A METHOD COMPARISON STUDY OF ACCELEROMETER BASED BLOCK RESPONSE TIMES IN SPRINTING

Jonathan Holmes[1], Kevin Hayes[2] and Andrew J. Harrison[1]

Biomechanics Research Unit, University of Limerick, Limerick, Ireland[1]
Department of Mathematics and Statistics, University of Limerick, Limerick, Ireland[2]

This study aimed to provide a method comparison of a rail mounted accelerometer for detection of block response-times (RT) with 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. An accelerometer was placed on the block rail of blocks and RT was determined using visual inspection of the accelerometer signal and using a 3SD threshold method. On average, the visual method detected the RT event 7 ms before, and the 3SD method detected RT 1 ms after the IAAF RT. The results indicated close agreement between the 3SD threshold method and the IAAF RT, however, this highlights the need for further re-examination of threshold-based detection algorithms which may delay the detection of the RT event.

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

INTRODUCTION: In major athletics competitions, sprint response times (RT) are currently detected using IAAF accredited false start detection systems. These systems determine athletes' RT using encased accelerometers or force sensors fixed to the rear of the starting block rail to detect changes in force or acceleration exerted on the blocks through the feet. Reaction time has been defined as the time from the presentation of a stimulus until the production of force (Mero & Komi, 1990), although a more accurate term for this time is response time, RT (Brosnan, Hayes & Harrison, 2017). In athletics, the RT is determined as the total time between the start signal and the athlete exerting a signal above a predetermined threshold of force or acceleration on the blocks. In recent years, the validity and reliability of RT measurements in athletics 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 RT using blocks instrumented with piezoelectric force transducers and a custom algorithm to detect the initial change in force following the start signal, and found that athletes could attain valid RT of <100 ms. Analysis of large data sets of RT from major championships indicated that legal RT of <120 ms are improbable when using IAAF approved systems (Lipps et al., 2011; Brosnan et al., 2017). These delays in RT detection could be caused by the threshold-based algorithms used to detect the RT. Consequently, there is a need to re-examine the effect of event detection method on the sprint start RT in athletics and revise the technology used to detect false starts.

This study aimed to provide a method comparison of RT derived from an IAAF-approved automatic control system with RT from a custom built accelerometer mounted on the block rails. This method comparison examined the total effect of the systems on RT determination including the sensor technologies and effect of the detection algorithms.

METHODS: Twenty national and international level sprinters (16 males, 4 females) were recruited for this study. Mean ± SD of age was 22.6±2.6 years and 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 and completed one testing session of sprints starts in a simulated competition. 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 sprints from blocks over a minimum distance of 10 m. The athletes completed trials 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 and automatically detect false starts. An additional accelerometer was secured to the block rail immediately in front of the TimeTronics system to provide a raw data output of block rail acceleration and direct comparison with the IAAF RT. Each athlete completed three valid trials (three athletes completed a fourth trial where a false start occurred; i.e. IAAF RT <100 ms, or there was a system malfunction). A recovery of at least 3 minutes was allowed between trials to maintain performance levels during trials.
Instrumentation: The starting signal from the IAAF approved system, was provided by an electronic starting gun (Pro Version TTC-063, TimeTronics, Olen, Belgium). A surface mounted micro-machined silicone capacitive Accelerometer X-AXIS sensitivity (MMA2241KEG, Freescale Semiconductor, Inc. Austin TX, USA) was secured horizontally to the back of the starting block rail. All 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 trigger to TimeTronics FalseStart III Pro system (TimeTronics, Olen, Belgium) and the Powerlab system.
Data Analysis: RT data from the rail accelerometer were determined by two methods; firstly by visual inspection using LabChart 8 software (Visual RT) to determine the last point before there was a continuous incline in the accelerometer signal for a sustained period consistent with the start of a significant movement that occurred after the start signal. Secondly, by implementing a threshold method where 3×SD of the accelerometer variance was added to the mean accelerometer signal during the set position (Rail 3SD). The TimeTronics FalseStart III Pro system automatically provided the RT results after each trial for comparison (i.e. IAAF RT). Intraclass correlation coefficients (ICC) were calculated to compare IAAF RT with Visual RT and IAAF RT with Rail 3SD. Pearson's correlations were used to determine the relationships between the Visual RT, the Rail 3SD RT and IAAF RT. Limits of agreement (LoA) were used to examine the level of agreement between the Visual RT vs IAAF RT and the Rail 3SD RT vs IAAF RT. All statistical analyses were completed in the statistical package R 3.3.2.

RESULTS: The minimum, mean, maximum, scores are provided for the Visual RT, Rail 3SD and IAAF RT in Table 2.

Table 2: Summary of the Visual RT, Rail 3SD RT and IAAF RT

Detection Method of RT	$\bar{x}$ RT (s)	SD (s)	Min RT (s)	Max RT (s)
Visual RT	0.131	0.030	0.008	0.182
Rail 3SD RT	0.139	0.031	0.012	0.188
IAAF RT	0.138	0.031	0.009	0.185

Figure 1 provides a typical example, of the output of the stimulus of the gun (black vertical line), Visual RT (blue vertical line), Rail 3SD (orange vertical line), and IAAF RT (red vertical line). The results show a large majority of participants displayed the same sequence of events as shown in Figure 1 with the Visual RT occurring before the IAAF RT on 57 of the 64 trials.

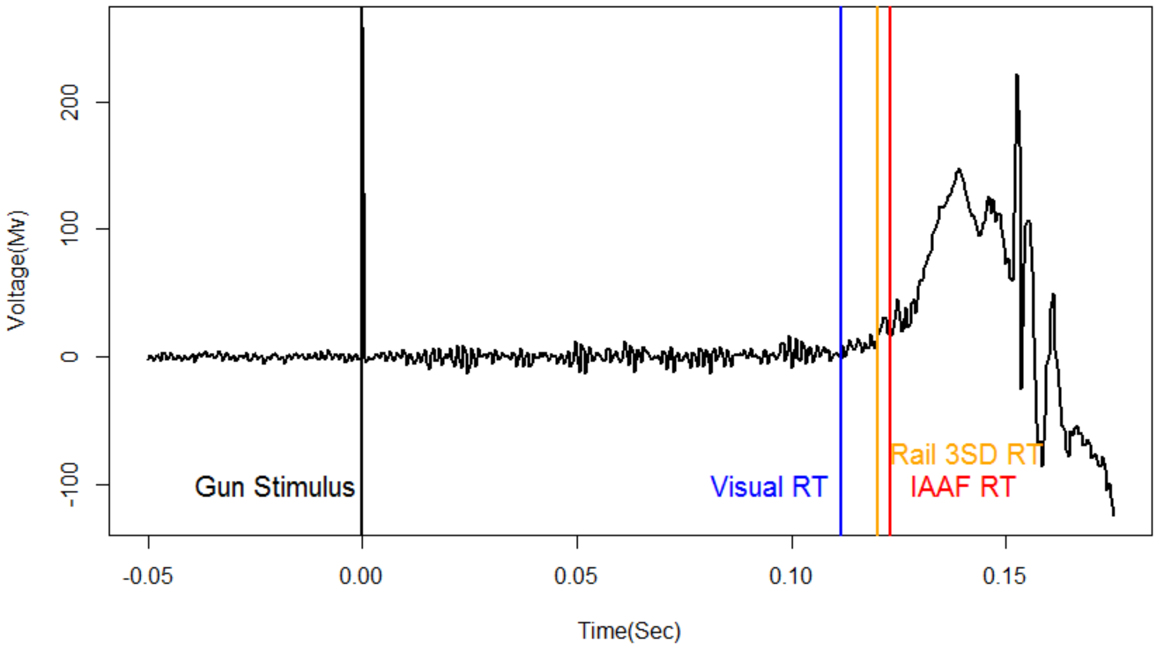

Figure 1: Graph demonstrating rail accelerometer data including additional lines specifying the Gun Stimulus (black), Visual RT (blue), Rail 3SD RT (orange) and IAAF RT (red), for one participant.

The ICCs comparing Visual RT vs IAAF RT and IAAF RT vs Rail 3SD are provided in Table 3 together with the 95% confidence LoA. The Pearson's correlations of 0.980 and 0.990 ($p < 0.001$) indicated very strong relationships between Visual RT and IAAF RT and Rail 3SD and IAAF RT. The mean difference between Visual RT and IAAF RT was -7 ms, indicating a bias towards an earlier detection of RT using visual inspection.

Table 3: Comparison of Visual RT and Rail 3SD methods with IAAF RT

Methods Compared	Mean difference (s)	Lower Limits of Agreement	Upper Limits of Agreement	Intraclass Correlation Coefficient	Pearson's Correlation
Visual - IAAF RT	-0.007	-0.020	0.005	0.960	0.980 **
IAAF - Rail 3SD	0.001	-0.010	0.011	0.990	0.990 **

** $p<0.001$

DISCUSSION: The results of the comparisons of both the Visual RT and the Rail 3SD RT with the IAAF RT revealed very strong correlations between Visual RT and Rail 3SD when compared to the IAAF RT. While the ICCs of 0.96 of 0.99 indicated excellent consistency between the measures, (Koo & Y Li, 2016), the LoA showed a clear systematic bias detecting RT using the visual method, which on average, detected RT 7 ms earlier than the TimeTronics system. The results of the comparison between the IAAF RT and the Rail 3SD RT methods indicate very good agreement between the methods and this suggests that the Rail mimics the IAAF RT detection procedure very well and could be used as an alternative to an IAAF approved system for detecting block RT. The very strong correlations provide good evidence that all three methods appear to be estimating the same phenomenon (RT in the blocks), but the LoA data for the visual method clearly indicates an earlier detection of the block RT. Recent studies have suggested that IAAF-approved systems may introduce delays in the detection of block RT due to the introduction of RT thresholds, leading to late detection of the event (Lipps et al., 2011; Brosnan et al., 2017). Poor control and lack of normalisation of thresholds could explain the observed differences in competition RT between men and women (Brosnan et al., 2017). Based on the results of this study, the observed difference between the Visual RT and IAAF RT is mostly due to the event detection method used. Pain & Hibbs, (2007) examined block RT using backwards extrapolation of the block forces and proposed that athletes could produce valid RT of <100 ms. This backwards extrapolation technique could be considered to be conceptually similar to the visual detection method used in this study, which visually identified a change, or point of inflection in the accelerometer signal.

The results of this study add further support for a re-evaluation of detection methods used to determine RT using starting blocks. The results show that measured RT is subject to variability depending on the nature of the detection algorithm used, and that threshold-based algorithms may introduce delays in RT detection. This problem is compounded further by the lack of standardisation of detection methods used in the various IAAF-approved starting systems. It has been estimated that when using force-based thresholds, that the threshold for female sprinters during the Beijing Olympics would have had to been reduced by 22% to produce the same reaction times as their male counterparts (Lipps et al., 2011). The Visual RT method used in this study has the advantage that the detected RT is unbiased, as it does not use any form of threshold which can be influenced by variations in body mass, gender or strength, however, implementation of a visual method would be impracticable in competition where the need for real time detection is essential. Despite this, the results indicated that the accelerometer technology developed for this study provides very similar results to an IAAF approved system and as such, it provides access to raw accelerometer data that are not readily available via the IAAF approved systems. Consequently, the accelerometer system developed for this study could provide an appropriate laboratory based system for exploring and optimising event detection algorithms for the sprint start.

CONCLUSION: This study found the Visual RT method detected block RT on average 7 ms earlier than IAAF RT using a TimeTronics system. There is a need for re-evaluation of block based RT and further research is required to create an algorithm that can replicate the results of the Visual method RT on a real-time basis.

REFERENCES

Brosnan, K., Hayes, K., & Harrison, A. J. (2017). Effects of false-start disqualification rules on response-times of elite-standard sprinters. *Journal of Sports Sciences, 35*(10), 929-935. doi:10.1080/02640414.2016.1201213

Komi, P., Ishikawa, M. & Salmi, J. (2009). IAAF sprint start research project: Is the 100 ms limit still valid? *New Studies in Athletics, 24*(1), 37-47.

Koo, T., & Y Li, M. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine*, 15(2), 155-163.Doi:10.1016/j.jcm.2016.02.012

Lipps, D., Galecki, A., & Ashton-Miller, J. (2011). On the implications of a sex difference in the reaction times of sprinters at the Beijing Olympics. *PLoS ONE,6*(10). doi:10.1371/journal.pone.0026141

Mero, A., & Komi, P. (1990). Reaction time and electromyographic activity during a sprint start. *European Journal of Applied Physiology and Occupational Physiology,* 61(1-2), 73-80. *doi:10.1007/bf00236697*

Pain, M. & Hibbs, A. (2007). Sprint starts and the minimum auditory reaction time. *Journal of Sports Sciences, 25*(1), 79-86. doi:10.1080/02640410600718004