A COMPARISON OF HAND FORCE AND STARTING BLOCK-BASED RESPONSE TIMES IN THE SPRINT START.

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This study provided a method comparison of sprint start response times (RTs) obtained using a custom designed hand force plate with block response-times (RT) from an International Association of Athletic Federation (IAAF) approved automatic start control system (IAAF RT). Twenty national and international sprinters completed sprint trials under simulated race conditions. The athletes' hand forces were obtained using the hand force plate, which was electronically synchronised with the IAAF approved system. The results showed that in all trials, the hand plate RT occurred significantly before the IAAF RT with an average difference of 64 ms. The consistent differences in RT's suggested that the two systems measured separate events. A re-evaluation of false start detection technology based on measuring hand RT is recommended.

KEYWORDS: reaction time, sprint start, track and field.

INTRODUCTION: The sprint start in athletics is an important element of competitive races, which can have a major influence in determining the outcome of the race, especially in shorter sprint events. The detection of RT in the sprint start presents a significant and important biomechanical problem since practicable methods for detecting RT must rely on force or acceleration changes detected using sensors which are external to the athlete. Current International Association of Athletic Federation (IAAF) rules define a false start as an athlete initiating their sprint earlier than 100 ms after the start signal (IAAF, 2015). In recent years, the validity and reliability of RT measurements have been questioned in the scientific literature (Komi, Ishikawa & Salmi, 2009; Lipps, Galecki & Ashton-Miller, 2011; Pain & Hibbs, 2007; Brosnan et al., 2017). Pain and Hibbs (2007) examined RTs using instrumented blocks and a custom algorithm to detect the initial change in force following the start signal, and found that athletes could attain valid RTs of <100 ms. Analysis of large data sets of RTs from major championships indicated that legal RTs of <120 ms are improbable when using IAAF approved systems (Lipps, Galecki & Ashton-Miller, 2011; Brosnan et al., 2017). Komi et al, (2009) examined the sprint start response sequence found and a clear trend of earlier responses in the hand forces compared with the block force RT. Despite this finding, Komi et al, (2009) did not consider the further step of examining the hand forces to detect the false start event and their recommendation was that a multi-camera system be explored as a means of detecting false starts in competition. It is significant that Komi et al, (2009) only examined responses in a laboratory-based set up and the measurement equipment employed in the study would not be suitable for use in athletics competition. The examination of alternative methods to detect RT in competition would require custom-built devices that could be used in a competition environment.

For fairness in competition, it is crucial that false starts are correctly and accurately determined and the technical equipment for detection of the athlete's first response to the start signal is valid, reliable and suitable for implementation in a competition environment. Consequently, there is a need to re-examine the reliability of event detection in the sprint start in athletics and the technology used to detect false starts. This study aimed to compare RT's detected from changes in hand forces with RT's determined by an IAAF approved automatic control system which used accelerometers mounted on the starting block rails.

METHODS: Twenty national and international level sprinters (16 males, 4 females) were recruited for this study. Participants mean age was 22.6 ±2.6 years (mean ±SD) and mean training age was 7.5 ±3.0 years. Table 1 provides the anthropometric characteristics of the participants. All participants were injury free for a minimum of six months before testing and were experienced in performing sprints starts from blocks. All participants provided written consent prior to participation and the study had ethical approval from the local university research ethics committee.

Table 1: Anthropometric Characteristics of Participants

Variable	Male (n=16)		Female (n=4)	
	$\bar{x}$	SD	$\bar{x}$	SD
Mass (kg)	75.55	6.82	61.60	11.42
Height (cm)	179.3	7.3	166.0	10.0

Sprint Testing Protocol: Following individualised competition warm-ups, each athlete performed three valid sprint starts from blocks over a minimum distance of 10 m. The athletes completed all trials in a simulated competition under IAAF race conditions with another athlete providing competition in the adjacent lane. All starts were under the control of IAAF accredited starters and an IAAF approved false start detection system was used to determine RT's and automatically detect false starts using IAAF rules (RT <100 ms). A recovery of at least 3 minutes was allowed between trials to maintain performance levels during trials.

Instrumentation: A custom-built force plate was used to determine hand forces during the start. The force plate incorporated a Tedea-Huntleigh 1042 single point cantilever load cell (Chatsworth, CA, USA) within a steel frame and top plate. The total dimensions of the plate were 1220 ×180×68 mm (L×W×H). The force plate was built into custom-built synthetic track surface, which ensured the top plate was level with the track surface. A white line was marked on the top plate to indicate the start line. The starting signal from the IAAF approved system, was provided by an electronic starting gun (Pro Version TTC-063, TimeTronics, FalseStart III Pro, Olen, Belgium). All force data was recorded using a PowerLab system 4/20 (ADInstruments, Sydney, Australia) sampling at 2000 Hz. The starting signal was split to provide a simultaneous event to FalseStart III Pro and Powerlab systems. RT data from the hand force plate was determined by visual inspection using LabChart 8 software (Visual RT).

Data Analysis: The RT from the hand force plate was visually determined by finding the last point before there was a continuous incline in the force signal for a sustained period consistent with the start of a significant starting movement. The IAAF RT was determined automatically by sensors attached to the block rail using a TimeTronics FalseStart III Pro system.

Limits of agreement, LoA (Bland and Altman, 1999), and the technical error of measurement, TEM (Perini et al., 2005) were used to examine the level of agreement between the visually determined Hand RT and IAAF RT. Differences in mean RT's between the two RT detection methods were evaluated using a paired t test and Cohen's d_z effect size.

RESULTS: The response time mean ($\bar{x}$), SD, minimum, maximum and the differences between methods are provided for the Hand RT and IAAF RT in table 2. The results showed that the hand force RT occurred before the IAAF system on every trial with a large range of difference in RT of 15 to 286 ms. The paired t test indicated a significant difference between the mean IAAF RT and the Hand RT ($p < 0.001$) with a very large effect size (d_z =1.55)

Table 2: Summary RTs from hand force plate and IAAF system and differences in RT between systems

RT Detection Method	$\bar{x}$ RT (s)	SD (s)	Min RT (s)	Max RT (s)
Hand force plate	0.074	0.050	-0.124	0.136

IAAF RT	0.138	0.032	0.009	0.185
Difference	0.064	0.042	0.015	0.286

Figure 1 provides a typical example, illustrating the output of the hand force plate and showing the start signal (red vertical line). In all trials for all participants, the visually determined hand plate response occurred before the IAAF RT.

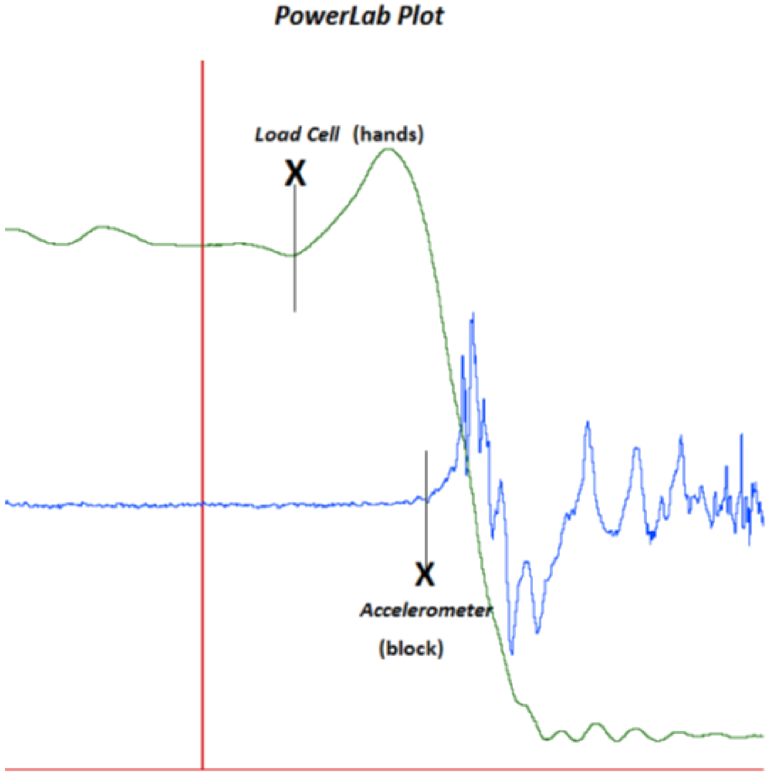

Figure 1: Schematic of hand force plot showing the start signal (red vertical line), hand plate RT (Load Cell) and IAAF RT (accelerometer).

The LoA and TEM scores comparing Hand RT with IAAF RT are provided in Table 3. The results indicated a very large relative TEM between the systems of 50.9%.

Table 3: Comparison of Hand with TimeTronics IAAF RT providing mean difference, Upper and Lower LoA, and Technical error of measurement

Methods Compared	Lower LoA (s)	Upper LoA (s)	Absolute TEM (s)	Relative TEM (%)
IAAF RT vs Hand RT	-0.017	0.145	0.054	50.9

DISCUSSION: The results of the comparisons of both the Hand RT and the IAAF RT revealed that the Hand RT always occurred before the IAAF RT. The wide range of differences and large relative technical error of measurement indicated that the differences in RT are unpredictable and therefore the IAAF RT does not reliably predict the true first response of the athlete to the start signal. These data fundamentally oppose the use of block-based sensors to detect the athletes' first response in competition and suggest that current IAAF approved false start detection technologies may be unreliable and not valid. The results also indicated that the RT delay currently set at 100 ms, is technology dependent and therefore support the conclusions of recent studies that have questioned the 100 ms rule (Komi, Ishikawa & Salmi, 2009; Lipps, Galecki & Ashton-Miller, 2011; Pain & Hibbs, 2007; Brosnan et al., 2017).

While the use of a visual method to detect the Hand RT has limited objectivity, the magnitude of the differences between the hand RT and IAAF RT is often so large that the IAAF RT generally occurred later than the peak hand force or even after the hands lost contact with the ground. More research and development is needed to improve the design of the hand force detection system and to test objective and reliable methods for determining the Hand RT within a system that could be implemented in real time in competition conditions. Since the participants in this study were all experienced national and international level sprinters and the Hand RT always preceded the IAAF RT, this suggests that it would be difficult for a sprinter to make technical adaptations to change the response sequence.

The results of this study add further support for a re-evaluation of detection methods used to determine RT's using starting blocks and provide support for the development of technology to detect false starts in competition using hand force. On a practical level the absolute TEM between Hand RT and IAAF RT was 54 ms, this would translate to a distance of approximately 50 cm in an international sprint competition. The results of this study also suggest that a revised RT limit would be required if Hand RT was introduced to detect false starts in competition. This revised RT limit could be determined using an exponentially modified Gaussian distribution as implemented by Brosnan et al (2017) when evaluating the existing 100 ms limit. The results suggest that the introduction of a Hand RT system for detecting false starts in competition would improve the fairness of competition by detecting false starts that currently may be undetected using existing IAAF approved technologies.

CONCLUSION: This study found that RT's detected using a hand force plate occurred on average 64 ms earlier than IAAF RT's using a TimeTronics system. There is a need for re-evaluation of block based RT's and further research is required to create an algorithm that can replicate the results of the Visual method RT on a real time basis.

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