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

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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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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 ± 7.6 cm; 78.3 ± 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 τ) 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.¹ While the radar is considered as a reference to measure speed,¹ 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.² However, most elite teams are now equipped with global positioning system (GPS)
73 devices,³ 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 devices⁴ or timing gates,⁵ with mixed results likely due to the limited accuracy of the GPS
78 units used. Moreover, Lacombe et al.⁶ 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 τ) 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 ± 7.6 cm; body mass; 78.3 ± 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 ± 0.10 and the number of satellites was 15.5 ± 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.⁷ and Morin et al.⁸ 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.⁹

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 ($CV > SWC$).¹⁰

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 τ (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*

142 *Insert Figure 2*

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.⁴ However, only a 10 Hz device including a double constellation
151 system has been used in our study compared with Naghara et al.⁴ 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.¹¹ 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.⁴ 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 τ 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.⁶ 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} repetitions¹²), 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, τ 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 ⁻¹)	τ (s)	Pmax (W·kg ⁻¹)	V0 (m·s ⁻¹)	F0 (N·kg ⁻¹)
Validity					
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 (%)					
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	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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280

281 **Figures**

282 **Figure 1**

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