VISUAL DETECTION OF RESPONSE TIME IN ATHLETICS: A “GOLD STANDARD”?

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1

The response time (RT) in the sprint start in athletics is determined automatically from sensors on the blocks but the final decision on whether an athlete is disqualified is determined by visual inspection of the sensor data. This study explored the level of uncertainty of the visual detection of athletes’ RT in the sprint start. Fifteen sprinters performed six sprint starts while forces from the front block, rear block and hands were recorded. Two experimenters performed visual RT detection on two consecutive occasions using two sizes for the analysis window. Intra- and inter-reliability analysis indicated that the mean level of uncertainty of the visual detection was approximately 20 ms for the starting block data. More research is needed to formally assess the precision of the visual detection, which may result in changes in the current false start regulation.

KEYWORDS: response time, sprint start, athletics.

INTRODUCTION: Regulation of sprint starts in athletics presents a challenging technical and biomechanical problem. The World Athletics (WA) Federation implements strict sprint start regulations to ensure no athletes gain an unfair advantage by responding in <100 ms after the start signal, (World athletics, 2019). WA certified Start Information Systems (SIS) are used in competition to record the athlete response time (RT) with an assumed precision of 1 ms. This assumption is based on the fact that an athlete may be disqualified with a RT of 99 ms and the minimum RT is defined as 100 ms. The SIS integrate sensors in the starting blocks which convert the leg actions on the blocks to a waveform signal which is processed by an automated event detection algorithm to determine RT. The validity and the reliability of the SIS have been questioned in the literature and the absence of a reference criterion to certify the SIS has been noted (Willwacher et al., 2013). The use of different event detection algorithms can be expected in absence of a reference criterion. Event detection algorithms can have an effect on RT detection, which can exceed 25 ms (Pain & Hibbs, 2007). The standardisation of different algorithms by the various SIS manufacturers is therefore important for fairness of competition since false starts across all systems are determined using the same 100 ms false start threshold. The definition of a reference criterion is required to improve and standardise event detection and ensure immediate detection of the onset of the change in the sensor waveform signal.

While SIS determine the RT automatically, the final decision on whether to disqualify an athlete is made by visual inspection of the block response data. In biomechanics, visual detection is considered more sensitive and accurate than event detection algorithms to detect the onset of an electromyography or force signal, and it has been suggested that visual detection should be used as a reference criterion for SIS certification (Milloz et al., 2021). Terczyński, (2014) showed that visual methods detected RT earlier than the RT from a WA certified SIS (7 ms for women and 21 ms for men on average) highlighting that SIS did not reliably predict the true first athlete response. No study to date, has assessed the precision of the visual RT detection in athletics. A recent study published the intra-reliability analysis of the visual identification of the onset of ground reaction force in an isometric mid-thigh pull task (Guppy et al., 2021). The mean, minimum and maximum differences between the two consecutive analysis sessions were respectively 6, -11 and 21 ms, highlighting some uncertainty in the visual detection, despite an “excellent” intraclass correlation coefficient. Assuming visual detection as the “gold standard” in event detection, it is crucial to determine precisely the level of uncertainty in the RT visual detection, as a preliminary step in the definition of a reference criterion for the SIS certification.

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. This study aimed to explore the level of uncertainty in visual detection of RT in athletics and compare it with the assumed SIS precision (1 ms).

METHODS: Fifteen Irish national and international level sprinters (8 males, 7 females) participated in this study. The participants' mean and SD of age were 22.9 ± 2.7 years, height 1.76 ± 0.10 m and mass 71.3 ± 9.9 kg. The mean athletes' WA scoring points was 1010.5 ± 98.2 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 six maximal intensity sprint starts from blocks over 3 m due to the dimension of the lab. Athletes wore their own spike shoes and were proficient with the block starting technique. The recovery between trials was three minutes.

Instrumentation: Front and rear foot reaction force data were recorded with custom-built instrumented starting blocks which integrated one mono-axial compensated load cell (F256EFR0KN, Novatech Measurements Limited, St Leonards on Sea, UK) into each block. The hand force was simultaneously recorded by a custom-built force plate which 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. All force data was recorded using a PowerLab system 4/20 (ADInstruments, Sydney, Australia) sampling at 2000 Hz. The starting signal delivery system was connected to PowerLab system. Visual RT inspection from the various force waveform signals was determined using LabChart 8 software.

Data Analysis: The RT visual detection from hands, front block and rear block was performed in LabChart 8. Two independent experimenters (Ex 1 and Ex 2) carried out the visual detection analysis on two occasions separated by few days. The analysis was standardised and consisted of: **1)** finding manually the start cue and set the time so that the zero was matched to the start cue **2)** Defining a window of analysis for the visual detection which included the impulse from hands or feet. Two different size windows were used. One time window was set at 3.5 s (Large window, LW) which was the average duration between the set and the start command (Pain & Hibbs, 2007) and allowed experimenters to have an overview of the variation of force signal during the set and before the impulse. The second time window (small window, SW) was set at 1 s which was long enough to have an overview of the variation of the force signal before the impulse. The height of the time window was set at 20 mV. **3)** Assessing RT as the significant onset of the force reaction. The average of the two consecutive visual detections was computed for each RT and used for the analysis of the inter-reliability and the effect of the size window on RT detection. The intra and inter-reliability and the effect of the window size on visual detection was assess using the mean differences and the 95% limit of agreement (95%LoA) (Bland & Altman, 1986).

RESULTS: The means and standard deviations of RT are presented in **Error! Reference source not found.**. **Error! Reference source not found.** provide the mean differences and the 95%LoA of the intra and inter-reliability analysis. The Bland and Altman plot representing the inter-reliability of the front foot RT, which was visually determined with a SW, is shown in **Error! Reference source not found.**. The effect of the size of the analysis window on the RT visual detection are presented in **Error! Reference source not found.**.

	Experimenter 1		Experimenter 2	
	Large Window	Small Window	Large Window	Small Window
Hands	0.095±0.035 s	0.107±0.036 s	0.103±0.031 s	0.109±0.032 s
Front block	0.167±0.04 s	0.175±0.042 s	0.171±0.041 s	0.178±0.042 s
Rear block	0.153±0.042 s	0.161±0.039 s	0.158±0.039 s	0.166±0.039 s

Table 1. Visually determined RT means and standard deviations according the experimenters and the size of the analysis window.

	Intra-reliability				Inter-reliability	
	LW		SW		LW	SW
	EX 1	EX 2	EX 1	EX2		
Hands	0±0.007 s	0.001±0.012 s	0±0.004 s	0.002±0.013 s	-0.008±0.032 s	-0.002±0.028 s
Front block	-0.001±0.011 s	0.001±0.016 s	0±0.006 s	-0.002±0.019 s	-0.004±0.021 s	-0.004±0.012 s
Rear block	0±0.008 s	0.001±0.010 s	-0.001±0.005 s	-0.001±0.011 s	-0.005±0.022 s	-0.005±0.017 s

Table 2.Intra and inter-reliability assessed by the mean difference ±95% LoA of RT according to the size of the analysis window.

	Experimenter 1	Experimenter 2
Hands	-0.013±0.028 s	-0.006±0.008 s
Front block	-0.008±0.017 s	-0.008±0.01 s
Rear block	-0.008±0.0203 s	-0.008±0.011 s

Table 3. Mean difference ±95% LoA of RT which were recorded with LW and SW.

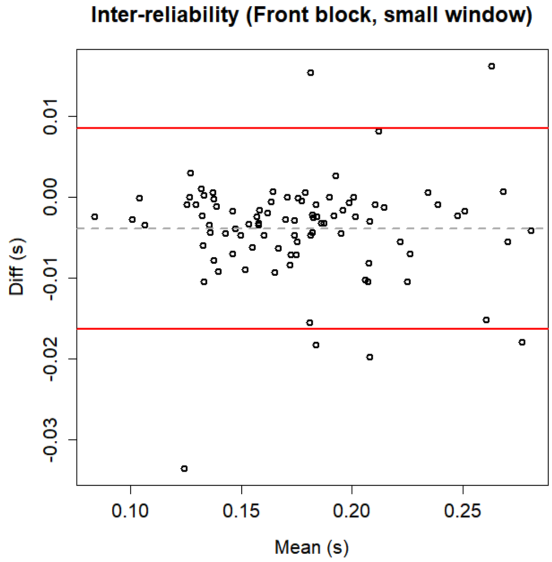

Figure 1. Bland and Altman plot with the RT mean difference (dotted grey line) and the two 95%LoA (red lines)

DISCUSSION: The intra and inter-reliability analysis indicated the level of uncertainty in the visual detection exceeded the WA 1 ms precision requirement. The mean differences in the intra-reliability analysis did not exceed 1 ms which could be considered as negligible. This absence of automatic bias in the intra-reliability analysis showed an overall level of consistency across the two consecutive analysis. Nevertheless, the intra-reliability 95%LoA scores ranged from 4 ms to 19 ms. This suggested that the level of uncertainty can reach 20 ms, which is consistent with the study of Guppy et al. (2021). The mean differences in the inter-reliability ranged from -2 to -8 ms, highlighting the tendency of Ex 1 to determine RT earlier than Ex 2. The inter-reliability analysis revealed that the visual detection from the force wave signals in the sprint start was influenced by subjectivity in experimenter visual judgement. Tillin et al. (2013) proposed a systematic approach that suppressed the subjectivity in the visual determination of the onset of force in a task of isometric knee extension. In this task, the variation in the baseline was mainly due to the dynamometer’s noise and trials were rejected from the analysis if the baseline force was not stable. Conversely, the baseline force from hands, front block, and rear block, contained more variation as the sprinter applied force on the sensors in the set position. The force variation prior the onset of the start highlighted the adjustment of the sprinter to keep his/her balance in the set position. This variability of

movement in set, could cause a lack of reliability of the onset of force detection (Soda et al., 2010) and challenge the precision of RT visual detection in sprint start. **Error! Reference source not found.** showed the lack of agreement between Ex 1 and Ex 2 is more important in some trials and emphasised the difficulty to deal with the variation in the set position.
The comparison of RT assessed with LW and SW showed a clear effect of the window size on RT detection. A larger window increased the slope of the variations in the force signal and led to an earlier event detection. This demonstrated that the window size should be standardised to improve the consistency of the visual analysis and studies should indicate the window size to ensure the reproducibility of the results. The 95%LoA from the inter-reliability analysis were reduced in the SW compared to the LW condition, highlighting that a window of 1 s would be more appropriate than a window of 3.5 s to improve the reliability of RT visual detection in sprint start.
This study is exploratory, and more research is needed to fully evaluate the level of uncertainty of the RT visual detection in sprint start and determine whether visual detection is suitable as the reference criterion for WA SIS certification. Several parameters such as, the size window, the software used, the experience of the visual detection performers may influence visual detection and require further investigation. These preliminary results suggest that the level of uncertainty of visual detection from blocks was ≈20 ms, which was much larger than the assumed WA 1 ms precision requirement. Improving the precision and including the level of uncertainty of the RT visual detection in the false start regulations is important, since the starter visually confirms the false start before disqualifying the responsible athlete when a false start is detected by a SIS in official competition.

CONCLUSION: The results of this study suggested that the level of uncertainty in determining RT from blocks using visual detection was around 20 ms. The visual detection did not reach the WA 1 ms precision requirement in the present study. More research is needed to improve the reliability of the visual detection in sprint start to ensure the validity of the WA certified SIS.

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