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

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## ► To cite this version:

Pauline Clavel, Cedric Leduc, Jean-Benoît Morin, Cameron Owen, Pierre Samozino, et al.. Concurrent Validity and Reliability of Sprinting Force–Velocity Profile Assessed With GPS Devices in Elite Athletes. *International Journal of Sports Physiology and Performance*, 2022, 17 (10), pp.1527-1531. 10.1123/ijsp.2021-0339 . hal-03881332

**HAL Id: hal-03881332**

**<https://insep.hal.science/hal-03881332>**

Submitted on 16 Dec 2022

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1 Title: Concurrent validity and reliability of sprinting force-velocity profile assessed with  
2 GPS devices in Elite athletes.

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26 Abstract count: 174

27 Text only word account: 2732

28 Numbers of tables: 2

29 Numbers of figures: 3

30 Conflicts of interest: The authors do not have any conflict of interest.

31 **Abstract**

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

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

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## 65 **Introduction**

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67 To assess the force velocity (F-v) profile, practitioners need to set standardised sprinting  
68 protocols and record special temporal or running velocity-time data using specific devices  
69 such as a radar.<sup>1</sup> While the radar is considered as a reference to measure speed,<sup>1</sup> not all high-  
70 level clubs have access to such a technology. Moreover, in elite sport environment, time is  
71 scarce and it may be difficult for practitioners to dedicate a full testing session to assess F-v  
72 profiles.<sup>2</sup> However, most elite teams are now equipped with global positioning system (GPS)  
73 devices,<sup>3</sup> which could represent a viable alternative to measure players' position-speed-time  
74 data and compute F-v profiles without additional equipment and associated time demand.

75 Recent investigations have already highlighted the possibility to use GPS devices to  
76 extrapolate sprint mechanical properties by analysing the validity against radar and laser  
77 devices<sup>4</sup> or timing gates,<sup>5</sup> with mixed results likely due to the limited accuracy of the GPS  
78 units used. Moreover, Lacombe et al.<sup>6</sup> observed trivial-to-small typical error and good-to-very  
79 good between-device intraclass correlation coefficients, suggesting that practitioners could  
80 reliably examine F-v profile with GPS. While only considerations have been made on the  
81 output variables (i.e. F-v profile variables), the validity and reliability of the model's input  
82 variables (speed-time curve characteristics) remains unknown. Finally, it is yet to be known if  
83 the integration of double constellation system improves the accuracy of GPS devices to  
84 produce F-v profile variables.

85

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

91

## 92 **Methods**

### 93 **Subjects**

94 16 male elite U18 rugby union players (height:  $178.3 \pm 7.6$  cm; body mass;  $78.3 \pm 13.2$  kg)  
95 were included as part a training camp for the French national squad. Participants provided  
96 informed consent prior to starting the study. Ethics approval was granted by the Leeds Beckett

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

## 99 **Design**

100 F-v profile was assessed at the beginning of a rugby training session and was performed on a  
101 natural open-field grass pitch. A 20-min warm up was performed including running drills and  
102 2 progressive 30-m sprints. Following the warm up, 2 sprints of 50 m with at least 5 min  
103 recovery between each trial were performed. No specific signal to initiate the sprint was given  
104 to players. However, they were asked to stand still in order to avoid any backward movement  
105 prior to starting their sprint. Additionally, immediate maximal acceleration at the beginning  
106 was asked. Each sprint was concurrently measured using a radar device sampling at 46.875  
107 Hz (Stalker Pro II Sports Radar Gun, Plano, TX) and two GPS units (Optimeye S7, Catapult  
108 Innovations, Melbourne, Australia). The radar was placed on a tripod 5 m behind the player  
109 and 1 m above the ground. Two GPS units were carried in a specific, tightly fit vest allowing  
110 the two units to be positioned side-by-side, 5 cm apart around C7-T1 were used. Each unit  
111 was sampled at 10 Hz and included a double constellation system. The average horizontal  
112 dilution of precision was  $0.74 \pm 0.10$  and the number of satellites was  $15.5 \pm 1.5$ .

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

118

119 \*Insert Figure 1\*

120

## 121 **Statistical Analyses**

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

128 The inter-unit reliability of F-v profile measured with GPS was assessed with the typical error  
129 of measurement expressed as a coefficient of variation (CV, 90% CI) as well as in

130 standardized units and intraclass correlation (ICC). Moreover, the smallest worthwhile change  
131 (0.2 x between-athletes SD) (SWC) was calculated. The sensitivity (signal to noise ratio) was  
132 classified as follows; good ( $CV < SWC$ ), OK ( $CV = SWC$ ) or poor ( $CV > SWC$ ).<sup>10</sup>

133

## 134 **Results**

135 Data related to the concurrent validity analysis and inter-unit reliability are displayed in Table  
136 1. Limits of agreements from the Bland et Altman analysis are reported in Figure 2. Pearson  
137 correlation revealed a moderate relationship for F0 (0.48 [0.29 to 0.62]), large for  $\tau$  (0.56  
138 [0.40 to 0.69]), very large for Pmax (0.74 [0.62 to 0.82]) and nearly perfect for MSS (0.96  
139 [0.94 to 0.97]) as well as V0 (0.94 [0.91 to 0.96]).

140

141 \*Insert Table 1\*

141

142 \*Insert Figure 2\*

142

143

## 144 **Discussion**

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

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

157 However, lower levels of concurrent validity (large to very large correlation and moderate  
158 typical errors) were observed for Pmax and F0 compared with V0 (nearly perfect correlation  
159 and small typical error). The origin of this difference is unclear and could be attributed to the  
160 ~5 times lower sample frequency of the GPS compared with the radar. In their study, Naghara

161 et al.<sup>4</sup> showed that the accuracy of GPS to measure F-v profiles was lowered when 5 Hz GPS  
162 was used compared to 20 Hz. Hence, with the inclusion of a double constellation system, the  
163 bias observed was similar despite lower sample frequency. Therefore, the integration of GPS  
164 systems with higher sampling rate is likely required to improve the validity of F-v profile  
165 measured with GPS devices. Moreover, while V0 is calculated based on MSS (corresponding  
166 to a steady state), F0 is mainly related to  $\tau$  which is associated to a rate of state change and  
167 could therefore be more affected by the measurement system and/or data processing,  
168 explaining the higher typical error compared to V0. Nevertheless, the use of GPS devices to  
169 assess F-v profiles are now within reach and could be considered by practitioners in their  
170 daily practice since double constellations system are common.

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

180

## 181 **Practical applications**

- 182 • F-v profile variables assessed through Catapult Optimeye S7 GPS devices (sampled at  
183 10 Hz and including a double constellation system) presented small-to-moderate error  
184 compared with a radar device. Practitioner could consider these GPS devices as an  
185 alternative for more frequent assessment.
- 186 • F-v profile variables obtained with GPS showed a high inter-unit reliability,  
187 confirming previous studies findings that GPS units can be used interchangeably to  
188 measure F-v profiles in team sports athletes.

189

## 190 **Conclusion**

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

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247 **Legend**

248

249 **Table 1.** Concurrent validity and inter-unit reliability analysis. Raw data for criterion (Radar)  
250 and practical (GPS) devices are presented as mean  $\pm$  SD. Other concurrent validity statistics  
251 are presented with 90% confidence intervals. TEE stands for Typical error of Estimate. Raw  
252 data for GPS 1 and 2 are presented as mean  $\pm$  SD. Reliability statistics are presented with  
253 90% confidence intervals. TE stands for Typical Error. SWC stands for Smallest Worthwhile  
254 Change.

255 **Figure 1.** Schematic representation of the automatic data processing. The left panel represents  
256 the validity analysis where GPS was compared with radar. The right panel represents the  
257 inter-units reliability analysis. Both share the same data processing via the script. Upper panel  
258 represents the identification of the beginning and end of the sprint from the raw velocity  
259 signal. The script identifies the beginning (i.e. first speed value  $> 0.2 \text{ m}\cdot\text{s}^{-1}$  from 0) and the  
260 end of the sprint (i.e. negative acceleration after player reach maximal speed). The middle  
261 panel represents the raw velocity data fitting into a mono exponential equation using a least  
262 square regression method from the *NLS* optimization function of the *nlstools* package (version  
263 3.6.2). A time delay (d) was integrated into the initial equation to improve the goodness of fit,  
264 if the actual start of the sprint did not occur at  $t=0 \text{ s}$  ( $0.09 \pm 0.04 \text{ s}$  on average in the present  
265 study). The lower panel aimed to calculate the speed-time data, theoretical maximal  
266 horizontal force ( $F_0 [\text{N}\cdot\text{kg}^{-1}]$ ), maximal horizontal sprinting power ( $P_{\text{max}} [\text{W}\cdot\text{kg}^{-1}]$ ) and  
267 theoretical maximal sprinting velocity ( $V_0 [\text{m}\cdot\text{s}^{-1}]$ ). All data analysis were performed with R  
268 statistical software (R v4.0.2. R Foundation for Statistical Computing). *MSS* stands for  
269 maximal sprint speed,  $\tau$  is the acceleration time constant and d the time delay.

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

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278 **Table 1**

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

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281 **Figures**

282 **Figure 1**

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