Title: Concurrent agreement and test-retest reliability of a global positioning system device for measuring maximal horizontal deceleration ability in elite youth academy soccer players.

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Abstract

Purpose: Investigate the concurrent agreement and test-retest reliability of 10 Hz global positioning system (GPS) device against a criterion measure (47 Hz radar device) to assess maximal horizontal deceleration ability (maximum deceleration [DEC_{Max}], average deceleration [DEC_{Ave}], time to stop [TTS], and distance to stop [DTS]). ***Methods:*** Thirty-two male elite youth academy soccer players (18.1 ± 1.6 yrs; 76.6 ± 7.9 kg) completed the acceleration-deceleration ability test with sixteen completing a second test to assess test-retest reliability. Maximal horizontal deceleration ability was measured concurrently using GPS_{Raw} (10 Hz data), GPS_{Export} (STATSports software), and a radar device. Bland-Altman method and Pearson correlations assessed concurrent agreement and intra-class correlations (ICC) with coefficient of variation (CV%) was used to assess test-retest reliability. ***Results:*** *Large* to *very large* correlations (r = 0.51 to 0.78) were observed between radar and GPS_{Raw} and GPS_{Export} derived values of DEC_{Max} and DEC_{Ave}. GPS_{Raw} and GPS_{Export} derived values of DEC_{Max} showed *good* overall (ICC = 0.84 to 0.86, CV% = 4.50 to 5.48) test-retest reliability. ***Conclusion:*** Practitioners can consider using GPS as a cost-effective, valid, and reliable alternative to radar technology to assess maximal horizontal deceleration ability in team sports players.

Key words: Braking, profiling, acceleration-deceleration ability test, football, validity

Introduction

Profiling horizontal deceleration ability can inform performance enhancement and injury-prevention strategies in team-sport environments[1]. However, there remains a paucity of valid and reliable methods to assess an athlete's horizontal deceleration ability in the field[1]. While radar or laser devices are considered the criterion measure of horizontal deceleration ability[1], not all high-level clubs have access to such technologies[2]. Moreover, these technologies only permit individual testing, making it difficult for practitioners to assess horizontal deceleration ability within time-constrained environments[3]. Instead, most clubs are now equipped with global positioning system (GPS) devices[2], which could be a viable alternative to assess horizontal deceleration capabilities without additional equipment and associated time demand.

Previous research has highlighted several variables to quantify horizontal deceleration ability[1]. The deceleration variables: maximum deceleration (DEC_{Max}), average deceleration (DEC_{Ave}), and time to stop (TTS) have all shown *moderate* inter-test reliability using radar technology during a maximal deceleration task[1]. However, the reliability for many of these variables obtained from GPS remains unclear. *Poor* to *moderate* inter-unit reliability for DEC_{Max} has been reported previously, with these mixed results likely due to differences in protocols used[4,5]. Furthermore, the concurrent agreement and test-retest reliability of these deceleration variables obtained from a GPS device during a maximal deceleration task remains unknown.

Therefore, the aims of this study were to examine 1) the concurrent agreement between deceleration variables obtained from GPS with a criterion measure and 2) the test-retest reliability of deceleration variables assessed using a GPS device in elite youth academy soccer players.

Methods

Subjects

Thirty-two male youth soccer players (age: 18.1 ± 1.6 years; body mass: 76.6 ± 7.9 kg) from an English Premier League academy were recruited and completed the concurrent agreement session. Due to congested fixtures, only sixteen players (age: 17.4 ± 1.3 years; body mass: 73.6 ± 8.0 kg) completed the test-retest reliability session. The research was approved by the University Ethics Committee and complied with the recommendations of the Declaration of Helsinki. All participants provided voluntary informed consent prior to starting the study.

Design

Within-subject repeated measures.

Methodology

The study was conducted during an in-season competition phase, with testing completed at the same time of day on an artificial turf surface. Participants all wore studded footwear and completed a 20 m maximal sprint test followed by two testing sessions, each separated by a week (Figure 1). Before testing, participants completed a 10-minute standardised warm-up and two progressive deceleration test trials.

Maximal 20 m sprint times were recorded using timing gates (TC, Brower Timing Systems, UT, USA) positioned at 0 and 20 m. Participants started 1 m behind the first gate and initiated their sprint from a stationary split stance, completing two trials with at least 2-minutes recovery. The fastest 20 m split was used as a 'criterion' time in the maximal horizontal deceleration test[2].

During both testing sessions, participants completed two repetitions of the acceleration-deceleration ability (ADA) test following a similar protocol used by Harper and colleagues[1] (Figure 1). Trials were considered unsuccessful if the 20 m time was 5% greater than the 'criterion' time and repeated after a 3-minute recovery.

Raw velocity data was recorded concurrently during the ADA test using two methods: A radar device (Stalker Pro II, Applied Concepts, Inc., TX, USA) positioned 5 m behind the participants on a tripod 1 m off the ground (Figure 1), sampled data at 46.875 Hz and a 10 Hz GPS unit (APEX, STATSports, Ireland) worn in a fitted vest. The average horizontal dilution of precision was 0.55 ± 0.38 and number of satellites was 20.3 ± 1.4.

Raw velocity data from the radar and GPS (GPS_{Raw}) was exported and processed in R statistical software (R v3.3.0. R Foundation for Statistical Computing) using a custom-made

R-script to calculate the deceleration variables (DEC_{Ave}, DEC_{Max}, TTS, and distance to stop [DTS]) based on methods in previous studies (see supplementary material)[1,6,7]. Maximum velocity (V_{Max}) and DEC_{Max} were also directly obtained from STATSports software (Sonra 4.0, STATSports, Ireland) (GPS_{Export}).

Insert Figure 1 here

Statistical Analysis

Concurrent agreement between the criterion measure (radar) and practical measures (10 Hz GPS_{Raw}/GPS_{Export}) was assessed with Bland-Altman method limits of agreement (95%) and mean difference. Mean difference was interpreted as *acceptable* based on a small effect in raw units and typical error of the criterion measure[1]: $V_{Max} = \pm 0.15\ m \cdot s^{-1}$, TTS = ±0.1 s, DTS = ±0.5 m, $DEC_{Ave} = \pm 0.25\ m \cdot s^{-2}$, and $DEC_{Max} = \pm 0.50\ m \cdot s^{-2}$. Secondary agreement analysis assessed mean bias, typical error of estimate (TEE) in standardised units, and Pearson correlation coefficients, interpreted by thresholds proposed by Hopkins[8].

Test-retest reliability of the practical measures (10 Hz GPS_{Raw}/GPS_{Export}) was assessed using the intraclass correlation coefficient (ICC), coefficient of variation (CV%), calculated from the typical error and expressed as a percentage, and standard error of measurement, expressed in raw units. Overall reliability was interpreted as follows: ICC > 0.9 and CV% < 5 = excellent; ICC 0.75 to 0.9 and CV% < 10 = good; ICC < 0.75 or CV% < 10 = moderate; ICC < 0.75 and CV% > 10 = poor[9,10].

All measures of agreement and test-retest reliability were calculated using Hopkins[8] excel spreadsheet and with 95% confidence intervals.

Results

Data related to the concurrent agreement and test-retest reliability are displayed in Table 1. Limits of agreement graphs from the Bland-Altman analysis are shown in Figure 2.

Insert Table 1 here

Insert Figure 2 here

Discussion

The main findings of this study suggest GPS as a valid and reliable device to assess deceleration variables (DEC_{Max} and DEC_{Ave}). Therefore, practitioners may consider using GPS as a cost-effective alternative to radar technology to assess maximal horizontal deceleration ability.

Concurrent agreement analysis and equivalence testing showed *acceptable* mean difference and *large* to *very large* correlations between radar and GPS derived values of DEC_{Max} and DEC_{Ave}. Crang et al.,[11] found similar mean error (-0.07 $m{\cdot}s^{-2}$) between a 10 Hz GPS and laser device measuring DEC_{Max}, supporting the current results. However, the decelerations were not performed from high speeds (< 7 $m{\cdot}s^{-1}$)[11], which may explain the greater mean difference found in the current study. This suggests the ability of GPS devices to adequately detect deceleration may be compromised when movement velocity is increased[3,12]. In support of this, higher sampling devices (e.g., 16 Hz) still exhibited error (TEE = 1.59 ± 0.42%) in V_{Max} during high-velocity movements[3]. Therefore, practitioners could consider using GPS derived values of DEC_{Max} and DEC_{Ave} to assess an athlete's horizontal deceleration ability.

However, *acceptable* mean difference was found for DTS, but the mean difference for TTS exceed *acceptable* thresholds. The origin of this difference is unclear but may be attributed to the higher sampling rate (47 Hz vs 10 Hz) of the radar compared to the GPS or data-processing methods. However, secondary analysis showed poor concurrent agreement (*small* to *moderate* correlation and *large* to *very large* TEE and bias) for TTS and DTS, therefore, their use in practice should be carefully considered.

The present study demonstrated *good* overall test-retest reliability for DEC_{Max}. In contrast, previous studies have shown *poor* to *moderate* inter-unit reliability in values of DEC_{Max}[4,5]. However, neither of these studies controlled the deceleration velocities (e.g., participants achieving ≥ 95% of 20 m split time), therefore, making it difficult to compare the current results. Nonetheless, the current findings suggest GPS_{Export} values of DEC_{Max} can be used as a time-efficient method (no additional data-processing) that could be easily implemented during in-situ pitch-based warmups to regularly monitor player horizontal deceleration ability. In addition, practitioners may wish to use GPS_{Raw} data as it enables the calculation of novel variables such as DEC_{Ave}, TTS, and DTS. Similar reliability (CV% = 6.0) in DEC_{Ave} measured using a 10 Hz GPS has been observed previously[12], supporting its use in practice. However, using GPS_{Raw} data requires additional post-processing and a script is needed to calculate these variables which may not be accessible to all practitioners. Furthermore, using radar technology, Harper et al.,[1] found similar test-retest reliability values for all deceleration variables compared to those found in the current study. This suggests error from testing procedure (e.g., deceleration strategy) rather than the measurement technique itself.

Practical Applications

- DEC_{Max} and DEC_{Ave} variables obtained from GPS devices presented *acceptable* mean difference and *large* to *very large* correlations with a radar device. Therefore, practitioners could consider GPS as a cost-effective alternative to radar technology to assess maximal horizontal deceleration ability.
- DEC_{Max} obtained with GPS showed *good* overall test-retest reliability, confirming GPS can be used to accurately monitor maximal horizontal deceleration ability over time.

While GPS devices were shown to be valid and reliable in measuring deceleration variables from a 20 m sprint distance. Future investigations are needed to confirm the practical application of GPS from other sprint distances. Additionally, as only test-retest reliability was assessed, further research is necessary to understand the sensitivity to changes (e.g. pre-post pre-season) of the deceleration variables obtained with GPS.

Conclusion

The present study indicates GPS as a cost-effective, valid, and reliable alternative to radar technology to assess maximal horizontal deceleration ability (DEC_{Max} and DEC_{Ave}) in elite youth soccer players. Future studies need to examine the use of GPS devices in measuring deceleration variables from different sprint distances to help inform more advanced insights into athlete's deceleration capabilities.

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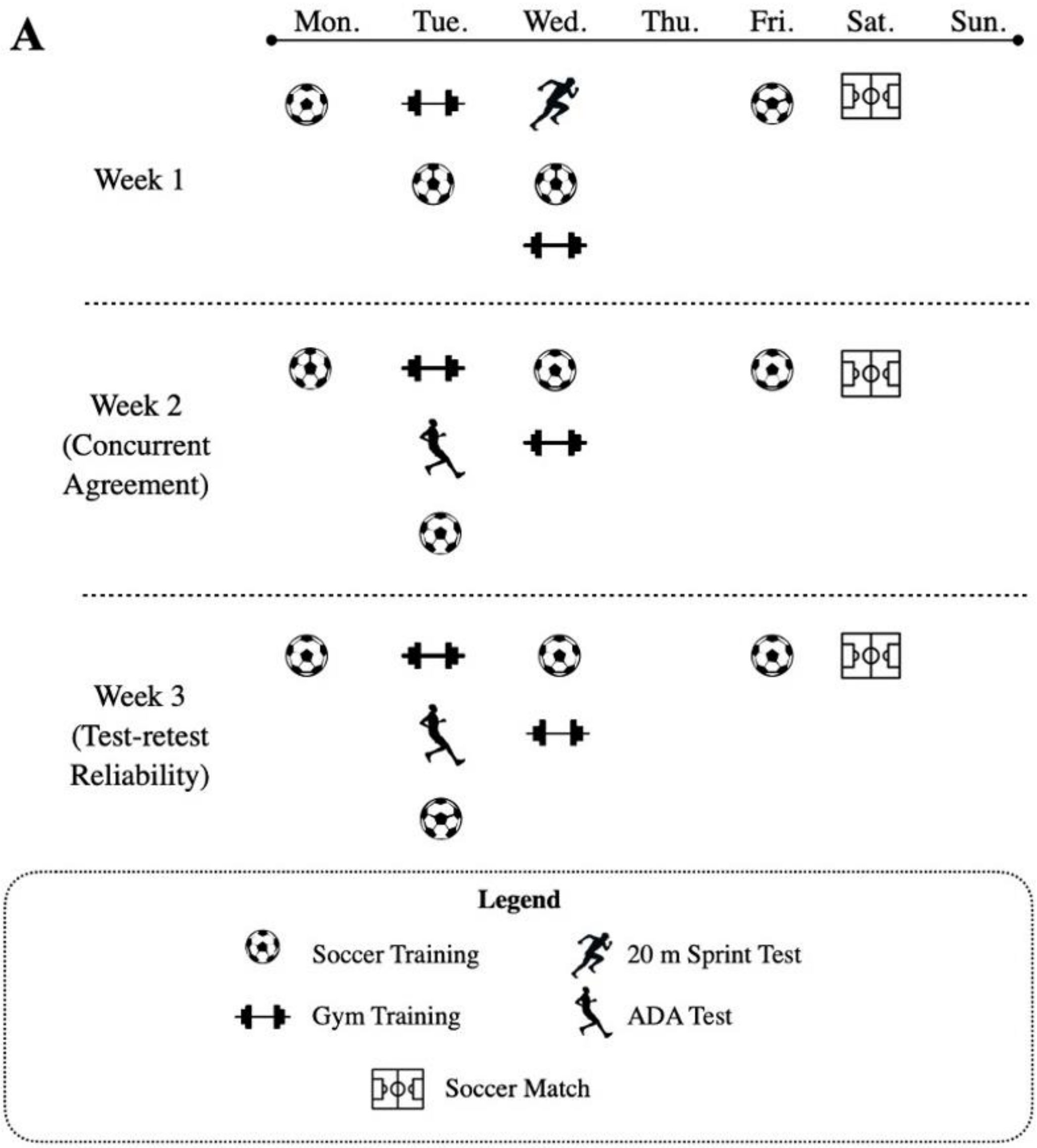
Legend

Figure 1. (A) Schematic representation of the study design. Testing was conducted within a three-week regular soccer training plan. Week one included a maximal 20 m linear sprint test and maximal horizontal deceleration ability was assessed using the global positioning system devices during week two and three. (B) Schematic representation of acceleration-deceleration ability (ADA) test layout. Timing gates were positioned at 0 and 20 metres (m). Participants were instructed to perform a maximal sprint over 20 m using the same starting procedure as the 20 m sprint test, followed by a maximal horizontal deceleration phase. The 20 m timing gate was used by the participants to initiate the deceleration phase. After the end of the deceleration, participants immediately backpedalled to the 20 m timing gate line.

Figure 2. Bland-Altman analyses. Black line represents the mean difference. Dashed lines represent 95% limits of agreements. V_{Max}: maximal velocity; TTS: time to stop; DTS: distance to stop; DEC_{Ave}: average deceleration and DEC_{Max}: maximum deceleration.

Table 1. Concurrent agreement and test-retest reliability analysis. Raw data for criterion (Radar) and practical (GPS_{Raw} and GPS_{Export}) are presented as mean ± SD. Mean difference, Effect size, Limits of Agreement, Mean bias, TEE and correlation statistics are presented with 95% confidence intervals. ES stands for effect size; LOA stands for limits of agreement and are presented as ± 95%; TEE stands for Typical Error of Estimate. Raw data for criterion (Radar) and practical (GPS_{Raw} and GPS_{Export}) are presented as mean ± SD. Reliability statistics are presented with 95% confidence intervals. ICC stands for intra-class correlation. CV standards for coefficient of variation. SEM stands for standard error of measurement. V_{Max}: maximal velocity; TTS: time to stop; DTS: distance to stop; DEC_{Ave}: average deceleration and DEC_{Max}: maximum deceleration.

Figure 1


A
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Week 1
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Agreement)
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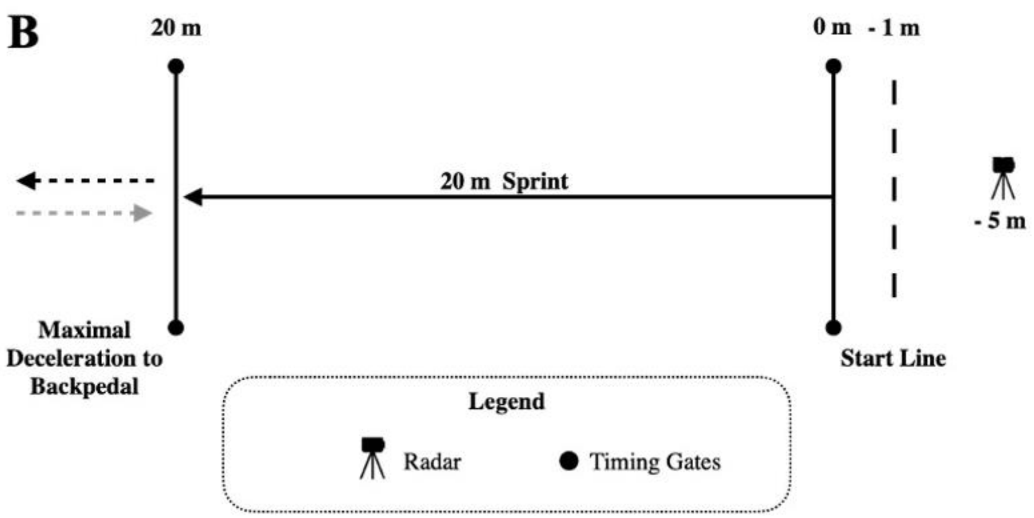
(Test-retest
Reliability)
Legend
Soccer Training
20 m Sprint Test
Gym Training
ADA Test
Soccer Match


B
20 m
0 m
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20 m Sprint
- 5 m
Maximal
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Backpedal
Start Line
Legend
Radar
Timing Gates

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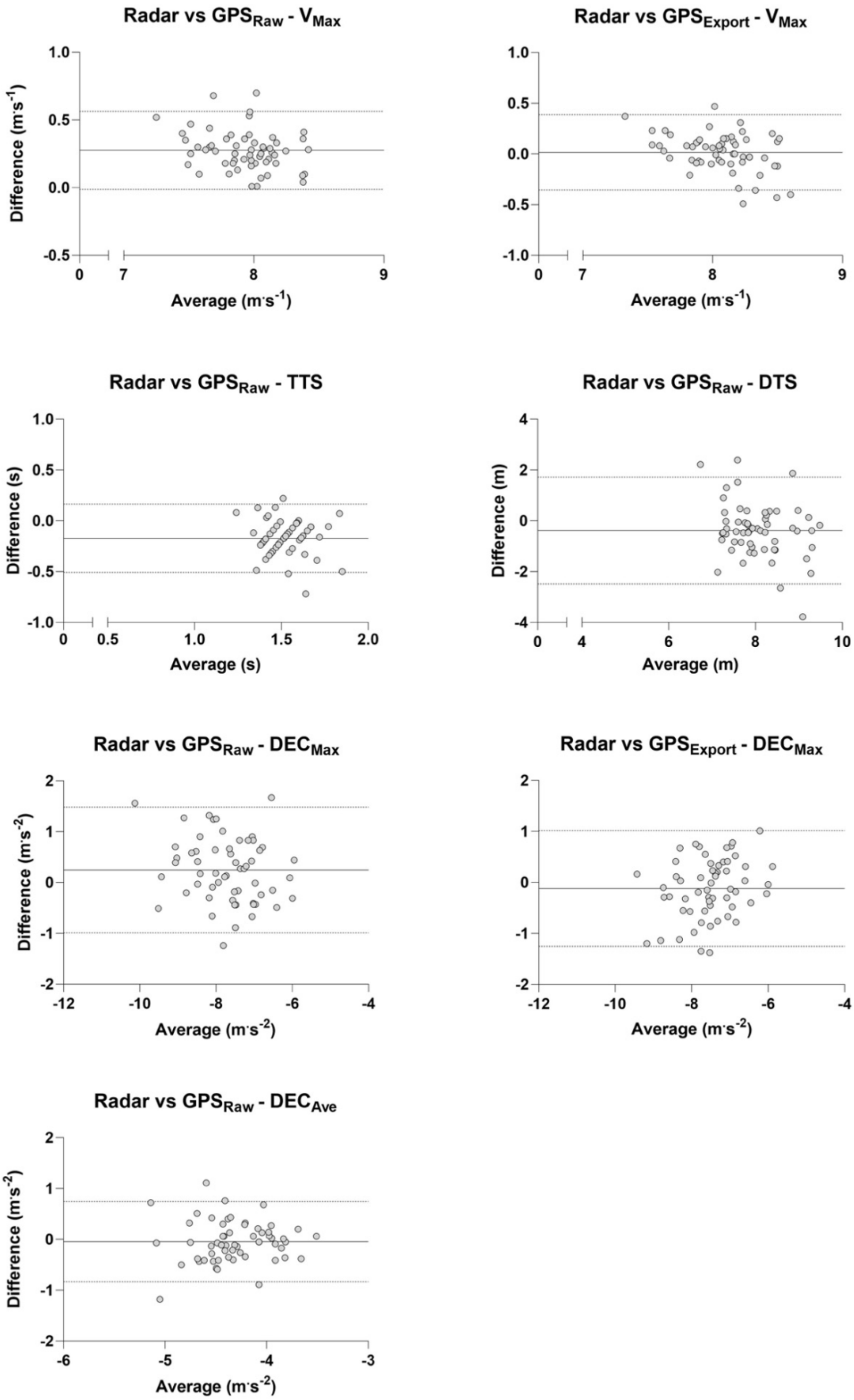
Figure 2



Radar vs GPSRaw - VMax
Radar vs GPSExport - VMax
Difference (m·s-1)
Average (m·s-1)
Radar vs GPSRaw - TTS
Difference (s)
Average (s)
Radar vs GPSRaw - DTS
Difference (m)
Average (m)
Radar vs GPSRaw - DECMax
Radar vs GPSExport - DECMax
Difference (m·s-2)
Average (m·s-2)
Radar vs GPSRaw - DECAve

Table 1

	Agreement vs Radar					Test-retest Reliability					
	Mean ± SD	**Mean Difference (95% CI)**	**TOST (Lower and Upper *p*-value)**	**Effect Size (95% CI)**	**LOA (Lower and Upper Bounds)**	**Day 1**	**Day 2**	**ICC (95% CI)**	**CV% (95% CI)**	**Rating**	**SEM (95% CI)**
Radar (Criterion)											
V_{Max} ($m \cdot s^{-1}$)	8.07 ± 0.26	-		-	-	8.16 ± 0.21	8.09 ± 0.25	0.88 (0.69 to 0.96)	1.06 (0.78 to 1.65)	*Good*	0.08 (0.06 to 0.12)
TTS (s)	1.43 ± 0.14	-		-	-	1.40 ± 0.13	1.34 ± 0.12	0.67 (0.28 to 0.87)	5.45 (4.00 to 8.56)	*Moderate*	0.07 (0.05 to 0.11)
DTS (m)	7.86 ± 0.73	-		-	-	7.77 ± 0.65	7.58 ± 0.63	0.62 (0.20 to 0.85)	5.48 (4.02 to 8.61)	*Moderate*	0.39 (0.29 to 0.60)
DEC_{Ave} ($m \cdot s^{-2}$)	-4.33 ± 0.41	-		-	-	-4.41 ± 0.41	-4.39 ± 0.28	0.73 (0.39 to 0.88)	4.36 (3.20 to 6.3)	*Moderate*	0.18 (0.13 to 0.28)
DEC_{Max} ($m \cdot s^{-2}$)	-7.58 ± 0.89	-		-	-	-7.52 ± 0.97	-7.64 ± 0.77	0.78 (0.48 to 0.92)	6.04 (4.43 to 9.51)	*Good*	0.41 (0.30 to 0.63)
GPS_{Raw}											
V_{Max} ($m \cdot s^{-1}$)	7.80 ± 0.30	0.28 (0.24 to 0.31)	Lower: $p < 0.001$ Upper: $p = 1$	1.87 (1.62 to 2.18)	0.28 (-0.01 to 0.56)	7.90 ± 0.25	7.78 ± 0.23	0.81 (0.54 to 0.93)	1.41 (1.04 to 2.18)	*Good*	0.10 (0.07 to 0.15)
TTS (s)	1.61 ± 0.15	-0.17 (-0.22 to -0.13)	Lower: $p = 0.999$ Upper: $p < 0.001$	-1.01 (-1.36 to -0.70)	0.33 (-0.51 to 0.16)	1.59 ± 0.14	1.56 ± 0.09	0.48 (0.00 to 0.78)	5.77 (4.23 to 9.07)	*Moderate*	0.09 (0.07 to 0.14)
DTS (m)	8.25 ± 0.96	-0.39 (-0.67 to -0.10)	Lower: $p = 0.209$ Upper: $p < 0.001$	-0.36 (-0.70 to -0.04)	2.11 (-2.49 to 1.72)	8.21 ± 0.85	7.97 ± 0.57	0.53 (0.06 to 0.81)	6.63 (4.85 to 10.44)	*Moderate*	0.49 (0.36 to 0.76)
DEC_{Ave} ($m \cdot s^{-2}$)	-4.29 ± 0.40	-0.04 (-0.15 to 0.06)	Lower: $p < 0.001$ Upper: $p < 0.001$	-0.11 (-0.37 to 0.15)	0.79 (-0.83 to 0.75)	-4.37 ± 0.40	-4.38 ± 0.35	0.57 (0.13 to 0.83)	6.07 (4.45 to 9.56)	*Moderate*	0.25 (0.18 to 0.39)
DEC_{Max} ($m \cdot s^{-2}$)	-7.83 ± 1.01	0.25 (0.08 to 0.41)	Lower: $p < 0.001$ Upper: $p = 0.002$	0.39 (0.22 to 0.57)	1.23 (-0.99 to 1.48)	-7.91 ± 1.06	-8.05 ± 1.03	0.86 (0.64 to 0.95)	5.48 (4.03 to 8.63)	*Good*	0.39 (0.29 to 0.60)
GPS_{Export}											
V_{Max} ($m \cdot s^{-1}$)	8.06 + 0.33	0.02 (-0.03 to 0.07)	Lower: $p < 0.001$ Upper: $p < 0.001$	0.08 (-0.07 to 0.24)	0.37 (-0.36 to 0.39)	8.16 ± 0.26	8.03 ± 0.28	0.82 (0.56 to 0.93)	1.51 (1.11 to 2.35)	*Good*	0.11 (0.08 to 0.17)
DEC_{Max} ($m \cdot s^{-2}$)	-7.46 ± 0.74	-0.12 (-0.27 to 0.03)	Lower: $p < 0.001$ Upper: $p < 0.001$	-0.21 (-0.39 to -0.02)	1.13 (-1.25 to 1.01)	-7.51 ± 0.78	-7.61 ± 0.73	0.84 (0.59 to 0.94)	4.50 (3.31 to 7.05)	*Good*	0.30 (0.22 to 0.46)