Concurrent Validity and Reliability of Sprinting Force–Velocity Profile Assessed With GPS Devices in Elite Athletes

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Abstract

Purpose: the aims of this study were to 1) assess the concurrent validity of global positioning systems (GPS) against a radar device to measure sprinting force-velocity (F-v) profiles and 2) evaluate the inter-unit reliability of GPS devices. **Methods:** 16 male elite U18 rugby union players (178.3 ± 7.6 cm; 78.3 ± 13.2 kg) participated. Two 50-m sprints interspersed with at least 5 min of recovery were used to obtain input (maximal sprint speed [MSS] and acceleration time constant τ) and output (theoretical maximal horizontal force [F0], sprinting velocity [V0], and horizontal power [Pmax]) F-v profile variables. Sprint running speed was concurrently measured with a radar and 2 GPS units placed on the upper back of the players. **Results:** Moderate to nearly perfect correlations were observed between radar and GPS-derived F-v variables, with small-to-large typical errors. Trivial-to-small coefficients of variation were found regarding the GPS inter-unit reliability. **Conclusion:** The GPS devices tested in this study represent a valid and reliable alternative to a radar device when assessing sprint acceleration F-v profiles in team sports players.

Key words: Team sport, Force, Power, Running, Sports performance

Introduction

To assess the force velocity (F-v) profile, practitioners need to set standardised sprinting protocols and record special temporal or running velocity-time data using specific devices such as a radar.[1] While the radar is considered as a reference to measure speed,[1] not all high-level clubs have access to such a technology. Moreover, in elite sport environment, time is scarce and it may be difficult for practitioners to dedicate a full testing session to assess F-v profiles.[2] However, most elite teams are now equipped with global positing system (GPS) devices,[3] which could represent a viable alternative to measure players' position-speed-time data and compute F-v profiles without additional equipment and associated time demand. Recent investigations have already highlighted the possibility to use GPS devices to extrapolate sprint mechanical properties by analysing the validity against radar and laser devices [4] or timing gates,[5] with mixed results likely due to the limited accuracy of the GPS units used. Moreover, Lacome et al.[6] observed trivial-to-small typical error and good-to-very good between-device intraclass correlation coefficients, suggesting that practitioners could reliably examine F-v profile with GPS. While only considerations have been made on the output variables (i.e. F-v profile variables), the validity and reliability of the model's input variables (speed-time curve characteristics) remains unknown. Finally, it is yet to be known if the integration of double constellation system improves the accuracy of GPS devices to produce F-v profile variables.

Therefore, the aims of this study were 1) to assess the concurrent validity of input (maximal sprint speed [MSS] and acceleration constant τ) and output (theoretical maximal horizontal force [F0], sprinting velocity [V0], and horizontal power [Pmax]) variables obtained with GPS and compared with radar device and 2) assess the inter-unit reliability of F-v profile variables assessed using GPS-data.

Methods

Subjects

16 male elite U18 rugby union players (height: 178.3 ± 7.6 cm; body mass; 78.3 ± 13.2 kg) were included as part a training camp for the French national squad. Participants provided informed consent prior to starting the study. Ethics approval was granted by the Leeds Beckett

University ethics board and the recommendations of the Declaration of Helsinki were respected.

Design

F-v profile was assessed at the beginning of a rugby training session and was performed on a natural open-field grass pitch. A 20-min warm up was performed including running drills and 2 progressive 30-m sprints. Following the warm up, 2 sprints of 50 m with at least 5 min recovery between each trial were performed. No specific signal to initiate the sprint was given to players. However, they were asked to stand still in order to avoid any backward movement prior to starting their sprint. Additionally, immediate maximal acceleration at the beginning was asked. Each sprint was concurrently measured using a radar device sampling at 46.875 Hz (Stalker Pro II Sports Radar Gun, Plano, TX) and two GPS units (Optimeye S7, Catapult Innovations, Melbourne, Australia). The radar was placed on a tripod 5 m behind the player and 1 m above the ground. Two GPS units were carried in a specific, tightly fit vest allowing the two units to be positioned side-by-side, 5 cm apart around C7-T1 were used. Each unit was sampled at 10 Hz and included a double constellation system. The average horizontal dilution of precision was 0.74 ± 0.10 and the number of satellites was 15.5 ± 1.5.

Raw data gathered via radar and GPS devices were uploaded into a custom-made script to calculate F-v profiles automatically with R statistical software (R v4.0.2. R Foundation for Statistical Computing) based on the computation method presented and validated by Samozino et al.[7] and Morin et al.[8] The whole data processing and script is further explained in Figure 1 and supplemental material.

Insert Figure 1

Statistical Analyses

All data were first log transformed to reduce bias arising from non-uniformity error. However, values presented in the text and figures are the back-transformed data. The concurrent validity was assessed with Bland-Altman method mean bias (90% confidence limits. CL), the typical error of the estimate (TEE, 90% CL) both in percentage and standardized units and Pearson correlation coefficients. The magnitude of the standardised mean bias, TEE and correlations were interpreted as proposed by Hopkins.[9]

The inter-unit reliability of F-v profile measured with GPS was assessed with the typical error of measurement expressed as a coefficient of variation (CV, 90% CI) as well as in standardized units and intraclass correlation (ICC). Moreover, the smallest worthwhile change (0.2 x between-athletes SD) (SWC) was calculated. The sensitivity (signal to noise ratio) was classified as follows; good (CV < SWC), OK (CV = SWC) or poor (CV > SWC).[10]

Results

Data related to the concurrent validity analysis and inter-unit reliability are displayed in Table 1. Limits of agreements from the Bland et Altman analysis are reported in Figure 2. Pearson correlation revealed a moderate relationship for F0 (0.48 [0.29 to 0.62]), large for τ (0.56 [0.40 to 0.69]), very large for Pmax (0.74 [0.62 to 0.82]) and nearly perfect for MSS (0.96 [0.94 to 0.97]) as well as V0 (0.94 [0.91 to 0.96]).

Insert Table 1

Insert Figure 2

Discussion

The main findings showed moderate-to-nearly perfect correlation between radar and GPS devices for output variables and small GPS inter-unit typical error highlighting the good level of reliability of these devices to assess F-v profile variables.

The present results showed moderate-to-nearly perfect correlation and small to moderate error between GPS and radar devices regarding F-v profile-related variables (F0, V0, Pmax), which was similar to Naghara et al.[4] However, only a 10 Hz device including a double constellation system has been used in our study compared with Naghara et al.[4] who used 20 Hz GPS units (from a different brand) and a single constellation. A previous study showed significant improvements both in positioning accuracy and integrity monitoring as a result of the use of double constellations system.[11] Moreover, our study was performed in an open-field (i.e. without surrounding metallic structure), which suggests that current GPS technology when combined with optimal environmental conditions is accurate enough to monitor F-v profiles.

However, lower levels of concurrent validity (large to very large correlation and moderate typical errors) were observed for Pmax and F0 compared with V0 (nearly perfect correlation and small typical error). The origin of this difference is unclear and could be attributed to the ~5 times lower sample frequency of the GPS compared with the radar. In their study, Naghara et al.[4] showed that the accuracy of GPS to measure F-v profiles was lowered when 5 Hz GPS was used compared to 20 Hz. Hence, with the inclusion of a double constellation system, the bias observed was similar despite lower sample frequency. Therefore, the integration of GPS systems with higher sampling rate is likely required to improve the validity of F-v profile measured with GPS devices. Moreover, while V0 is calculated based on MSS (corresponding to a steady state), F0 is mainly related to τ which is associated to a rate of state change and could therefore be more affected by the measurement system and/or data processing, explaining the higher typical error compared to V0. Nevertheless, the use of GPS devices to assess F-v profiles are now within reach and could be considered by practitioners in their daily practice since double constellations system are common.

The results of the present study highlighted that the inter-unit GPS reliability was very high when analysing F-v profile-related data. Similar results were observed by Lacome et al.[6] who reported small typical errors, supporting that GPS is a reliable method to monitor F-v profiles. While lower sensitivity was observed for F0, this could be improved using more testing repetitions (as the error decrease by a factor of $\sqrt{n}$ repetitions[12]), which would be more feasible by using GPS devices in practice (e.g. 4 to 6 sprints within warm-up). As only the inter-unit reliability has been measured in the present study, further research is necessary to understand the week-to-week variability and the sensitivity to changes (e.g. pre-post pre-season) of the F-v profile obtained with GPS.

Practical applications

- F-v profile variables assessed through Catapult Optimeye S7 GPS devices (sampled at 10 Hz and including a double constellation system) presented small-to-moderate error compared with a radar device. Practitioner could consider these GPS devices as an alternative for more frequent assessment.
- F-v profile variables obtained with GPS showed a high inter-unit reliability, confirming previous studies findings that GPS units can be used interchangeably to measure F-v profiles in team sports athletes.

Conclusion

The present study confirms that the Catapult Optimeye S7 GPS devices could be a potential cost-effective, valid and reliable alternative to a radar device when assessing sprint acceleration F-v profiles in team sports players. Future studies need to compare F-v profile related kinetic variables with the gold standard (i.e. tracks equipped with force plates) or consider other reference systems with a higher sample frequency than radar devices (i.e. laser, robotic sprint resistance device).

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Legend

Table 1. Concurrent validity and inter-unit reliability analysis. Raw data for criterion (Radar) and practical (GPS) devices are presented as mean ± SD. Other concurrent validity statistics are presented with 90% confidence intervals. TEE stands for Typical error of Estimate. Raw data for GPS 1 and 2 are presented as mean ± SD. Reliability statistics are presented with 90% confidence intervals. TE stands for Typical Error. SWC stands for Smallest Worthwhile Change.

Figure 1. Schematic representation of the automatic data processing. The left panel represents the validity analysis where GPS was compared with radar. The right panel represents the inter-units reliability analysis. Both share the same data processing via the script. Upper panel represents the identification of the beginning and end of the sprint from the raw velocity signal. The script identifies the beginning (i.e. first speed value > 0.2 m.s^{-1} from 0) and the end of the sprint (i.e. negative acceleration after player reach maximal speed). The middle panel represents the raw velocity data fitting into a mono exponential equation using a least square regression method from the *NLS* optimization function of the *nlstools* package (version 3.6.2). A time delay (d) was integrated into the initial equation to improve the goodness of fit, if the actual start of the sprint did not occur at t=0 s (0.09 ± 0.04 s on average in the present study). The lower panel aimed to calculate the speed-time data, theoretical maximal horizontal force (F0 [N.kg^{-1}]), maximal horizontal sprinting power (Pmax [W.kg^{-1}]) and theoretical maximal sprinting velocity (V0 [m.s^{-1}]). All data analysis were performed with R statistical software (R v4.0.2. R Foundation for Statistical Computing). *MSS* stands for maximal sprint speed, τ is the acceleration time constant and d the time delay.

Figure 2. Bland et Altman analyses. Black line represents the bias. Das lines represents 90% limits of agreements.

Table 1

	MSS ($m \cdot s^{-1}$)	τ (s)	Pmax ($W \cdot kg^{-1}$)	V0 ($m \cdot s^{-1}$)	F0 ($N \cdot kg^{-1}$)
Validity					
Criterion (Radar) Mean ± SD	8.84 ± 1.06	1.24 ± 1.14	16.7 ± 1.12	9.26 ± 1.06	6.98 ± 1.11
Practical (GPS) Mean ± SD	8.81 ± 1.05	1.25 ± 1.08	16.08 ± 1.10	9.23 ± 1.06	6.96 ± 1.07
Standardised mean bias	-0.28 (-0.63 to 0.07)	0.51 (-1.85 to 2.93)	-0.56 (-2.25 to 1.17)	-0.27 (-0.73 to 0.20)	-0.19 (-2.33 to 1.99)
Mean bias (%)	1.7 (1.4 to 2.0)	11.30 (9.77 to 13.45)	7.99 (6.92 to 9.48)	2.16 (1.88 to 2.55)	10.12 (8.76 to 12.04)
Standardised TEE	0.29 (0.24 to 0.37)	1.48 (1.05 to 2.32)	0.92 (0.70 to 1.26)	0.36 (0.29 to 0.46)	1.85 (1.25 to 3.25)
TEE as coefficient of variation (%)	0.29 (0.24 to 0.37)	1.48 (1.05 to 2.32)	0.92 (0.70 to 1.26)	0.36 (0.29 to 0.46)	1.85 (1.25 to 3.25)
Reliability					
GPS 1 Mean ± SD	8.81 ± 1.06	1.25 ± 1.08	16.02 ± 1.10	9.24 ± 1.06	6.93 ± 1.07
GPS 2 Mean ± SD	8.81 ± 1.05	1.25 ± 1.07	16.14 ± 1.11	9.23 ± 1.05	6.99 ± 1.07
TE as coefficient of variation (%)	0.5 (0.4 to 0.7)	2.0 (1.7 to 2.6)	1.4 (1.2 to 1.8)	0.6 (0.5 to 0.8)	1.8 (1.5 to 2.4)
Standardised TE	0.10 (0.08 to 0.12)	0.28 (0.23 to 0.36)	0.15 (0.12 to 0.18)	0.12 (0.10 to 0.15)	0.28 (0.23 to 0.35)
ICC (90% CI)	0.99 (0.98 to 1.00)	0.93 (0.88 to 0.96)	0.98 (0.96 to 0.99)	0.99 (0.98 to 1.00)	0.93 (0.88 to 0.96)
SWC (%)	1.0	1.5	2.0	1.1	1.4
Sensitivity	Good	Poor	Good	Good	Poor

Figures

Figure 1

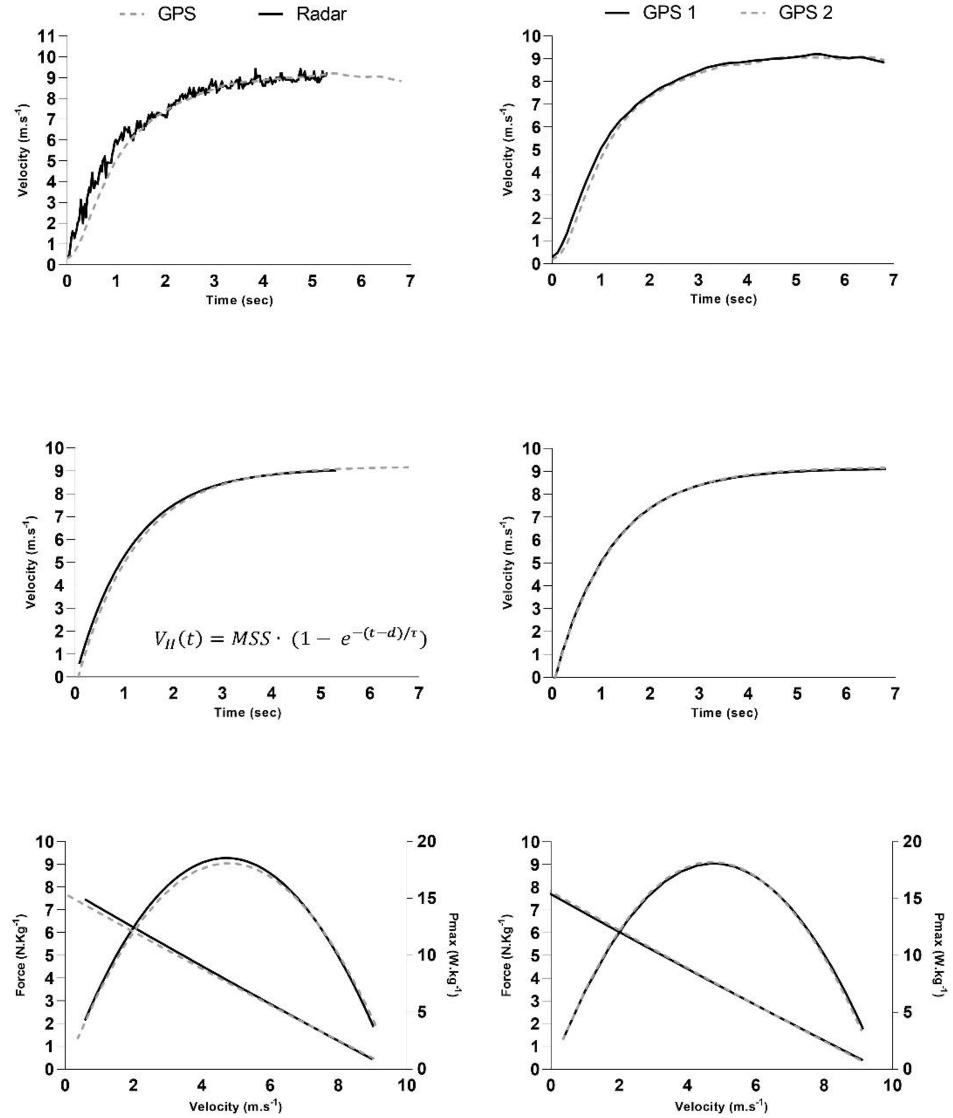
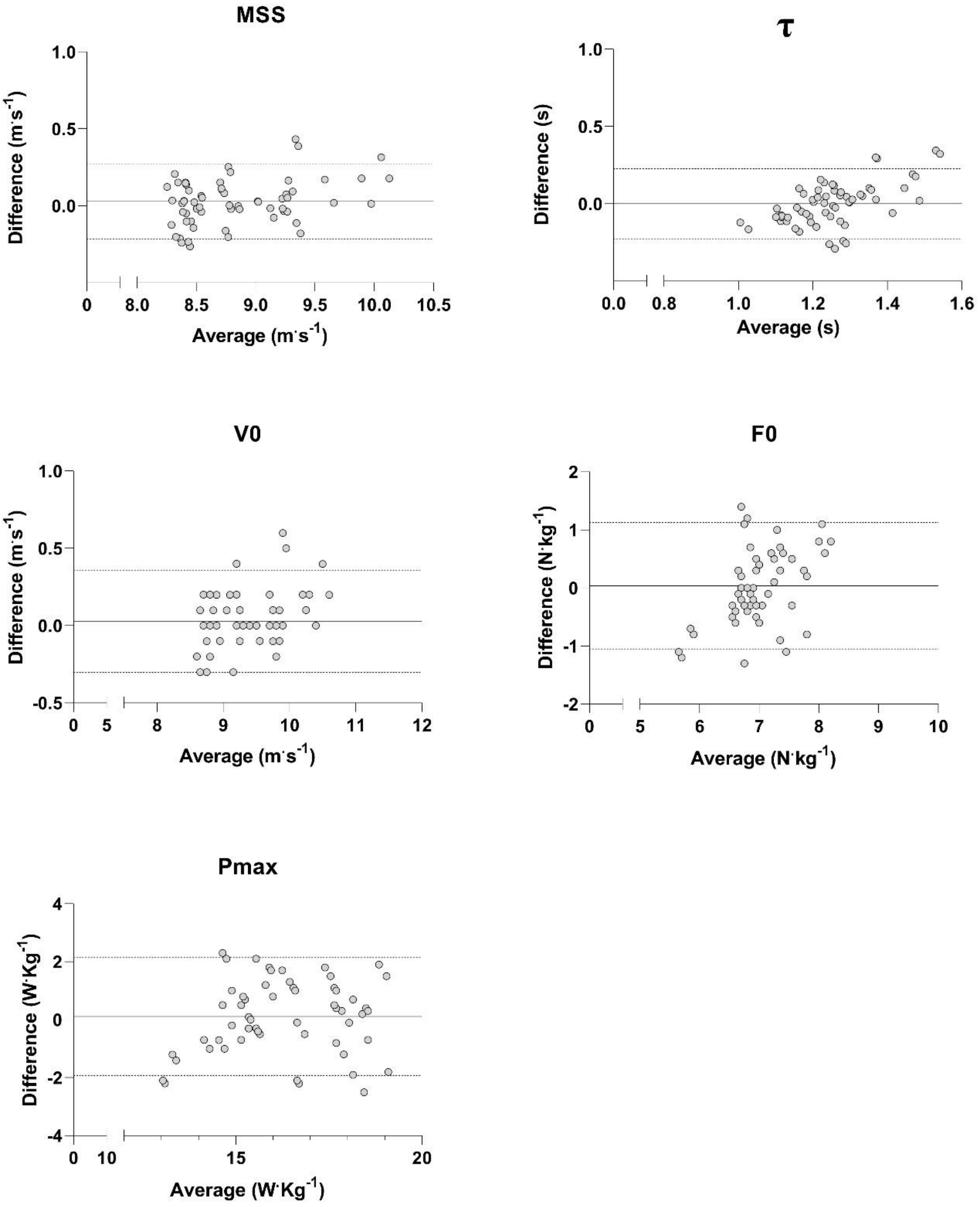


Figure 2


MSS
Difference (m·s⁻¹)
1.0
0.5
0.0
0
8.0
8.5
9.0
9.5
10.0
10.5
Average (m·s⁻¹)
τ
Difference (s)
1.0
0.5
0.0
0.0
0.8
1.0
1.2
1.4
1.6
Average (s)
V0
Difference (m·s⁻¹)
1.0
0.5
0.0
-0.5
0
5
8
9
10
11
12
Average (m·s⁻¹)
F0
Difference (N·kg⁻¹)
2
1
0
-1
-2
0
5
6
7
8
9
10
Average (N·kg⁻¹)
Pmax
Difference (W·Kg⁻¹)
4
2
0
-2
-4
0
10
15
20
Average (W·Kg⁻¹)