



Interchangeability of the Polar Team Pro system in determining match load and intensities in semi-professional rugby union players

Jacobus J. Oosthuizen, Martinique Sparks, Christo A. Bisschoff, Marike Cockeran & Ermanno Rampinini

To cite this article: Jacobus J. Oosthuizen, Martinique Sparks, Christo A. Bisschoff, Marike Cockeran & Ermanno Rampinini (04 Feb 2025): Interchangeability of the Polar Team Pro system in determining match load and intensities in semi-professional rugby union players, International Journal of Performance Analysis in Sport, DOI: [10.1080/24748668.2025.2461862](https://doi.org/10.1080/24748668.2025.2461862)

To link to this article: <https://doi.org/10.1080/24748668.2025.2461862>



© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



Published online: 04 Feb 2025.



Submit your article to this journal [↗](#)



Article views: 540



View related articles [↗](#)



View Crossmark data [↗](#)

Interchangeability of the Polar Team Pro system in determining match load and intensities in semi-professional rugby union players

Jacobus J. Oosthuizen ^a, Martinique Sparks ^{a,b,c}, Christo A. Bisschoff ^a,
Marieke Cockeran ^d and Ermanno Rampinini ^{e,f}

^aPhysical activity, Sport and Recreation Research Focus Area, Faculty of Health Sciences, North-West University, Potchefstroom, South Africa; ^bSchool of Health and Wellbeing, University of Southern Queensland, Ipswich, Australia; ^cCentre for Health Research, University of Southern Queensland, Ipswich, Australia; ^dMedicine Usage in South Africa, Faculty of Health Sciences, North-West University, Potchefstroom, South Africa; ^eHuman Performance Laboratory, MAPEI Sport Research Centre, Varese, Italy; ^fSport and Exercise Discipline Group, Human Performance Research Centre, Faculty of Health, University of Technology Sydney, Moore Park, New South Wales, Australia

ABSTRACT

This study assessed the interchangeability of the 10-Hz Polar and Catapult GPS during competitive matches. The agreement between data from both GPS units worn simultaneously and processed with the manufacturer's individual GPS-filtered software was also assessed. Thirty players competing in the Currie Cup first division competition were monitored using two different tracking systems across six matches. To determine the interchangeability between systems, player movement variables including total distance (TD), low-speed running (LSR, 0.0–14.4 km/h), high-speed running (HSR, 14.4–18.9 km/h), very high-speed running (VHSR, >18.9 km/h), acceleration efforts > 2.5 m/s² (ACC), deceleration efforts < -2.5 m/s² (DEC) and maximum velocity reached during each half were compared. The two systems showed good to excellent agreement (CCC = 0.83–0.98) during all selected variables. During the entire match, Polar had, on average, higher values than Catapult, except for LSR and HSR. The percentage differences between systems were 3.6% TD, 1.9% maximum velocity, -4.7% LSR, -4.6% HSR, 16.5% VHSR, 13.7% ACC and 11.9% DEC. In addition, Bland-Altman plots showed a low average difference for TD (129.1; 90.1 m), maximum velocity (0.5; 0.5 km/h), LSR (138.2; 80.9 m), HSR (21.3; 5.4 m), VHSR (35.7; 22.3 m), ACC (1.6; 1.8 efforts) and DEC (2.0; 1.2 efforts).

ARTICLE HISTORY

Received 18 April 2024
Accepted 27 January 2025

KEYWORDS

External load; global positioning systems (GPS); elite performance; team sports; interchangeability; player movement

1. Introduction

In professional sports, technologies can support the training process in order to optimise performance (Wilson & Plumley, 2017). Player tracking through objective devices has been introduced and widely used in a professional team sports setting (Noon et al., 2018).

CONTACT Jacobus J. Oosthuizen  cobus.oosthuizen@nwu.ac.za  Physical Activity, Sport and Recreation Research Focus Area, Faculty of Health Sciences, North-West University, Potchefstroom Campus, Potchefstroom 2520, South Africa

© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (<http://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

The ability of global positioning systems (GPS) to provide accurate and reliable data has allowed teams to quantify individual and team activities during training and matches (Terziotti et al., 2018).

A decisive factor why teams employ GPS over time-motion analysis (captured video recordings of training or matches) or other modalities at present is due to the biases of data interpretation by the user that can affect the reliability and may also be time-consuming or complicated (Venter et al., 2011). Nevertheless, GPS provides users with objective and trustworthy data in addition to being incredibly portable; more significantly, it is a useful tool since it provides real-time feedback on a variety of variables in many athletes unlike LPS, lidar or optical tracking (Adesida et al., 2019; Hulin et al., 2016). Furthermore, the convenient portability of GPS systems allows for easy data collection anywhere without any infrastructure compared to the fixed nature of time-motion analysis (Hennessy & Jeffreys, 2018). Popular GPS-derived variables teams use to monitor match load include the following: total distance, distance covered in different speed thresholds/zones, and number of accelerations or decelerations, to name but a few (Rago et al., 2020). Monitoring these variables could affect the outcome of the match due to the optimal management of players' load (Ellens, Hodges, et al., 2022).

However, there are still aspects limiting teams' ability to obtain certain technologies. One of the main prohibitive factors associated with high-quality GPS systems is the purchase costs that are accompanied by yearly subscription costs (Willmott et al., 2019). These authors emphasise that teams' interest in athlete tracking has required them to investigate less renowned brands that still offer reliable data at an affordable price (Willmott et al., 2019). There are currently many GPS manufacturers involved in athlete tracking (e.g. STATSports, Johan Sports, Catapult, PlayerTek, and VX Sport), with Catapult being used in the majority of studies involving GPS (Ellens, Middleton, et al., 2022). Catapult GPS has been proven accurate during matches compared to two optical tracking systems (TRACAB® and Second Spectrum®) during professional soccer matches with very strong positive correlations ($r > 0.72$) demonstrated for all chosen variables (Ellens, Hodges, et al., 2022). Nevertheless, Van den Tillaar et al. (2023) highlighted the use of the Catapult GPS system over the last two decades to measure distance and intensities accurately and questioned its relative cost compared to available low-cost systems. More recently, Polar launched their Polar Team Pro (PTP) system as a more affordable alternative to existing renowned brands (Van den Tillaar et al., 2023).

However, emerging GPS companies must demonstrate the accuracy of their systems and, more importantly, how their products compare to established GPS systems known for their accuracy (Scott et al., 2016). The sampling frequency of the GPS system has also evolved over time to improve reliability. Researchers have employed 1–15 Hz units in athlete tracking studies. The modified location determination algorithms, which influence the sensitivity of the GPS receiver with an increased sample rate and enhanced chipset, have made 10 Hz GPS units the preferred frequency range in GPS devices (Cummins et al., 2013; Varley et al., 2012). However, more recently, GPS devices employ multiple Global Network Satellite Systems (GNSS) instead of single GNSS access, which also affects accuracy (Ellens, Hodges, et al., 2022). Thus, developing GPS systems and their sample rate over time does not always equate to increased accuracy. According to Scott et al. (2016), this may be attributed to the indirect calculation of sampling rate through interpolated data detected in 15 Hz GPS devices during linear and sport-

simulated running (Johnston et al., 2014; Malone et al., 2017). This might be because the 15 hz sampling rate is determined by boosting a 10 hz GPS sampling rate with accelerometer data (Aughey, 2011; Johnston et al., 2014).

In light of this, a more affordable alternative to expensive GPS units such as Catapult is the Polar Team Pro (PTP) system. However, limited studies explored the accuracy of the PTP system in outdoor conditions. Only three studies employed the PTP during outdoor activities and reported that the system was a valid tool to measure total distance covered, maximum velocity and time spent at different speeds (Akyildiz et al., 2022; Huggins et al., 2020; Sandmæl et al., 2023). In none of these studies has the PTP been compared during matches or to a validated system like the Catapult. Therefore, the aim was to establish the interchangeability between the 10 hz PTP and the 10 hz Catapult (Vector S7) GPS during official competitive matches of semi-professional rugby players. Due to the lack of research on the PTP system in team sports, interchangeability studies are needed to compare the accuracy of the system to other devices.

2. Methods

2.1. Experimental approach to the problem

An observational study design was implemented to examine the interchangeability between two GPS systems of different manufacturers during six official rugby union matches during a competitive season. During matches, players wore two GPS devices in the provided manufacturer vest. Due to the ideal setting for both vests, it was found that the Catapult (Vector S7, Catapult, Catapult Sports Ltd, Melbourne) unit sat below the Polar unit (Polar Team Pro Sensor and Shirt; Polar Electro, Kempele, Finland). Both vests were fitted according to the manufacturer's suggested instructions, ensuring a "tight fit" to ensure that the GPS sensors were snug on the upper back between the superior and medial portions of the scapulae. This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Health Research Ethics Committee of the university where the research was conducted (NWU-00177-21-A1). The players were not required to participate in the study and had an opportunity to withdraw at any time during the study without fear of discrimination.

2.2. Subjects

Data were collected from 30 male rugby players (age 26.6 ± 2.9 , training experience 9.3 ± 2.5 years) who participated in the study and gave their informed consent after the risks and benefits of the study were explained. A total of 115 individual match observations were included in the analysis. After a visual inspection of the data, five outliers were removed.

2.3. Procedures

All matches within this study were played during the competitive season of the 2021 Currie Cup first division between June and August. Due to COVID-19, the seven teams only played one round, with two games cancelled due to positive COVID-19 cases. The

data for the team, therefore, includes 4 league matches with a semi-final and final match. Data collected with each system was analysed using the manufacturer's specific software (Openfield, version 3.7 for Catapult and Polar Team Pro web service, version 1.4.2 for Polar). The thresholds for both systems were set identically for all investigated parameters. Both GPS units sampled positioning data at 10 Hz frequency and contained a triaxial accelerometer that sampled at 100 Hz. The researcher and strength and conditioning coach of the team assigned and fitted the twenty PTP and twenty Catapult GPS units on match days. Units were assigned to random players in the five positional groups found in rugby union: tight forwards (props and locks), loose forwards (hooker, flanks, and eighth man), scrumhalf, inside backs (flyhalf and centres), and outside backs (wings and fullback) to ensure an even distribution of collected data. Both systems' units were switched on before the warm-up, which started ~45 minutes before kick-off, to ensure that both systems' satellite signals were received. After each match, the GPS data files were downloaded to a personal computer. The playing time was segmented into the 1st and 2nd half data, and selected variables were compared after each system filtering process was applied and exported to Microsoft Excel (Microsoft Corp, USA). GPS analysis within team sports has been confirmed reliable (Akenhead et al., 2014; Cummins et al., 2013; Hoppe et al., 2018; Johnston et al., 2014; Scott et al., 2016; Vickery et al., 2014) by previous researchers.

As mentioned above, the sole purpose of this study was to test the level of agreement between GPS systems to provide practitioners with confidence to use data between different systems interchangeably. The PTP system was compared with a validated system (Catapult Vector S7 GPS device) certified by FIFA (Ellens, Hodges, et al., 2022). For all matches, data were analysed individually using both systems' software throughout the match, including stoppage time. Player locomotor movement variables analysed included total distance (TD), low-speed running distance (LSR) (0.0–14.4 km/h), high-speed running distance (HSR) (14.4–18.9 km/h), very high-speed running distance (VHSR) (>18.9 km/h), acceleration efforts >2.5 m/s² (ACC), deceleration efforts <-2.5 m/s² (DEC) and maximum velocity (km/h) reached during each half (Dubois et al., 2017).

2.4. Statistical analysis

Unless otherwise stated, values are reported as average \pm SD. Bland-Altman plots with adjusted limits of agreement to account for repeated observations were used (Bland & Altman, 2007). The upper and lower 95% confidence limits, the standard error and the bias of each plot will also be reported.

All statistical analyses were computed with an available R script for agreement methods for continuous repeated measures data using R and RStudio (Parker et al., 2020; Posit Connect, 2022; The R Project for Statistical Computing, 2022). This study followed the methodology outlined by Parker et al. (2020) for assessing agreement with repeated measures data. For all analyses, potential outliers were flagged when Cook's distance exceeded a given threshold calculated as $4/n$ (where n is the number of observations) (Hebbali, 2024). Descriptive statistics are calculated for all variables and presented as mean and standard deviation. The percentage difference was calculated as the difference in the devices' mean values divided by the average of the means.

The concordance correlation coefficient (CCC) method was developed by Lawrence and Lin (1989), with the longitudinal repeated measures version of the CCC developed by King et al. (2007), Carrasco and Jover (2003) and Carrasco et al. (2009). The CCC is a standardised coefficient taking values from -1 to 1 , where 1 indicates perfect agreement, and -1 indicates perfect disagreement. Thus, the concordance correlation coefficient (CCC) was used to test the agreements between the two GPS systems. Values less than 0.5 indicate poor agreement, values between 0.5 and 0.75 indicate moderate agreement, values between 0.75 and 0.9 indicate good agreement and values greater than 0.90 indicate excellent agreement (Koo & Li, 2016; Lawrence & Lin, 1989). The total deviation index (TDI) calculation provides the boundary within which the differences will be contained 95% of the time (L. Lin et al., 2002; L. I. K. Lin, 2000). The practitioner must then decide whether the calculated boundary is narrow enough for the devices to be used interchangeably. The agreement between observations was also studied with Bland – Altman plots through analysis of differences of observation pairs against their mean values (Bland & Altman, 2007).

3. Results

3.1. Descriptive analysis

In Table 1, descriptive values of the variables considered for each half of the matches and for each GPS system used (Polar and Catapult) are presented. Furthermore, the percent

Table 1. Total distance, velocity, accelerations and decelerations for all matches.

	Polar(mean \pm sd)	Catapult (mean \pm sd)	Percentage Difference (%)	CCC (p _c)	TDI (CI 95%)
Total distance 1 st half (m)	3138.4 \pm 300.2	3263.3 \pm 304	-3.9	0.90***	281.3 (-263.4–13.6)
Total distance 2nd half (m)	2226.7 \pm 824.5	2298.5 \pm 877.5	-3.2	0.99***	266.6 (-298.3–154.6)
Max velocity 1st half (km/h)	27.1 \pm 3.9	26.6 \pm 3.7	1.9	0.98***	1.49 (-0.59–1.61)
Max velocity 2nd half (km/h)	25.5 \pm 4.2	25.1 \pm 4.2	1.9	0.99***	1.33 (-0.48–1.43)
Low Speed Running 1st half (m)	2570.4 \pm 218.4	2708.6 \pm 230.5	-5.2	0.81**	298.3 (-263.2–13.3)
Low Speed Running 2nd half (m)	1910.5 \pm 648.9	1991.4 \pm 719	-4.2	0.98***	280.1 (-312.8–151.1)
High Speed Running 1st half (m)	311.1 \pm 94.2	332.5 \pm 102.3	-6.6	0.94***	65.7 (-72.0–29.3)
High Speed Running 2nd Half (m)	212.1 \pm 116.3	217.6 \pm 122.3	-2.5	0.98***	42.4 (-46.5–35.7)
Very-High Speed Running 1st Half (m)	233.5 \pm 148.1	197.8 \pm 134.0	16.6	0.96***	82.9 (-8.7–80.1)
Very-High Speed Running 2nd Half (m)	148.2 \pm 111.8	125.9 \pm 98.0	16.3	0.96***	56.0 (-12.7–57.3)
Accelerations 1st Half (total efforts)	16.6 \pm 5.9	15.0 \pm 6.6	10.4	0.86**	6.7 (-4.3–7.5)
Accelerations 2nd Half (total efforts)	11.4 \pm 6.5	9.6 \pm 6.3	17.0	0.89**	5.9 (-3.0–6.5)
Decelerations 1st Half (total efforts)	17.4 \pm 5.7	15.4 \pm 6.3	12.1	0.86**	6.5 (-3.3–7.2)
Decelerations 2nd Half (total efforts)	11.2 \pm 6.4	9.9 \pm 6.3	11.7	0.93***	4.8 (-3.0–5.4)

Abbreviations: CCC (Concordance correlation coefficient < 0.5: poor agreement, 0.5–0.75: moderate agreement*, 0.75–0.90: good agreement **, and >0.90: excellent agreement ***; CI (95% Confidence interval); Max velocity (maximum velocity); Polar (Polar Team Pro GPS system); Catapult (Catapult GPS system), Total deviation index (TDI).

difference and total deviance index are also indicated in the same table. All variables analysed to establish GPS interchangeability showed a good to excellent agreement. The Polar GPS system measured less TD, LSR and HSR distances. For all other variables, max speed, VHRSR, ACC and DEC efforts, the Polar GPS system measured higher values when compared to that of Catapult (Table 1).

3.2. Agreement between PTP and Catapult GPS

Bland-Altman plots between Polar and Catapult GPS systems regarding TD (m) and maximum velocity (Km/h) measures collected during the 1st and 2nd half are reported in Figure 1. For TD measurement, the average difference between the GPS systems was 129.1 m and 90.1 m for 1st and 2nd half (panels A1 and A2), respectively. Small limits of agreement (LOA) were noticed during both halves. The maximum velocity showed an average agreement of 0.5 km/h during both halves, emphasised through narrow limits being -0.6–1.6 km/h during 1st and -0.5–1.5 km/h during the second half.

Bland Altman plots between the Polar and Catapult GPS systems regarding LSR (panels A1 and A2), HSR (panels B1 and B2) and VHRSR (panels C1 and C2) are

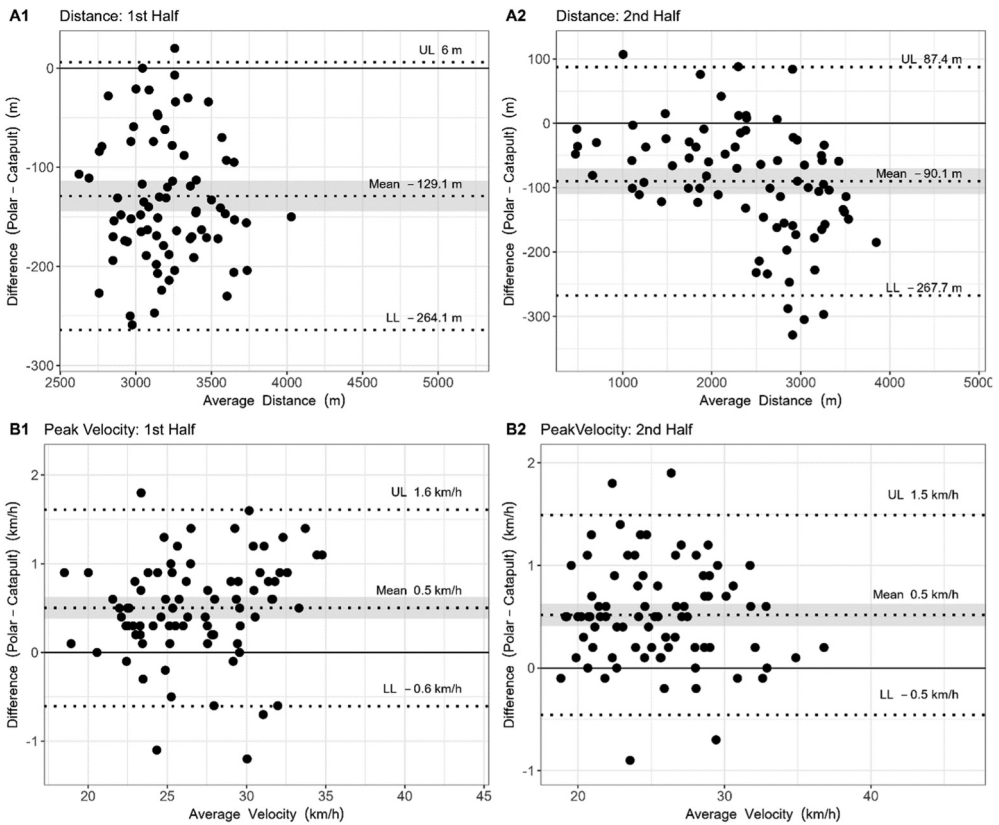


Figure 1. Bland-Altman plots between Polar and Catapult GPS systems regarding distance (m) and velocity (km/h) measures. In this figure, differences are expressed as absolute differences, Bias values are indicated by the bracket area and limits of agreement (LOA) by the dashed lines.

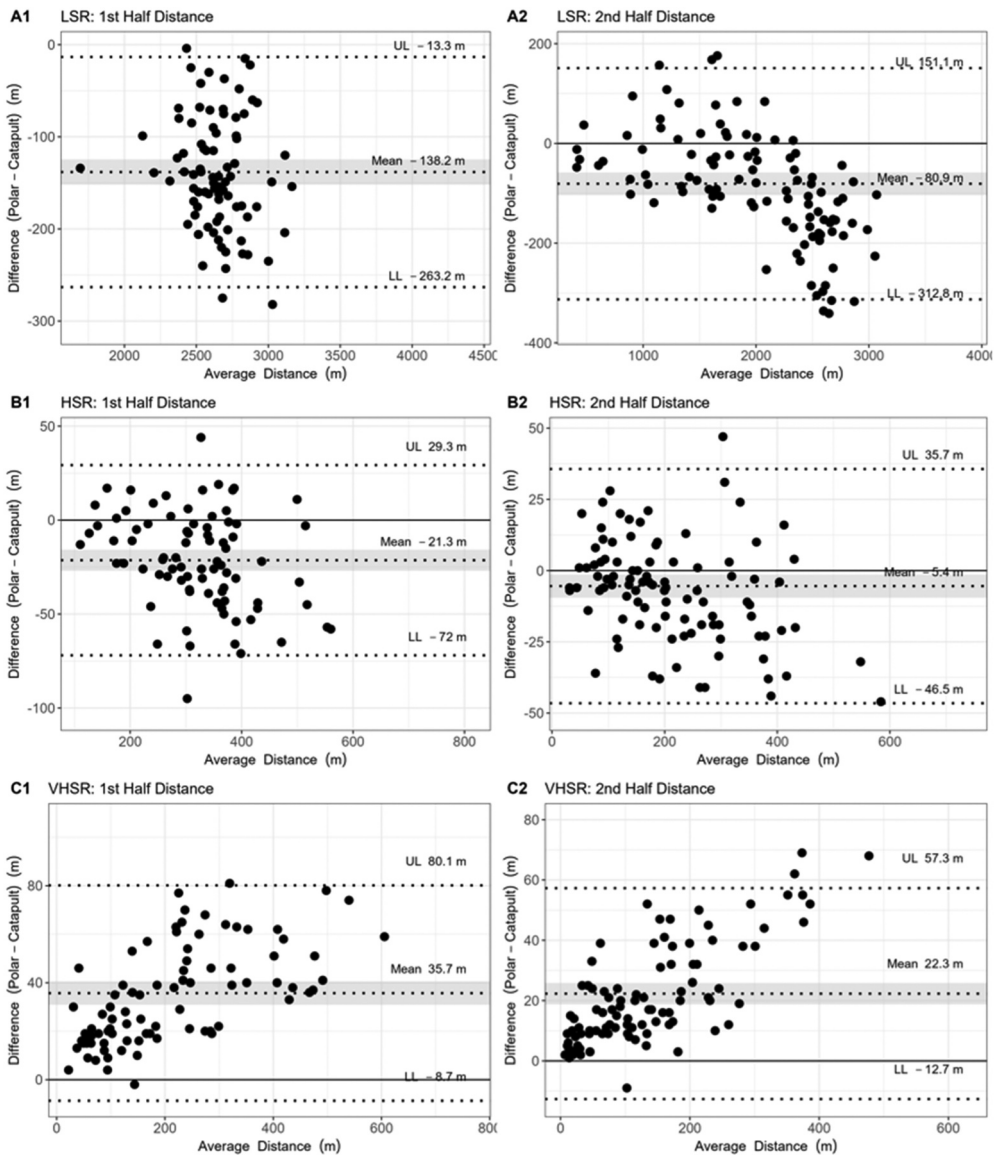


Figure 2. Bland-Altman plots between Polar and Catapult GPS systems regarding distance in different running speeds (m). In this figure, differences are expressed as absolute differences, Bias values are indicated by the bracket area and limits of agreement (LOA) by the dashed lines.

reported in [Figure 2](#). Narrow LOA can be seen during LSR (1st -263.2-13.3 m; 2nd -312.8-151.1 m, 95% CI), HSR (1st -72.0-29.3 m; 2nd -46.5-35.7 m, 95% CI), and VHSR (1st -8.7-80.1 m; 2nd -12.7-57.3 m, 95% CI). The GPS systems showed an average difference for the 1st and 2nd half of 138.2 m and 80.9 m during LSR, 21.3 m and 5.4 m during HSR and 35.7 m and 22.3 m during VHSR, respectively.

Bland Altman plots between the Polar and Catapult GPS systems regarding ACC and DEC efforts are reported in [Figure 3](#). ACC efforts showed an average difference between

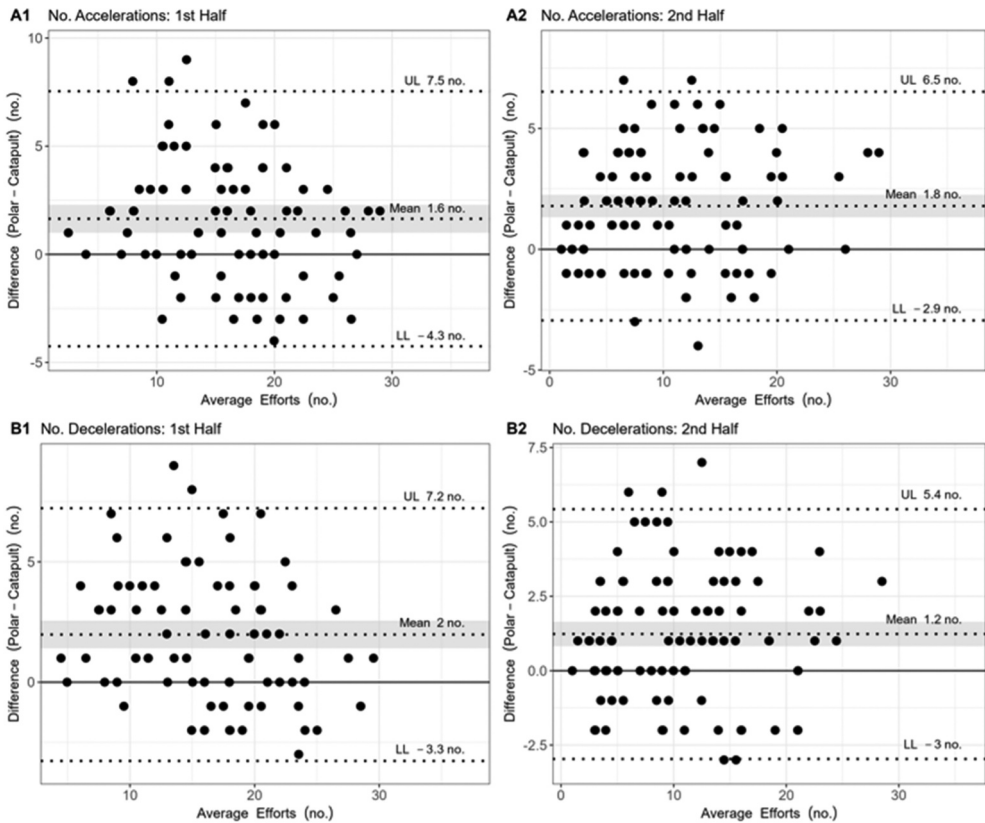


Figure 3. Bland-Altman plots between Polar and Catapult GPS systems regarding acceleration and deceleration efforts. In this figure, differences are expressed as absolute differences, Bias values are indicated by the bracket area and limits of agreement (LOA) by the dashed lines.

GPS systems of 1.6 and 1.8 efforts during the 1st and 2nd half (panels A1 and A2), respectively. The difference between GPS systems during DEC was 2 and 1.2 efforts during the first and second half (panels B1 and B2), respectively. Wide LOA were noted between ACC and DEC efforts when data were compared between the Polar and Catapult during the 1st (ACC: -4.3- 7.5 efforts, DEC: -3.3- 7.2) and 2nd (ACC: -2.9- 6.5 efforts, DEC: -3.0- 5.4) Half.

4. Discussion

The purpose of this study was to determine the interchangeability between two 10 hz GPS systems (Polar Team Pro vs. Catapult Vector S7) when used during competitive matches. We compared both the 1st and 2nd half independently with units assigned to all positional groups within the rugby team. Findings suggest a good to excellent agreement within all selected GPS-derived parameters.

When the TD during both halves was compared, an excellent agreement was established with small differences between the 1st (281.3 m or 3.9%) and the 2nd (266.6 m or 3.2%) half. Less distance during both halves was noted when Polar was compared to Catapult. In

another study, when different Catapult GPS units were compared, one unit overestimated (about 3%), and two other units underestimated (up to 4%) their distance, but still found the GPS units' validity acceptable (Petersen et al., 2009). When Ellens, Hodges, et al. (2022) compared the Catapult Vector system against optical tracking systems during professional soccer matches, a very large to huge mean difference (SEE = 11.4–166.3 m) was noted, but a strong positive correlation ($r > 0.72$) was still reported. Buchheit et al. (2014) also found small differences (5.4%) between GPSports and optical tracking systems in their study and confirmed that position-tracking variables may be used interchangeably. When Catapult was compared to ProZone matchviewer, Catapult reported a 7% higher distance; according to Harley et al. (2011), the difference may simply be the measurement error between systems, but still deemed the difference acceptable. Although this was not the focus of our study, when we compare our distances covered during the matches across all positions (Polar = 5286 m, Catapult = 5458 m), it compares well against other research on elite rugby union that found players cover between 4500 and 7500 m (Dubois et al., 2017). Dubois et al. (2017) further specified the distance spent above 14.4 km/h (HSR) will vary between 300 and 800 m. Our HSR distance for both Polar and Catapult were 523 m and 550 m, respectively.

When the maximum running velocity for each half was calculated, an excellent relationship was established. Polar speed values were higher when compared against Catapult during the 1st (1.49 km/h, 1.9%) and 2nd (1.33 km/h, 1.9%) half. Ellens, Hodges, et al. (2022) investigated the interchangeability of the Catapult Vector GPS system against the “gold standard” for assessing human position, both linear and non-linear (TRACAB and VICON). Their results indicate the Catapult GPS system underestimated (<1.66 km/h) maximum velocity when compared to optical tracking systems with a small to large difference (Ellens, Hodges, et al., 2022). Researchers attribute the changes in maximum velocity to different data filtering techniques applied within the manufacturer software (Ellens, Hodges, et al., 2022).

When running distances were compared during different velocities, a good to excellent agreement was noted. When the Polar data was compared to Catapult, both LSR (1st = 298.3 m, 5.2% and 2nd = 280.1 m, 4.2%) and HSR (1st = 65.7 m, 6.6% and 2nd = 42.4 m, 2.5%) measured lower running distance. In contrast, VHRS (1st = 82.9 m, 16.6% and 2nd = 56.0 m, 16.3%) distance was higher for Polar compared to Catapult. It is noticeable that the systematic error increased when speed thresholds increased. When HSR and VHRS were compared between the Catapult GPS and ProZone matchviewer, there was a 9% difference during HSR and 16% during VHRS (Harley et al., 2011). Consequently, Harley et al. (2011) suggested Catapult and Prozone may be used interchangeably. In contrast, they suggested sprint pace running (>7.0 m/s) during matches may not be used interchangeably due to a moderate difference (60–138 m, 40%) between devices. Petersen et al. (2009) found a 5 to 24% difference that coincided with earlier findings (12–30%) by Coutts and Duffield (2010) when very high-intensity running (>5.5 m/s) was compared between GPS devices and concluded that increased movement velocities are related with reduced validity and reliability. This notion was supported by Beato et al. (2018), who agree that sports-specific movements and high-intensity activities are linked to poor GPS accuracy due to lower sampling rates. In contrast, Willmott et al. (2019) reported their CV improved from 9.5% to 5.3% while walking and high sprinting

during straight-line sprinting, respectively. When the StatsSports Apex GPS was compared to the Catapult Vector S7 GPS during controlled testing, differences were noted, Catapult overestimated LSR (227 m) but underestimated MSR (436 m) and HSR (73 m) on average (Crang et al., 2022). Lastly, Jackson et al. (2018) found similar differences during different sprint speeds in a hockey match when Catapult GPS overestimated low-speed running (<10.8 km/h) and underestimated both moderate-speed (10.8–18 km/h) and high-speed (>18 km/h) velocity bands when compared to GNSS (global navigation satellite system).

During all ACC and DEC efforts, a good to excellent agreement was noticed. The Polar system underestimated ACC efforts during the 1st (6.7 efforts or 10.4%) and 2nd (5.9 efforts or 17.0%) half. This was also the case for DEC efforts when compared during the 1st (6.5 efforts or 12.1%) and 2nd (4.8 efforts or 11.7%) half against the Catapult system and these results were similar to what previously reported by Varley et al. (2012). It is possible that their 19.3% overestimation of velocity during deceleration reflected a poor relationship between GPS and reference measure (LAVEG laser). Accordingly, multiple considerations (between and within each tracking system) may be involved when the detection of efforts between tracking systems is compared (Ellens, Hodges, et al., 2022). Jackson et al. (2018) compared a Catapult GPS system to a GNSS and found that Catapult overestimated ACC (2.6 efforts on average) and DEC (2.2 efforts on average) efforts during a hockey match.

5. Conclusion & practical applications

To our knowledge, this study is the first to determine if the 10 Hz Polar Team Pro GPS system may be used interchangeably when compared to other 10 Hz GPS systems during competitive matches. Based on the current findings, the Polar Team Pro system has a good to excellent agreement with an already validated Catapult GPS system. However, some variables compare better than others, with TD, LSR, HSR and maximum velocity showing a better relationship than VHRSR, ACC and DEC when Polar is compared to Catapult. Through previous research and our findings, it is clear that caution should be used when VHRSR, ACC and DEC are compared. This phenomenon is noticeable across most GPS systems and is not unique to Polar. Our suggestion would be that the Polar Team Pro system may only be seen as partially interchangeable when compared to the Catapult system. For the purpose of this study, each GPS file was analysed using the manufacturer's digital software to prove its usability for coaches. Prospective Polar Team Pro customers or coaches may use our findings to make minor adjustments to their analysed data when they want to compare their data to other teams making use of 10 Hz Catapult systems. This means the following for different variables: adjusting distance measures ~ >3.6%, mean maximum velocity ~ <1.9%, LSR ~ >4.7%, HSR ~ >4.6%, VHRSR ~ <16.5%, accelerations efforts ~ <13.7 and decelerations efforts ~ <11.9% on average. It is noteworthy to mention that each GPS manufacturer uses their own filtering processes through their own independent software and hardware applications and may influence each GPS system's data. For future research, filtering processes of different GPS manufacturers need to be studied to provide users and researchers with information on how data are analysed when individual filtering is applied.

Acknowledgements

The authors would like to thank all the rugby players who participated.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Jacobus J. Oosthuizen  <http://orcid.org/0000-0002-2509-0212>

Martinique Sparks  <http://orcid.org/0000-0001-9251-6108>

Christo A. Bisschoff  <http://orcid.org/0000-0001-5477-3875>

Marike Cockeran  <http://orcid.org/0000-0002-3990-8345>

Ermanno Rampinini  <http://orcid.org/0000-0002-9729-0862>

References

- Adesida, Y., Papi, E., & McGregor, A. H. (2019). Exploring the role of wearable technology in sport kinematics and kinetics: A systematic review. *Sensors (Switzerland)*, 19(7), 1597. <https://doi.org/10.3390/s19071597>
- Akenhead, R., French, D., Thompson, K. G., & Hayes, P. R. (2014). The acceleration dependent validity and reliability of 10 hz GPS. *Journal of Science & Medicine in Sport*, 17(5), 562–566. <https://doi.org/10.1016/j.jsams.2013.08.005>
- Akyildiz, Z., Alvrudu, S., Ceylan, H. I., & Clemente, F. M. (2022). Validity and reliability of 10 hz GPS sensor for measuring distance and maximal speed in soccer: Possible differences of unit positioning. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering & Technology*, 238(3), 215–225. <https://doi.org/10.1177/17543371221098888>
- Aughey, R. J. (2011). Applications of GPS technologies to field sports. *International Journal of Sports Physiology & Performance*, 6(3), 295–310. <https://doi.org/10.1123/ijsp.6.3.295>
- Beato, M., Coratella, G., Stiff, A., & Iacono, A. D. (2018). The validity and between-unit variability of GNSS units (STATSports Apex 10 and 18 hz) for measuring distance and peak speed in team sports. *Frontiers in Physiology*, 9, 1288. <https://doi.org/10.3389/fphys.2018.01288>
- Bland, J. M., & Altman, D. G. (2007). Agreement between methods of measurement with multiple observations per individual. *Journal of Biopharmaceutical Statistics*, 17(4), 571–582. <https://doi.org/10.1080/10543400701329422>
- Buchheit, M., Al Haddad, H., Simpson, B. M., Palazzi, D., Bourdon, P. C., DiSalvo, V., & Mendez-Villanueva, A. (2014). Monitoring accelerations with GPS in football: Time to slow down? *International Journal of Sports Physiology & Performance*, 9(3), 442–445. <https://doi.org/10.1123/ijsp.2013-0187>
- Carrasco, J. L., & Jover, L. (2003). Estimating the generalized concordance correlation coefficient through variance components. *Biometrics*, 59(4), 849–858. <https://doi.org/10.1111/j.0006-341X.2003.00099.x>
- Carrasco, J. L., King, T. S., & Chinchilli, V. M. (2009). The concordance correlation coefficient for repeated measures estimated by variance components. *Journal of Biopharmaceutical Statistics*, 19(1), 90–105. <https://doi.org/10.1080/10543400802527890>
- Coutts, A. J., & Duffield, R. (2010). Validity and reliability of GPS devices for measuring movement demands of team sports. *Journal of Science & Medicine in Sport*, 13(1), 133–135. <https://doi.org/10.1016/j.jsams.2008.09.015>
- Crang, Z. L., Duthie, G., Cole, M. H., Weakley, J., Hewitt, A., & Johnston, R. D. (2022). The inter-device reliability of global navigation satellite systems during team sport movement across

- multiple days. *Journal of Science & Medicine in Sport*, 25(4), 340–344. <https://doi.org/10.1016/j.jsams.2021.11.044>
- Cummins, C., Orr, R., O'Connor, H., & West, C. (2013). Global positioning systems (GPS) and microtechnology sensors in team sports: A systematic review. *Sports Medicine*, 43(10), 1025–1042. <https://doi.org/10.1007/s40279-013-0069-2>
- Dubois, R., Paillard, T., Lyons, M., McGrath, D., Maurelli, O., & Prioux, J. (2017). Running and metabolic demands of elite rugby union assessed using traditional, metabolic power, and heart rate monitoring methods. *Journal of Sports Science & Medicine*, 16(1), 84–92.
- Ellens, S., Hodges, D., McCullagh, S., Malone, J. J., & Varley, M. C. (2022). Interchangeability of player movement variables from different athlete tracking systems in professional soccer. *Science and Medicine in Football*, 6(1), 1–6. <https://doi.org/10.1080/24733938.2021.1879393>
- Ellens, S., Middleton, K., Gastin, P. B., & Varley, M. C. (2022). Techniques to derive and clean acceleration and deceleration data of athlete tracking technologies in team sports: A scoping review. *Journal of Sports Sciences*, 40(16), 1772–1800. <https://doi.org/10.1080/02640414.2022.2054535>
- Harley, J. A., Lovell, R. J., Barnes, C. A., Portas, M. D., & Weston, M. (2011). The interchangeability of global positioning system and semiautomated video-based performance data during elite soccer match play. *The Journal of Strength & Conditioning Research*, 25(8), 2334–2336. <https://doi.org/10.1519/JSC.0b013e3181f0a88f>
- Hebbali, A. (2024). *Olsrr: Tools for Building OLS Regression Models*. Retrieved February 26, 2024 from <https://olsrr.rsquaredacademy.com/>
- Hennessy, L., & Jeffreys, I. (2018). The current use of GPS, its potential, and limitations in soccer. *Strength & Conditioning Journal*, 40(3), 83–94. <https://doi.org/10.1519/SSC.0000000000000386>
- Hoppe, M. W., Baumgart, C., Polglaze, T., Freiwald, J., & Ardigò, L. P. (2018). Validity and reliability of GPS and LPS for measuring distances covered and sprint mechanical properties in team sports. *PLOS ONE*, 13(2), e0192708. <https://doi.org/10.1371/journal.pone.0192708>
- Huggins, R. A., Giersch, G. E., Belval, L. N., Benjamin, C. L., Curtis, R. M., Sekiguchi, Y., Peltonen, J., & Casa, D. J. (2020). The validity and reliability of global positioning system units for measuring distance and velocity during linear and team sport simulated movements. *The Journal of Strength & Conditioning Research*, 34(11), 3070–3077. <https://doi.org/10.1519/JSC.00000000000003787>
- Hulin, B. T., Gabbett, T. J., Lawson, D. W., Caputi, P., & Sampson, J. A. (2016). The acute: Chronic workload ratio predicts injury: High chronic workload may decrease injury risk in elite rugby league players. *British Journal of Sports Medicine*, 50(4), 231–236. <https://doi.org/10.1136/bjsports-2015-094817>
- Jackson, B. M., Polglaze, T., Dawson, B., King, T., & Peeling, P. (2018). Comparing global positioning system and global navigation satellite system measures of team-sport movements. *International Journal of Sports Physiology & Performance*, 13(8), 1005–1010. <https://doi.org/10.1123/ijsp.2017-0529>
- Johnston, R. J., Watsford, M. L., Kelly, S. J., Pine, M. J., & Spurr, R. W. (2014). Validity and interunit reliability of 10 hz and 15 hz GPS units for assessing athlete movement demands. *The Journal of Strength & Conditioning Research*, 28(6), 1649–1655. <https://doi.org/10.1519/JSC.0000000000000323>
- King, T. S., Chinchilli, V. M., & Carrasco, J. L. (2007). A repeated measures concordance correlation coefficient. *Statistics in Medicine*, 26(16), 3095–3113. <https://doi.org/10.1002/sim.2778>
- Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine*, 15(2), 155–163. <https://doi.org/10.1016/j.jcm.2016.02.012>
- Lawrence, I., & Lin, K. (1989). A concordance correlation coefficient to evaluate reproducibility. *Biometrics*, 45(1), 255–268. <https://doi.org/10.2307/2532051>
- Lin, L., Hedayat, A., Sinha, B., & Yang, M. (2002). Statistical methods in assessing agreement: Models, issues, and tools. *Journal of the American Statistical Association*, 97(457), 257–270. <https://doi.org/10.1198/016214502753479392>

- Lin, L. I. K. (2000). Total deviation index for measuring individual agreement with applications in laboratory performance and bioequivalence. *Statistics in Medicine*, 19(2), 255–270. [https://doi.org/10.1002/\(SICI\)1097-0258\(20000130\)19:2<255::AID-SIM293>3.0.CO;2-8](https://doi.org/10.1002/(SICI)1097-0258(20000130)19:2<255::AID-SIM293>3.0.CO;2-8)
- Malone, J. J., Lovell, R., Varley, M. C., & Coutts, A. J. (2017). Unpacking the black box: Applications and considerations for using GPS devices in sport. *International Journal of Sports Physiology & Performance*, 12(s2), S2–18–S12–26. <https://nwulib.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=122825755&site=eds-live>
- Noon, M. R., James, R. S., Clarke, N. D., Taylor, R. J., & Thake, C. D. (2018). Next day subjective and objective recovery indices following acute low and high training loads in academy rugby union players. *Sports*, 6(2), 56. <https://doi.org/10.3390/sports6020056>
- Parker, R. A., Scott, C., Inácio, V., & Stevens, N. T. (2020). Using multiple agreement methods for continuous repeated measures data: A tutorial for practitioners. *BMC Medical Research Methodology*, 20(1), 1–14. <https://doi.org/10.1186/s12874-020-01022-x>
- Petersen, C., Pyne, D., Portus, M., & Dawson, B. (2009). Validity and reliability of GPS units to monitor cricket-specific movement patterns. *International Journal of Sports Physiology & Performance*, 4(3), 381–393. <https://doi.org/10.1123/ijspp.4.3.381>
- Posit Connect. (2022). *Posit Team*. Retrieved May 29, 2022 from <https://posit.co/>
- Rago, V., Brito, J., Figueiredo, P., Costa, J., Barreira, D., Krstrup, P., & Rebelo, A. (2020). Methods to collect and interpret external training load using microtechnology incorporating GPS in professional football: A systematic review. *Research in Sports Medicine*, 28(3), 437–458. <https://doi.org/10.1080/15438627.2019.1686703>
- The R Project for Statistical Computing. (2022). *R Core Team*. Retrieved May 29, 2022 from <https://www.r-project.org/>
- Sandmæl, S., van den Tillaar, R., & Dalen, T. (2023). Validity and reliability of polar team pro and playermaker for estimating running distance and speed in indoor and outdoor conditions. *Sensors (Switzerland)*, 23(19), 8251. <https://doi.org/10.3390/s23198251>
- Scott, M. T., Scott, T. J., & Kelly, V. G. (2016). The validity and reliability of global positioning systems in team sport: A brief review. *The Journal of Strength Conditioning Research*, 30(5), 1470–1490. <https://doi.org/10.1519/JSC.0000000000001221>
- Terziotti, P., Sim, M., & Polglaze, T. (2018). A comparison of displacement and energetic variables between three team sport GPS devices. *International Journal of Performance Analysis in Sport*, 18(5), 823–834. <https://doi.org/10.1080/24748668.2018.1525650>
- Van den Tillaar, R., Gaustad Pettersen, F., & Lagestad, P. (2023). Reliability and validity of polar team pro measurements in running at different velocities in an indoor setting. *Frontiers in Sports and Active Living*, 5, 1165801. <https://doi.org/10.3389/fspor.2023.1165801>
- Varley, M. C., Fairweather, I. H., & Aughey, R. J. (2012). Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *Journal of Sports Sciences*, 30(2), 121–127. <https://doi.org/10.1080/02640414.2011.627941>
- Venter, R. E., Opperman, E., & Opperman, S. (2011). The use of global positioning system (GPS) tracking devices to assess movement demands and impacts in under-19 rugby union match play. *African Journal for Physical, Health Education, Recreation & Dance*, 17(1), 1–8. <https://doi.org/10.4314/ajpherd.v17i1.65242>
- Vickery, W. M., Dascombe, B. J., Baker, J. D., Higham, D. G., Spratford, W. A., & Duffield, R. (2014). Accuracy and reliability of GPS devices for measurement of sports-specific movement patterns related to cricket, tennis, and field-based team sports. *The Journal of Strength & Conditioning Research*, 28(6), 1697–1705. <https://doi.org/10.1519/JSC.0000000000000285>
- Willmott, A. G., James, C. A., Bliss, A., Leftwich, R. A., & Maxwell, N. S. (2019). A comparison of two global positioning system devices for team-sport running protocols. *Journal of Biomechanics*, 83, 324–328. <https://doi.org/10.1016/j.jbiomech.2018.11.044>
- Wilson, R., & Plumley, D. (2017). Different shaped ball, same financial problems? A holistic performance assessment of english rugby union (2006–2015). *Sport, Business and Management: An International Journal*, 7(2), 141–156. <https://doi.org/10.1108/SBM-10-2016-0063>