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

Article *in* International Journal of Sports Physiology and Performance · May 2022

DOI: 10.1123/ijspp.2021-0339

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Abstract count: 174

Text only word account: 2732

Numbers of tables: 2

Numbers of figures: 3

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

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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 10 Hz GPS devices (Vector S7, Catapult Innovations, Melbourne, Australia). **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 completed to obtain input (maximal sprint speed [MSS] and acceleration time constant τ) and output (theoretical maximal horizontal force [F0], sprinting speed [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. Concurrent validity and inter-unit reliability analyses were performed. **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 sprint force velocity (F-v) profile, practitioners need to set standardised protocols and record special temporal or running speed-time data using specific devices such as a radar.[1] While the radar is considered as a reference measure to assess speed,[1] not all high-level clubs have access to such a technology. Moreover, in elite sport environments, 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 the raw 10 Hz data (i.e. from GPS) to extrapolate sprint mechanical properties by analysing the validity against radar and laser devices[4] or timing gates.[5] They observed mixed results likely due to the limited accuracy of the GPS units used. Moreover, Lacome et al.[6] examined the inter-unit reliability and observed trivial-to-small typical error and good-to-very good between-device intraclass correlation coefficients. This, suggests that practitioners could reliably examine F-v profile with GPS. While considerations have only 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 determined if the integration of double constellation system (including GNSS and GPS) improves the accuracy of GPS devices to produce F-v profile variables.

Therefore, the first aim of this study was to assess the concurrent validity of input variables (maximal sprint speed [MSS] and acceleration constant τ). Secondarily similar analyses were conducted on the output variables (theoretical maximal horizontal force [F0], sprinting speed [V0], and horizontal power [Pmax]) obtained with GPS. Finally, the inter-unit reliability of F-v profile variables assessed using GPS-data were investigated.

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 complied with the recommendations of the Declaration of Helsinki.

Design

The F-v profile was assessed at the beginning of a rugby training session 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 athletes. However, they were instructed to stand still in order to avoid any backward movement prior to starting their sprint, and to accelerate maximally once they commenced. Each sprint was concurrently measured using a radar and 2 GPS devices. The radar (Stalker Pro II Sports Radar Gun, Plano, TX) sampling at 46.875 Hz, was placed on a tripod 5 m behind the player and 1 m above the ground. The GPS units (Vector S7, Catapult Innovations, Melbourne, Australia) sampled at 10 Hz and encompassed a double constellation system (i.e. GNSS and GPS). The 2 GPS units were carried in a tightly fit vest allowing the two units to be positioned side-by-side 5 cm apart around C7-T1. The average horizontal dilution of precision was 0.74 ± 0.10 and number of satellites was 15.5 ± 1.5,which are considered to be within range of good signal quality.[7]

Raw speed signal gathered via radar (firmware 2.0.7) and GPS (firmware 8.1.0) devices were downloaded from their respective manufacturer software and 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 in previous studies.[8-9] The whole data processing and analysis 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. CI), the typical error of the estimate (TEE, 90% CI) 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.[10]

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-Altman analysis are reported in Figure 2. Pearson correlation revealed a moderate relationship for F0 (r=0.48 [CI=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 of this study showed that GPS could be considered as a valid and reliable device to assess F-v profile variables. These results are promising and could open-up new possibilities in terms of players physical testing.

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 constellation 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, poorer concurrent validity (large to very large correlation and moderate typical errors) was 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 or the instantaneous signal precision. In other research, 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. Consequently, F0 could be more affected by the measurement system and/or data processing, explaining the higher typical error compared to V0.[12] As such, the validity of FVP (and especially F0) using GPS seems dependent of the device sampling rate and the system precision. Nevertheless, the use of GPS devices to assess F-v profiles are now appropriate and could be considered by practitioners in their daily practice since double constellation 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 decreases by a factor of $\sqrt{n}$ repetitions[13]), 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 intra-unit reliability, 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 Vector S7 GPS devices (sampled at 10 Hz and including a double constellation system) presented small-to-moderate error compared with a radar device. Practitioners 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 findings from previous studies that GPS units can be used interchangeably to measure F-v profiles in team sports athletes.

Conclusion

The present study indicates that the Catapult Vector S7 GPS device is a valid, reliable and time-effective alternative to radar when assessing sprint acceleration F-v profiles in team sport 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. F0: theoretical maximal horizontal force; Pmax: maximal horizontal sprinting power. V0: theoretical maximal sprinting speed. *MSS* stands for maximal sprint speed. τ is the acceleration time constant and d the time delay.

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-unit reliability analysis. Both share the same data processing via the script. Upper panel (figure a and b) represents the identification of the beginning and end of the sprint from the raw speed 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 (figure c and d) represents the raw speed 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 (figure e and f) 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 speed (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-Altman analyses. Black line represents the bias. Dashed lines represent 90% limits of agreements.

Table 1

	MSS (m·s^{-1})	τ (s)	Pmax (W·kg^{-1})	V0 (m·s^{-1})	F0 (N·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
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)
Standardised mean bias	-0.05 (-0.11 to 0.01)	0.04 (-0.15 to 0.23)	-0.05 (-0.20 to 0.10)	-0.04 (-0.12 to 0.03)	-0.02 (-0.22 to 0.18)
TEE as coefficient of variation (%)	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)
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

Figure 1

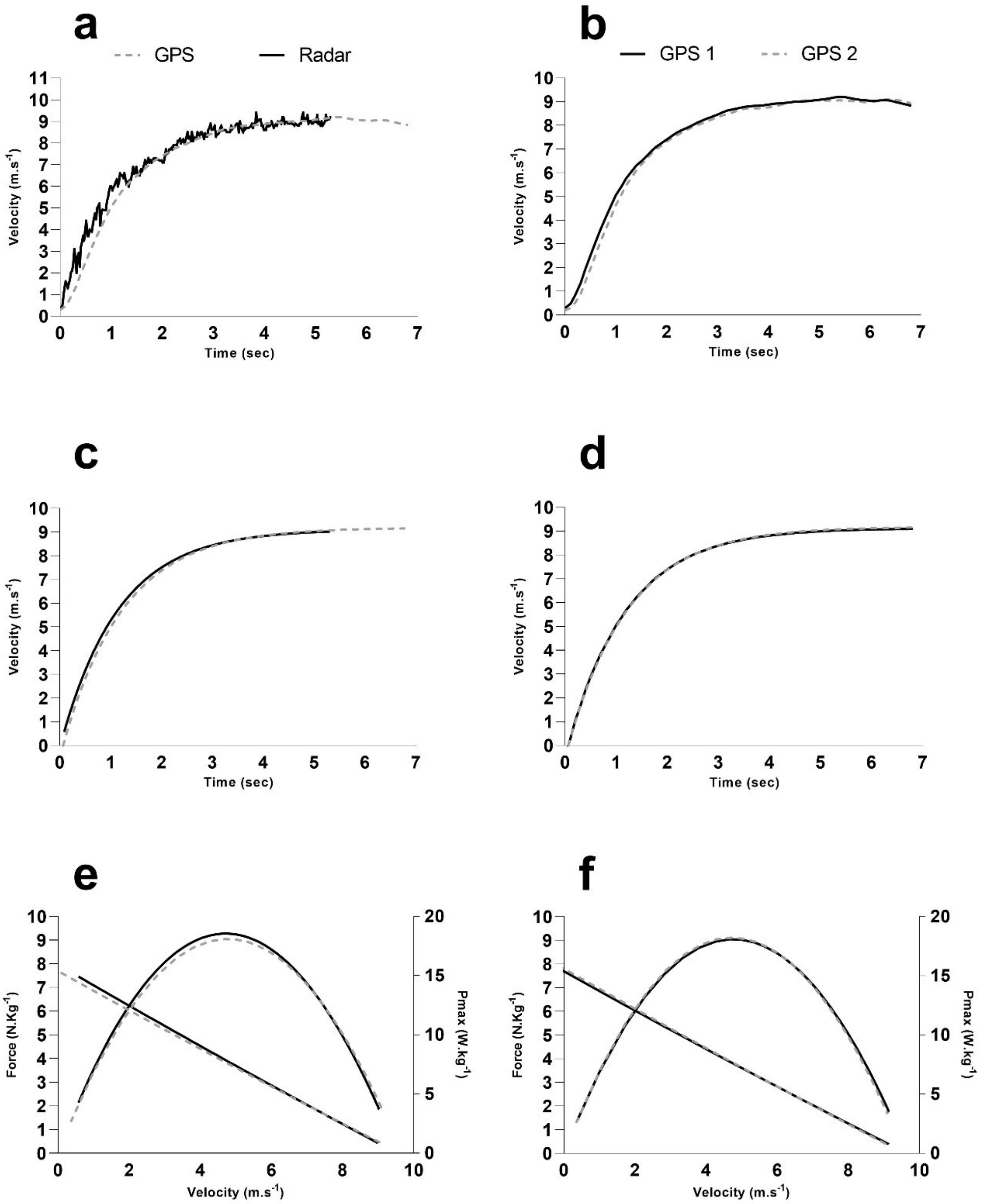
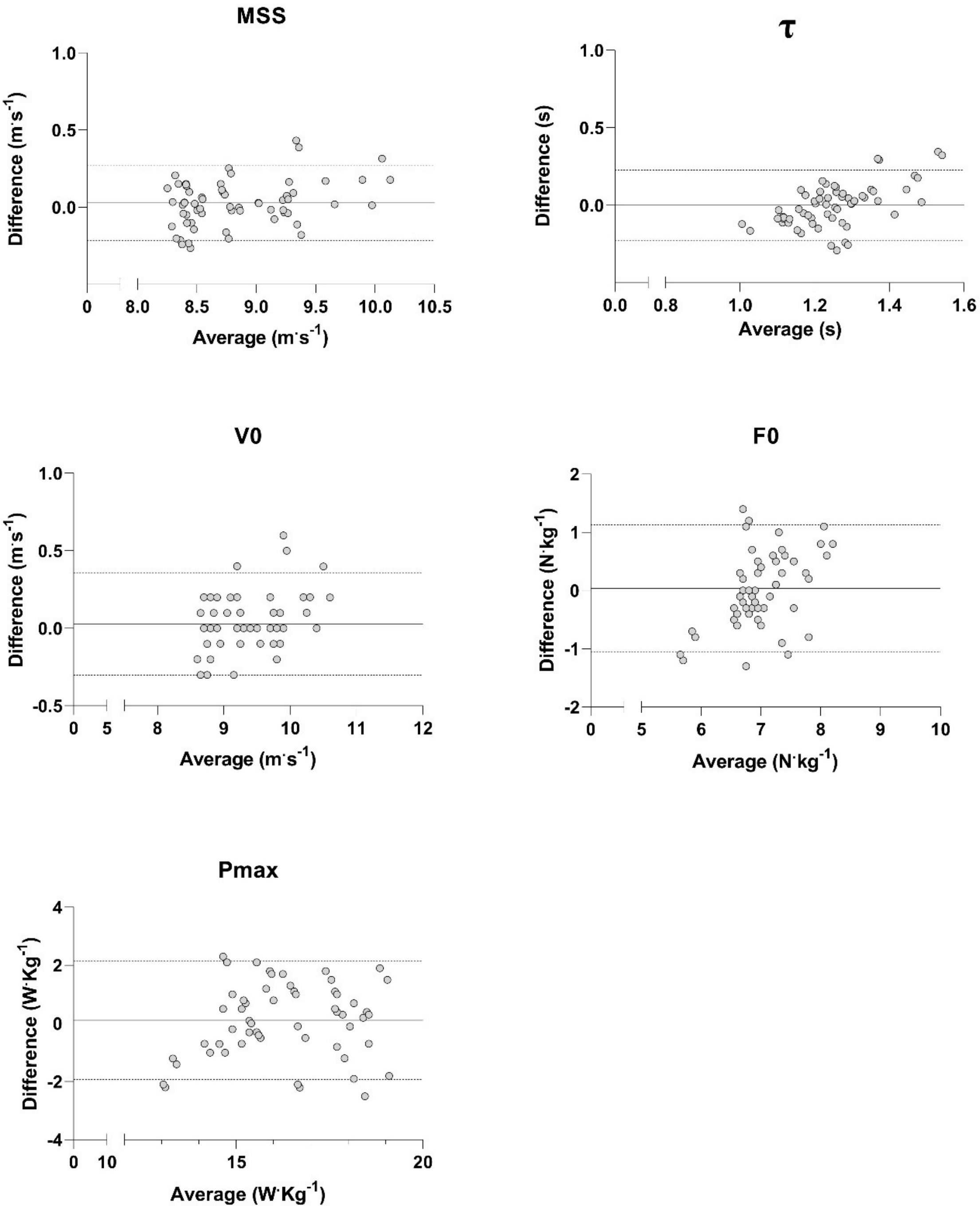

a
GPS
Radar
Velocity (m.s^{-1})
Time (sec)
b
GPS 1
GPS 2
Velocity (m.s^{-1})
Time (sec)
c
Velocity (m.s^{-1})
Time (sec)
d
Velocity (m.s^{-1})
Time (sec)
e
Force (N.Kg^{-1})
Pmax (W.kg^{-1})
Velocity (m.s^{-1})
f
Force (N.Kg^{-1})
Pmax (W.kg^{-1})
Velocity (m.s^{-1})

Figure 2


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