CONTRIBUTION OF NEW START INFORMATION SYSTEM PROTOTYPE TO THE FALSE START DETECTION IN ATHLETICS

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This study aimed at comparing a prototype of a new Start Information System (SIS) with a World Athletics (WA) certified SIS which was used in competition. Twenty sprinters performed sprints under simulated race conditions. Response time (RT) was recorded by the WA certified SIS and the new SIS prototype based on a custom force plate and a new event detection algorithm to assess RT as the onset of arm force reaction. The mean value from RT recorded by the new SIS prototype for trials for which the RT given by the WA certified SIS were ranged between 100 ms and 119 ms ($RT_{WA\ 100\text{-}119\ ms}$) was 0.047±0.019 s. This result highlighted $RT_{WA\ 100\text{-}119\ ms}$ were probably false start according to the theoretical minimum auditory RT, despite being valid by the current WA regulation. The revisited new SIS prototype technologies were more appropriate to detect false start in athletics.

KEYWORDS: response time, sprint start, athletics.

INTRODUCTION: The sprint start in athletics is strictly controlled to ensure the fairness of the competition. According to the World Athletics (WA) federation (formerly International Association of Athletics Federations or IAAF) Book of Rules, if the athlete responds under the 100 ms, he or she is assumed to have anticipated the start signal and is removed from the race. The response time (RT) is assumed to be measured to a precision of one millisecond by the Start Information Systems (SIS), which are certified by the WA to be used in competition. The SIS assesses RT by evaluating force or acceleration changes recorded by sensors integrated in within, or secured to the starting blocks. The validity and the reliability of the SIS have been questioned in the literature (Willwacher et al., 2013; Komi et al., 2009; Lipps, et al., 2011; Pain & Hibbs, 2007). The event detection algorithms have been criticised for delaying the RT detection, especially for women athletes (Komi et al., 2009; Lipps, et al., 2011; Pain & Hibbs, 2007). It is reasonable to expect that RT should be determined from the first practically detectable biomechanical event that accompanies the response to the start signal. It has been shown that the onset of the leg pushing action occurs after the onset of arm force reaction (Harrison et al., 2018; Komi et al., 2009). Consequently, there is an urgent need to revise the WA approved SIS which could be improved by assessing RT from the onset of arm force reaction and by improving the event detection algorithm.

The 100ms false start threshold has also been questioned in the literature. Some studies have carried out statistical analysis with large samples of RT recorded during the major international competitions (Brosnan et al., 2017; Lipps, et al.,2011). Brosnan et al. (2017) suggested increases were required in the false start threshold of 15 ms for men and 19 ms for women. This would mean that RTs between 100 ms and 119 ms for women, and between 100 ms and 115 for men ms, were redefined as false start despite as being considered by valid by the current WA certified SIS. RTs between 100 ms and 119 ms may be considered as controversial and this highlights the importance of correctly defining the minimum auditory RT to detect false start in athletics.

For fairness in competition, it is crucial that RTs are correctly and accurately determined, and the WA false start detection regulation is supported by robust evidence. A new SIS prototype was developed for this purpose to improve false start detection. The prototype is based on a custom hand force plate, which was built and validated to detect RT from the arm force reaction in a simulated competition environment (Harrison et al., 2018) and uses an event detection algorithm to detect RT without inducing threshold-based delay. This study aimed to evaluate the potential contribution of the new SIS prototype to the false start detection and RT detection, especially for RT ranged between 100ms and 119 ms by an actual WA certified SIS.

METHODS: The protocol of this study was previously described (see Harrison et al., 2018). Twenty Irish national and international level sprinters (16 males, 4 females) participated in this study. Participants mean age was 22.6 ±2.6 years (mean ±SD) and mean training age was 7.5 ±3.0 years. The mean athletes' WA scoring points was 953.0 ± 116.0 points. All athletes were proficient with the block starting technique and had extensive starting block experience. All sprinters were injury free and gave written informed consent to participate in the study following institutional ethical approval.

Sprint Testing Protocol: After an individualised competition warm-up, each athlete performed three valid sprint starts from blocks over a minimum distance of 10 m on an indoor track with a three-minute recovery between each trial. If the WA certified SIS used to record RT (FalseStart III Pro, TimeTronics, Olen, Belgium) displayed a false start, the athlete performed an additional sprint start until three valid start were recorded for each athlete. Athletes completed all trials in a simulated competition under IAAF race conditions with another athlete providing competition in the adjacent lane. WA accredited starters supervised starts according the WA book of rules.

Instrumentation: Hand forces were recorded during the start by a custom-built force plate. The force plate consisted of two steel blades, which enclosed a Tedea-Huntleigh 1042 single point cantilever load cell (Chatsworth, CA, USA). The total dimensions of the plate were 1220 ×180×68 mm (L×W×H). A custom-built synthetic track surface was used to ensure that the top plate was level with the track surface. A white line on the top of the plate materialized the start line. Force data was recorded using a PowerLab system 4/20 (ADInstruments, Sydney, Australia) sampling at 2000 Hz. RT was recorded by a WA certified SIS (FalseStart III Pro, TimeTronics, Olen, Belgium). A WA certified electronic starting gun (Pro Version TTC-063, TimeTronics, FalseStart III Pro, Olen, Belgium) delivered the start signal and provide a simultaneous event to FalseStart III Pro and Powerlab systems to compare RT from the hand plate and the WA certified SIS.

Data Analysis: The force data were imported to R software (R Core Team, 2018) to be analysed. The signal from the hand force plate was proceed by a custom algorithm. The signal was smoothed by a fourth-order zero-lag low-pass Butterworth filter with a cut-off frequency of 20 Hz. The algorithm detected the beginning of the longest series of the consecutive "substantial" increasing values. The "substantial" increase between two consecutive values was defined by a personalized threshold computed from the signal recorded during the set position. The beginning of the longest series is defined as the RT. All RT given by the algorithm were visually checked and validated by two independent experimenters. The RT mean and standard deviation was computed.

Table 1: Mean and standard variation of RTs classified according the time given by the WA certified SIS

$RT_{WA\ false\ start}$ N=3	WA certified SIS	0.039 ± 0.034 s
	new SIS prototype	-0.037 ± 0.069 s
$RT_{WA\ 100\text{-}119\ ms}$ N=10	WA certified SIS	0.111 ± 0.005 s
	new SIS prototype	0.047 ± 0.019 s
$RT_{WA\ >119\ ms}$ N=50	WA certified SIS	0.150 ± 0.018 s
	new SIS prototype	0.076 ± 0.02 s

RESULTS: 63 trials were recorded and analysed. Figure 1 illustrates the RT given by the custom algorithm and the WA certified SIS RT was added to illustrate the delay between both events. RT recorded by the new SIS prototype were shorter than RT from the WA certified SIS (0.067 ± 0.0349 s vs 0.138 ± 0.0316 s). The mean and standard deviation for RT false start (i.e., RT<100ms, $RT_{WA\ false\ start}$), RT in the range of 100-119 ms ($RT_{WA\ 100\text{-}119\ ms}$) and RT above 119 ms ($RT_{WA\ >119\ ms}$) according to the WA certified SIS are presented in Table 1.

DISCUSSION: The results of the comparison of the new SIS prototype, based on a hand force plate and a new detection event algorithm, and one WA certified SIS currently used in competition offered a new understanding of false start in athletics. The new SIS prototype confirmed false starts given by the WA certified SIS since the mean average RT given by the new SIS prototype was negative, indicating that athletes had effectively anticipated the start signal. Secondly, the new SIS prototype seemed to confirm results of Brosnan et al. (2017) who claimed that RT recorded from WA certified SIS in the range of 100-119 ms could be false starts. A mean RT of 0.047 ± 0.019 s from the new SIS prototype for $RT_{WA\ 100\text{-}119\ ms}$ indicated that $RT_{WA\ 100\text{-}119\ ms}$ were false start since the neuromuscular-physiological limit of simple auditory RT should be around 73-83 ms (Pain & Hibbs, 2007). The new SIS prototype RTs, therefore, showed that athletes probably anticipated the start signal when RTs from WA certified SIS were ranged between 100-119ms. This result also confirmed that the current 100 ms false start threshold should be increased when using the current WA certified SIS. However, it is likely that a simple adjustment of the existing 100 ms threshold to 119ms would not be sufficient to ensure fairness, since RT detection should seek to determine the athlete's true first response to the start signal, which clearly occurs in the hand force signal rather than the block force response.

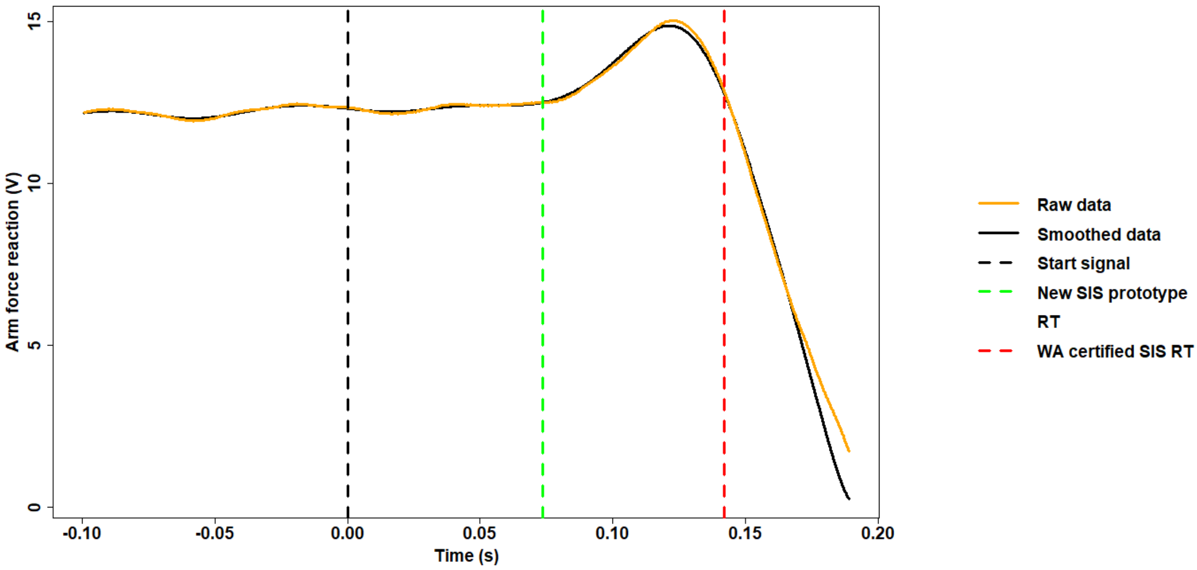

Figure 1 : Example of hand force plot showing the RT (green dotted line) after the hand force reaction signal was processed by the custom algorithm and RT given by the WA certified SIS (red dotted line).

The average RT given by the new SIS prototype for $RT_{WA\ >119\ ms}$ was very close of the theoretical neuromuscular-physiological limit of simple auditory RT. These near optimum RT's found in the study could be explained by the high-level experience of the sprinters in this sample, who were all international or national level sprinters. It has been shown that competition related training can improve RT to an auditory stimulus (Papic et al., 2019) and the experienced sprinters in this study had acquired optimal RT through training. These preliminary results also highlighted the need to redefine the false start criterion according to the SIS technology used for detecting the response. A potential adoption of a new generation of SIS based on the detection of the onset of arm force reaction would therefore require the reduction of the 100 ms false start threshold; however, the exact duration of the revised minimum RT is as yet unknown, but will most likely be between 73 and 85 ms.

The new SIS prototype provided some improvements in comparison with the WA certified SIS currently used in competition. The RT $_{WA\ >119\ ms}$ was very close of the theoretical neuromuscular-physiological limit of simple auditory RT and this provided evidence that the onset of the arm force reaction was the first detectable biomechanical event during sprint start. The results support the implementation of the new SIS since the current SIS technologies and WA sprint start regulations failed to detect all the false starts. The results also showed that the new custom algorithm did not induce delays in RT detection in comparison with previous event detection algorithms used by SIS (Komi et al., 2009; Lipps, et al.,2011; Pain & Hibbs, 2007). The main limitation of this study is that the existing prototype cannot be used in competition because of its dimensions. The prototype requires miniaturisation to fulfil the competition requirements, improve portability and be easily set up on the track surface. Further research and development are therefore required to miniaturise the hand plate and facilitate real-time detection of the onset of arm force reaction. Despite this limitation, the prototype demonstrates the need to consider hand forces in determining RT.

The current WA false start regulations increases the level of caution by sprinters who prefer to respond later instead of risking disqualification (Haugen et al., 2013). The adoption of a revised regulation closer to the true minimum RT in athletics, based on the onset of arm force reaction and a better event detection algorithm, would allow sprinters to respond without the fear of being disqualified for false start. Such regulation would likely improve sprinters' RT, and consequently, race time improvements could be expected. Further research is therefore required to revise false start regulations based on robust scientific data.

CONCLUSION: This study evaluated a new SIS prototype based on a hand force plate technology and a new event detection algorithm. The results show that the revised technology could detect false starts that would go undetected by existing WA certified SIS. There is an urgent need to revisit the current 100 ms false start threshold and event detection technology. Further research is required to miniaturise a device, which will be able to detect the onset of arm force reaction during sprint start in competition.

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ACKNOWLEDGEMENTS: Matthieu Milloz was supported by an Irish Research Council Government of Ireland Scholarship.