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Section I – Kinesiology

Validity and Reliability of a 10 Hz GPS for Assessing Variable and Mean Running Speed

by

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Our purpose was to assess the 10 Hz Viper GPS devices' validity and reliability (STATSport) in both instantaneous and mean speed measuring in accelerations and decelerations in straight-line running conditions. Eight amateur team sport players participated in the study, performing firstly 21 x 40 m sprints at submaximal incremental speed, and secondly 21 x 40 m sprints, with the first stage consisting of submaximal incremental speed, and the second stage of subsequent submaximal decreasing speed. Criteria systems used to evaluate the GPS validity were a radar gun for instantaneous speed, and timing-gates for mean speed. Reliability was measured with two GPS devices carried by the same athlete, running 10 x (20 m + 20 m) sprints with a 180º change of direction and a 10 s inter-set rest interval. Results showed an agreement between GPS devices and the criteria systems measuring instantaneous speed (r = 0.98; standardized mean bias (SMB) = -0.07; standard typical error (STE) = 0.22) and mean speed (r = 0.99; SMB = 0.38; STE = 0.17). The reliability study presented a nearly perfect correlation between devices, a trivial SMB and a small STE (r = 0.97; SMB = 0.04; STE = 0.23). 10 Hz GPS devices are an adequate solution to monitor straight-line running speed in acceleration and deceleration conditions, but we would like to draw attention to the small errors and bias detected, such as the speed overestimation compared with timing gates.

Key words: *speed testing, sprint, radar gun, photo training.*

Introduction

Speed measuring is a highly valuable variable in both team- and individual-endurance sports for scheduling training sessions and programming training loads in an objective way (Mujika, 2016; Cummins et al., 2013). Currently, there are many systems with which to monitor speed: radar guns, photocells, laser guns, etc. Nevertheless, their use presents two handicaps: these systems only allow the assessment of individual players, and this happens outside of a real sports context. However, Global Positioning System (GPS) devices, placed on athletes' upper back, allow the monitoring of both their position at every moment and their instantaneous speed, based on GPS coordinates. They can be used in both test and real game situations, so that all data required to be determined are related to specific game situations, thus avoiding testing biases (Bacon and Mauger, 2017).

As with many other devices, prior to the use of these tools for acquiring data, they must be tested in order to check their reliability and validity. In recent years, there has been a large number of studies researching the reliability and validity of 1 Hz (Edgecomb and Norton, 2006; Barbero-Alvarez et al., 2010; Coutts and Duffield,

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2010; Gray et al., 2010) and 5 Hz (Duffield et al., 2010; Jennings et al., 2010; Petersen et al., 2009) GPS units in assessing athletes' movements. They have been widely used by numerous professional outdoor team sports, such as rugby (Roe et al., 2016), cricket (Petersen et al., 2009), baseball (Murray et al., 2016), and soccer (Castagna et al., 2017), to monitor training sessions and matches. These studies have demonstrated the ability of 1 Hz and 5 Hz GPS units to measure the total distance (TD) covered, peak speed, and the distance covered at a variety of velocities. They are easy to use, non-invasive, and developed to monitor team sports, although from a scientific point of view it is necessary to check reliability and validity in these measurements. Validation of GPS devices will add value as an own monitoring tool to manage training and game loads. There is a lack of validation of these 10 Hz GPS units measuring movements during outdoor exercises, and only a small number of published studies have checked the reliability and validity of 10 Hz GPS units (Johnston et al., 2012; Varley et al., 2012), both from different companies (Catapult and STATSports). Following the lack of, and need for validation of these GPS devices, it is essential to test them in scientific studies alongside previously validated measuring systems. There is one study that used video analysis (25 frames/s) to validate instantaneous speed values (Beato et al., 2016), but according to a review by Haugen and Buchheit (2016), photocells were selected as the previously validated tool for mean speed measuring, and a radar gun was not considered as a gold standard in instantaneous speed control. If GPS devices can be validated, they would be very useful in future studies in both team and individual sports, where speed assessment is needed.

One of the least studied variables is the ability of GPS devices to determine distance and speed during accelerations and decelerations. This speed is even more important and influential for team sports games than average time measured at different speeds, which has been widely determined (Bacon and Mauger, 2017; Castillo et al., 2016; Torreño et al., 2016). Given that acceleration values obtained from GPS data represent the mean acceleration between samples, and this can only be compared with the average acceleration over 5 or 10 m when using photocells, it would be more effective to use a radar gun with the same sampling frequency of GPS devices, in order to reduce this measurement error (Haugen and Buchheit, 2016).

Consequently, the purpose of this study was to validate Viper 10 Hz GPS units, comparing them with a radar gun and photocells as criteria systems, in order to measure instantaneous speed in acceleration and deceleration under straight-line running conditions. It was hypothesized that Viper 10 Hz GPS units would measure instantaneous and mean speed in accelerations and decelerations with greater accuracy compared to other devices.

Methods

To evaluate the Viper 10 Hz GPS unit as a tool for measuring speed under acceleration and deceleration conditions, each participant performed either 10 drills of 20 m to assess reliability, or 21 drills of 40 m at a submaximal incremental speed (IncS) and another 21 x 40 m sprints with a submaximal incremental speed in the first stage, and a subsequent submaximal decreasing speed during the second stage (Inc-DecS). All testing was undertaken on a one-lane athletics track. Distance and instantaneous speed during tests were calculated using three methods: wireless timing gates (Microgate Witty Wireless Training Timer, Bolzano, Italy); a radar gun device (ATS II Applied concepts, Dallas, TX, USA), sampling at 50 Hz; and a GPS device (Viper, STATSport Group, Newry, Ireland, UK), sampling at 10 Hz. The radar gun presented a reported accuracy of 0.16 km/h, and its reliability had been previously reported (Morin et al., 2006).

Participants

Eight amateur team sports players, all males (age: 21 ± 3 years old; body mass: 69.2 ± 6.3 kg; body height: 174.2 ± 4.6 cm), were voluntarily recruited from Sports Sciences degree students to wear a GPS unit on the upper back to assess its validity. Another athlete (age: 33 years old; body mass: 70.1 kg; body height 176 cm) voluntarily participated in the GPS reliability test. Ethics approval was granted by the Universidad San Jorge ethics board and written informed consent was acquired from all subjects.

Design and procedures

Reliability of the GPS devices was determined by comparing the data collected by two Viper 10 Hz GPS units carried by one participant. To this end, a 20 m distance was marked on the athletics one-lane track, using a 50 m tape. The participant performed an intermittent maximal effort of 10 x (20 m + 20 m) sprints, with a 180º change of direction and a 10 s inter-set (InterS) rest interval. During the drill the athlete carried two 10 Hz GPS units (GPS1 and GPS2, one above the other), positioned between the shoulder blades on the upper-back region.

Once the reliability was determined, validity of the Viper 10 Hz GPS was assessed by comparing practical speed from the previously mentioned devices with following criterion speeds: instantaneous speed by the radar gun, and mean speed by timing gates.

A 40 m distance was marked on the track with a 50 m tape, where timing gates were placed at 0, 10, 20, 30 and 40 m. The radar gun was placed on a tripod 10 m behind the start-point at a 1 m height, corresponding approximately to the participants' centre of mass. Participants were instructed to begin in their own time and run from a starting point placed 0.5 m behind the first timing gate. Each subject decided freely on his sprint speed. Speed values were registered by the radar gun from the beginning of the movement (detected by an increase in speed), to the end of the drill, which was determined by the time recorded at the last photocells (40 m).

Each of the eight participants carried one Viper 10 Hz GPS unit in an individual specialized vest, placed between the shoulder blades on the upper-back region. After the reliability was checked, a total of 20 GPS units were included in this part of the study and randomly assigned to participants.

Firstly, all participants involved in the study performed 21 x 40 m sprints at a submaximal incremental speed (IncS). Secondly, the same athletes performed 21 x 40 m sprints with a submaximal incremental speed in the first stage and a subsequent submaximal decreasing speed during the second stage (Inc-DecS). Instantaneous speed was measured in each split by the radar gun. Time required to cover 10 m was taken under IncS conditions by timing gates.

Every test was performed after a standardized 10 min warm-up (5 min of light jogging, dynamic stretching exercises and 5 submaximal sprints).

Instantaneous speed was determined by a radar system following filtering in custom software designed for ATS II use (SATS version 5.0.3.0). The Viper 10 Hz GPS position and speed were taken from Doppler-shift using STATSport Viper Software Version 1.2. To obtain instantaneous speed from raw data, a logarithmic transformation was implemented. This transformation reduced bias derived from the radar's non-uniformity error of measure. To calculate mean speed, the 10 m distance was divided by timing gates split record.

Statistical analysis

Agreement between both results (criterion and practical measures in validity assessment, GPS1 and GPS2 in reliability evaluation) was explored using an Excel spreadsheet designed to calculate the mean bias, standardized mean bias (SMB), standard typical error (STE), Pearson correlation coefficient, all with 90% confidence limits. In addition, the method of Bland and Altman allowed to determine systematic bias and random error as well as lower and upper limits of agreement (95%) (Bland and Altman, 1990). The intraclass correlation coefficient (ICC) was included to describe how strongly devices resembled each other in validity and reliability measurements (Bland and Altman, 1986). The SMB was rated as trivial (< 0.19), small (0.2 – 0.59), medium (0.6 – 1.19) or large (1.2 – 1.99). The STE was rated as trivial (< 0.1), small (0.1 – 0.29), moderate (0.3 – 0.59) or large (> 0.59). The magnitude of correlation was rated as trivial (< 0.1), small (0.1 – 0.29), moderate (0.3 – 0.49), large (0.5 – 0.69), very large (0.7 – 0.89) or nearly perfect (0.9 – 0.99). An ICC value r > 0.9 was considered to indicate excellent agreement.

To verify a lineal relation between criteria and practical measures, empirical regression analysis was included. This analysis was performed by the minimal squares method.

Results

Main results of this study are presented in Tables 1 and 2. They are divided into two sections, Reliability and Validity, to summarize the principal findings.

Reliability

Data for the reliability study was performed under IntS conditions with 1042 samples in 10 trials. Instantaneous speed was compared between two GPS devices in the same sprint situation. This comparison showed a *nearly* *perfect* correlation, a *trivial* SMB and a *small* STE (r = 0.97; SMB = 0.04; STE = 0.23).

Validity

A total of 2981 samples were collected in 42 trials or sprint situations, in order to obtain data for instantaneous speed validity assessment. Criterion speed with the radar gun and practical speed with GPS devices were *nearly perfectly* correlated, showing a *trivial* standardized mean bias (SMB) and a *small* standardized typical error (STE) under IncS conditions (r = 0.98; SMB = -0.07; STE = 0.19), Inc-DecS conditions (r = 0.97; SMB = -0.08; STE = 0.25), and considering the totality of the trials (r = 0.98; MSB = -0.07; STE = 0.22). GPS devices underestimated instantaneous speed in comparison with the radar system in all conditions tested.

Testing for mean speed validity was performed only under IncS conditions, with 82 samples in 21 trials. Criterion speed with timing gates and practical speed with GPS devices were *nearly perfectly* correlated, showing a *small* SMB and a *small* STE under acceleration conditions (r = 0.99; SMB = 0.38; STE = 0.17). Despite the *nearly perfect* correlation, GPS devices overestimated mean speed in comparison with timing gates in the acceleration conditions evaluated. In Figure 1 it is shown that speed recorded by GPS units was a little bit higher than the timing gate records.

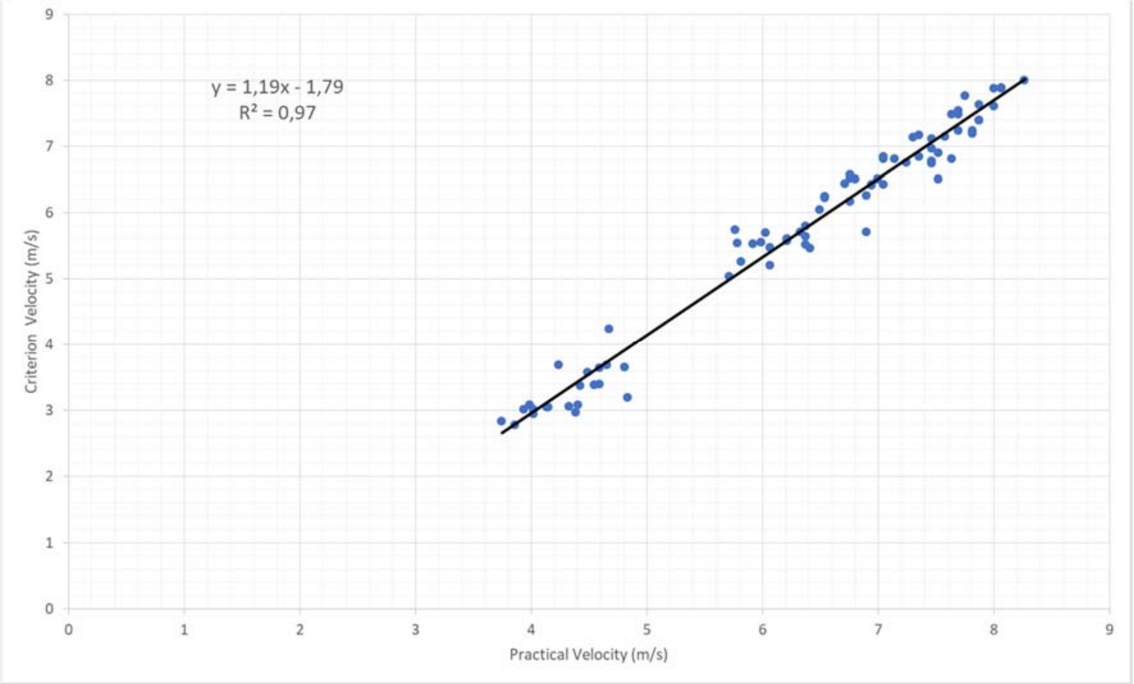

Figure 1

Correlation between criterion velocity (timing gates) and 10 Hz GPS practical velocity in the acceleration conditions evaluated.

Table 1

Mean Bias, Standard Mean Bias and Standard Typical Error for Instantaneous Speed Validity, Mean Speed Validity, and Reliability between GPS devices.

	Trials (Samples)		Speed (m/s)	MB (m/s)	SMB	STE	BAE	ICC
			mean ± SD	MB ± SD [LCL_{90} ,UCL_{90}]	SMB ± SD [$LCL_{90,}$ UCL_{90}]	STE [LCL_{90},UCL_{90}]	BAE [LCL_{95}-UCL_{95}]	ICC [LCL_{95}, UCL_{95}]
ISV IncS	21 (1516)	CS	5.61 ± 1.93	-0.13 ± 0.38	-0.07 ± 0.20	0.19	0.75	0.99
		PS	5.48 ± 1.96	[-0.14, -0.11]	[-0.07, -0.06]	[0.19, 0.20]	[-0.88, 0.62]	[0.98 - 0.99]
ISV Inc-DecS	21 (1465)	CS	5.53 ± 1.78	-0.14 ± 0.45	-0.08 ± 0.25	0.25	0.88	0.98
		PS	5.39 ± 1.82	[-0.16, -0,12]	[-0.09, -0.07]	[0.24, 0.25]	[-1.02, 0.74]	[0.98 - 0.99]
ISV Total	42 (2981)	CS	5.57 ± 1.86	-0.13 ± 0.42	-0.07 ± 0.22	0.22	0.81	0.98
		PS	5.44 ± 1.89	[-0.15, -0,12]	[-0.08, -0.07]	[0.22, 0.22]	[-0.94, 0.68]	[0.98 - 0.99]
MSV	21 (81)	CS	5.71 ± 1.62	0.61 ± 0.36	0.38 ± 0.23	0.17	0.71	0.94
		PS	6.32 ± 1.34	[0.55, 0.68]	[0.34, 0.42]	[0.14, 0.20]	[-0.1, 1.32]	[0.88 - 0.97]
IVR	10 (1042)	CS	3.96 ± 1.38	0.05 ± 0.32	0.04 ± 0.24	0.23	0.63	0.99
		PS	4.01±1.40	[0.04 - 0.07]	[0.03, 0.05]	[0.22, 0.24]	[-0.58, 0.68]	[0.98 - 0.99]

ISV IncS: instantaneous speed validation in submaximal increase speed conditions;
ISV Inc-DecS: instantaneous speed validation in submaximal increase and decrease speed conditions;
ISV Total: instantaneous speed validation in all conditions tested; MSV: mean speed validation;
IVR: instantaneous velocity reliability; CS: criterion speed; PS: practical speed; MB: mean bias;
SMB: standard mean bias; STE: standard typical error; BAE: Bland–Altman estimate;
ICC: intraclass correlation coefficient; SD: standard deviation;
LCL90: lower 90% confidence limit; UCL90: upper 90% confidence limit;
LCL95: lower 95% confidence limit; UCL95: upper 95% confidence limit.

Table 2

Regression analysis between Criterion and Practical measures in validity assessment and reliability between GPS devices.

	Pearson Correlation	**Regression analysis**	
	r [LCL, UCL]	Intercept [LCL, UCL]	Slope [LCL, UCL]
ISV IncS	0.98 [0.98, 0.98]	0.31 [0.26, 0.36]	0.97 [0.96, 0.97]
ISV Inc-DecS	0.97 [0.97, 0.97]	0.43 [0.37, 0.49]	0.95 [0.94, 0.96]
ISV Total	0.98 [0.97, 0.98]	0.37 [0.33, 0.40]	0.96 [0.95, 0.96]
MSV	0.99 [0.98, 0.99]	-1.79 [-2.03, -1.56]	1.19 [1.15, 1.22]
IVR	0.97 [0.97, 0.98]	0.13 [0.08, 0.18]	0.95 [0.94, 0.97]

ISV IncS: instantaneous speed validation in submaximal increase speed conditions,
ISV Inc-DecS: instantaneous speed validation in submaximal increase and decrease speed conditions,
ISV total: instantaneous speed validation in all conditions tested, MSV: mean speed validation,
IVR: instantaneous velocity reliability, r: Pearson correlation,
LCL: lower 90% confidence limit, UCL: upper 90% confidence limit

Discussion

The purpose of this study was to check the reliability and validity of Viper 10 Hz GPS units, comparing them with the radar gun and photocells as criteria systems, to measure instantaneous speed under acceleration and deceleration conditions. Just as our results show, the main findings of the study are: i) good reliability of these devices is shown for measuring instantaneous speed when running in a straight line, and ii) there is an agreement between 10 Hz GPS devices and two other gold standards (timing gates and a radar gun) for measuring instantaneous speed and mean speed.

Reliability of GPS devices was assessed based on instantaneous speed, comparing two GPS units placed on the upper back of the same athlete. Our results show trivial differences between both GPS units, and a nearly perfect Pearson correlation when data obtained from both devices were analysed.

The validity of timing gates in comparison with the radar gun when assessing speed has been reported in a previous study (Roe et al., 2016). Therefore, in our research both devices were used to evaluate the validity of 10 Hz GPS devices.

Regarding GPS devices' validity for measuring instantaneous speed, our results show trivial differences between the radar gun criterion and the GPS, and a nearly perfect Pearson correlation when data obtained from both methods were analysed. A previous study revealed that the relationship between peak instantaneous speed acquired by 5 Hz GPS devices and by a radar gun did not have a very strong correlation (Johnston et al., 2012). With regard to lower-frequency devices, 1 Hz GPS units presented a good-to-moderate reliability level for moderate running speed, although a poor level for high-intensity and very high-intensity running for all GPS devices (Coutts and Duffield, 2010). In another study, laser sampling was the criterion to validate 10 Hz GPS units. According to this, GPS units' validity was shown to be inversely related to acceleration, especially over 4 m/s2 (Akenhead et al., 2014), which is over the maximal acceleration in the best 100 m sprint ever (Mackala and Mero, 2013), so it could be useful for most running speed analyses in sports. In comparison with previous GPS devices, these 10 Hz GPS units demonstrated higher validity when measuring instantaneous speed in straight-line running, independent of constant or variable (acceleration or deceleration) speed.

In terms of mean speed in a drill, data from GPS units were compared with those from timing gates. Our results indicate small mean standard differences with a nearly perfect Pearson correlation. Similar data were obtained from different GPS devices with 10 Hz sampling frequency in comparison with timing gates (Roe et al., 2016). In another study, 10 Hz GPS units with some inaccuracy in measuring distance were also reported, which could interfere with mean speed measures, especially when there were changes of direction during running (Beato et al., 2016). Similar results were obtained when mean speed was assessed over longer distances or straight-line running (Beato et al., 2016). Despite the nearly perfect correlation, it is surprising that GPS devices overestimated mean speed in comparison with timing gates under the acceleration conditions evaluated. As previously reported, speed recorded by GPS units is higher than the timing gate records (Figure 1).

In conclusion, this study demonstrates that Viper 10 Hz GPS units are capable of measuring mean speed and instantaneous speed under acceleration and deceleration conditions. In terms of reliability, a nearly perfect correlation when athletes were running in a straight line was also shown. These devices are accurate in comparison with radar guns or timing gates, but we suggest that the same measuring methods should be used over the whole assessment time because of the small errors and bias between these tools, such as the overestimation of speed when comparing with timing gates.

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