specifically for use with the Nintendo Wii was chosen. This system possesses two separate LED clusters 19.5 cm apart, allowing each gate to utilise a dual light beam protocol. These clusters were positioned vertically, with a "break" recorded if both beams were broken concurrently. A diagram of the light gate setup using the Nintendo Wii controller is provided in Fig. 1.

The data from the NWHC were transmitted to a laptop computer (Dell Inspiron 1720, U.S.A.) with an inbuilt Bluetooth device (Dell Truemobile 355 Bluetooth + EDR, U.S.A.). The data from the NWHC were acquired using a custom-designed LabView 8.6 (National Instruments, U.S.A.) acquisition and analysis program sampling at 100 Hz, which provided a stable sampling rate based on the investigators pilot work.The accuracy, precision and validity of the NWHC-based timing light gates were established using three protocols

(1) Initial laboratory validation – 20 × 2 m walking and running trials from a standing start
(2) Standing start running – 20 × 5 m running trials from a standing start
(3) Flying start running – 20 × 5 m running trials from a flying start

All protocols were undertaken by a single participant (age = 29 years, height = 1.72 m, body mass = 70.4 kg) who provided informed consent, and were performed at different intensities to provide variance. Data were synchronously collected during all protocols using the NWHC-based system, a CTLS and three independent operators of HS. The CTLS consisted of a SmartSpeed (Fusion Sport, Australia) setup in an identical position to the NWHC-based system. The HS were operated by three exercise scientists standing in their preferred timing position, with the instruction to start the timer once they observed the participant begin the run and to stop the timer once the participant passed through the final set of timing light gates. The only difference between the protocols was the "gold-standard" timing comparison, which in the case of the 2 m trials was a calibrated eight-camera 3D VICON system sampling at 120 Hz. Briefly, a sacral marker was deemed the centre of mass position, with the time between this marker passing through the first and second CTLS gate recorded. Due to the restricted field of view of this system it could not be implemented as the gold-standard for the 5 m trials, and consequently the CTLS was used in this comparison. The two 5 m running protocols were utilised to represent different facets of performance assessment, acceleration from a static start (from 0 to 5 m) and from a flying start (from 5 to 10 m). The participant randomly varied his running intensity in a self-perceived range from 60 to 100% of peak ability during each trial. Single subject, variable intensity studies with 3D kinematic validation have been used previously to establish the validity of photocell-based timing light systems.[6]

Statistical analysis consisted of a comparison of the validity of the different timing systems during each of the 2 m and 5 m trials using two-way, random effects intraclass correlation coefficient ($ICC_{(2,1)}$) models and Bland–Altman plots. Point estimates of the ICCs were interpreted as follows: excellent (0.75–1), modest (0.4–0.74), or poor (0–0.39).[7] The absolute error quartiles and percentage of trials in error range thresholds are also reported.

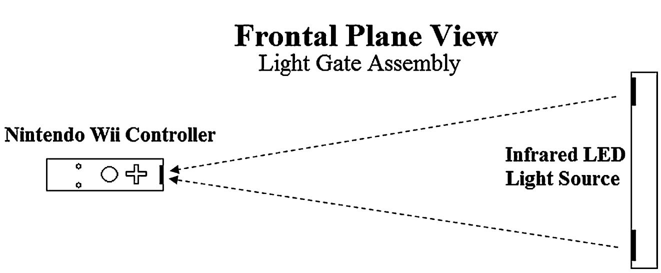

Fig. 1. Timing light gate setup using the Nintendo Wii hand controller and a dual cluster infrared LED light source.