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Interchangeability of position tracking technologies; can we merge data?

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Abstract

Purpose: The purpose of this study was to assess the interchangeability of position tracking metrics obtained using global positioning systems (GPS) versus those obtained by a semi-automatic high definition (HD) optical camera system. Methods: Data was collected from a cohort of 29 elite soccer players (age: 23.1 ± 5.1 years, height: 180.4 ± 5.8 cm, mass: 74.6 ± 6.7 kg) in four matches played in four different stadiums. In two matches 10Hz GPS (GPS-1, StatSports, Belfast, UK) were used, while in the other two matches augmented 10Hz GPS (GPS-2, StatSports, Belfast, UK) were used. All four matches were analysed concomitantly using six semi-automated HD motion cameras sampling at 25Hz (TRACAB, Chyronhego, New York, USA). Results: Mean bias was between 6-10% for GPS-1 and 1-4% for GPS-2 respectively. No proportional bias was found ($p > 0.184$). The SEE within calibration functions (expressed in % to mean) was between 5-22% for GPS-1 and 4-14% for GPS-2. While some significant differences existed between GPS-1 and TRACAB (total distance and high-speed), positional tracking variables were highly correlated between GPS-1, GPS-2 and TRACAB ($r^2 > 0.92$) with GPS-2 displaying stronger correlations (> $r^2 = 0.96$). Conclusion: In the present study augmented GPS technology (GPS-2) and the TRACAB camera system provided interchangeable measures of positional tracking metrics to allow concurrent assessment and monitoring of training and competition in soccer players. However, we recommend practitioners evaluate their own systems to identify where errors exist and re-calibrate accordingly to confidently interchange data.

Introduction

Until recently, the use of global positioning systems (GPS) was prohibited in official competition conditions by FIFA. Despite a law change in 2015, GPS remains under-utilised due to practical reasons such as comfort and player compliance. As such, commercial optical semi-automatic camera systems are still commonly used to track the locomotive patterns of professional players during official match-play. Recently a semi-automated HD optical tracking system known as TRACAB has been installed in every English Premier League stadium and numerous soccer stadiums around the world. Six HD cameras track both the movement of players and the ball, allowing the calculation of the same variables derived from GPS systems, including total distance and distances travelled within specific velocity bands (Cummins et al. 2013).

External load metrics such as total distance, high-speed and sprint distance are frequently monitored in high-level professional clubs across many leagues around the world including the English Premier League, La Liga, Serie A, Major League Soccer and Australian A-league (Akenhead and Nassis, 2016). Monitoring changes in these external load metrics that are commonly related to varying demands in training and match-play is used by practitioners to mitigate potential injury risk (Bowen et al. 2019). The application of evidence-based periodised football specific loading strategies (Walker et al. 2018) serves to enhance performance, build chronic load, improve physical qualities and potentially reduces injury risk (Malone et al. 2017; Duhig et al. 2016). A player’s retrospective external load data also provides an important benchmark to consider in both the planning and delivery of outdoor physical preparation sessions during rehabilitation and return to play (RTP) (Taberner et al. 2018; Blanch and Gabbett, 2016).

Surprisingly, limited information currently exists regarding the interchangeability of data derived from contemporary GPS and optical tracking technologies (Buchheit et al. 2014) especially considering how widely used GPS is in professional clubs alongside TRACAB data (Beato et al. 2018a). Without such information practitioners are unable to confidently combine training and match data in order to monitor weekly total volumes, intensities and frequencies of various components of external load. It is important for practitioners to be able to do so to support; 1) training monitoring and prescription to enhance performance, 2) management of load to minimise cumulative fatigue, 3) mitigation of injury risk, and 4) rehabilitation and RTP of injured players (Gabbett, 2016; Gabbett et al. 2017; Bowen et al. 2016; Taberner and Cohen 2018).

The purpose of this study was to assess the interchangeability between position tracking variables derived from GPS and those of a semi-automatic HD camera system in elite football players.

Methods

Participants

A cohort of twenty-nine elite football players from the first team (n = 9 players) and under-23 (n = 20 players) squads belonging to an English Premier League soccer club participated (age: 23.1 ± 5.1 years, height: 180.4 ± 5.8 cm, mass: 74.6 ± 6.7 kg), with data collected over four matches. For GPS-1 and TRACAB comparison, data was collected from two competitive under-23 matches in the 2016/2017 season. In match one, data was collected from 12 players (age: 21.8 ± 4.6 years, height: 180.4 ± 5.1 cm, mass 73.0 ± 4.5 kg) and in match two from 11 players (age: 20.5 ± 0.9 years, height: 181.1 ± 6.1 cm, mass: 71.5 ± 5.3 kg). For the GPS-2 and TRACAB comparison, data was collected from 9 players during one pre-season first team friendly match (age: 27.9 ± 4.4 years, height: 180.4 ± 6.4 cm, mass: 77.4 ± 9.1 kg) and from

10 players (age: 20.2 ± 1.4 years, height: 181.3 ± 5.1 cm, mass: 74.3 ± 4.7 kg) during one competitive under-23 match in the 2017/2018 season.

All data arose as a condition of employment in which players were routinely monitored over the course of the competitive season. Nevertheless, approval for the study from the club was obtained (Winter and Maughan, 2009) and ethics approval was granted by the University of Santander ethics committee. To ensure confidentiality, all data were anonymised before analysis.

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Experimental overview

Positional information was recorded by two commercially available GPS units; GPS-1 (10Hz Viper, StatSports, Belfast, UK), GPS-2 (augmented 10Hz Apex, StatSports, Belfast, UK) and concomitantly by an optical tracking system using six semi-automated HD cameras sampling at a frequency of 25Hz (TRACAB, Chyronhego, New York, USA). Information regarding both validity and relative reliability of GPS-1 and GPS-2 is available within the literature (Beato et al. 2018a, Beato et al. 2018b, Heidi et al. 2018). For example, GPS-1 has reported a small mean bias (<5%) in the evaluation of distance, sports-specific activity and peak speed (Beato et al. 2018b). More recently GPS-2, a 10Hz multi-GNSS augmented unit capable of acquiring and tracking multiple satellites was validated, with a small error of 1-2% reported compared to a criterion distance of 400m track, a 128.5m sports specific circuit, and peak speed assessed using a gold standard criterion (radar gun) (Beato et al. 2018a). Furthermore, GPS-2 inter-unit reliability was <2% for components of external load including total distance and high-speed running (>5ms^{-1}) (Heidi et al. 2018).

GPS units were positioned between the players' scapulae housed by a specifically designed vest garment used to minimise movement artefacts (Varley et al. 2017) and were activated accordingly to manufacturer's guidelines prior to kick-off. To avoid potential inter-unit variation players wore the same GPS unit for each match (Malone et al. 2017). The GPS signal quality and horizontal dilution of position were unavailable for GPS-1. GPS-2 was connected to a mean number of 18 satellites, range 16-20 between the two games, while HDOP for both matches was 1.3 (1st team) and 1.1 respectively (under-23).

Following each match, raw GPS data files and TRACAB files (XML, DAT) were analysed and position variables were derived automatically using the manufacturer's software (Viper and Apex PSA software, StatSports, Belfast, UK). Position tracking variables analysed consisted of total distance, high speed running distance (HSR, >5.5ms^{-1}), and sprint distance (>7ms^{-1}) as defined by the manufacturer[1]. These position tracking variables were selected for analysis as they were the top 3 variables monitored by professional clubs in high-level OR "elite" football to quantify training practices and competitive matches (Akenhead and Nassis, 2016). Data were downloaded for analysis using the manufacturer's software, as software-derived data is a more simple and efficient way for practitioners to obtain data in an applied environment, with no differences reported between processing methods (software-derived to raw processed; Heidi et al. 2018). The dwell time (minimum effort duration) was set at 0.5s to detect high speed running and 1s to detect sprint distance efforts; in-line with manufacturers recommended and default settings to maintain consistent data processing (Malone et al. 2017). Furthermore, the internal processing of both GPS-1 and GPS-2 units utilised the Doppler shift method to calculate both distance and velocity data which is shown to display a higher level of precision and less error compared with data calculated via positional differentiation (Townshend et al. 2008).

[1] http://statsports.com/technology/apex-software/

Statistical Analysis

Data are presented as mean ± standard deviation (s). A two-sample Kolmogorov-Smirnov goodness-of-fit hypothesis test was used to check the normality distribution of the data and findings indicated normality in every examined measure ($p > 0.195$).

To examine the interchangeability between positional tracking variables derived from the GPS-1, GPS-2 and TRACAB, a Bland-Altman plot and regression analysis were used. The resulting correlation coefficient (Pearson) was used to examine shared variation ($r^2 < .3$ small, $.3 < r^2 < .5$ moderate and $r^2 > .5$ large), while the standard error estimate (SEE) as well as the confidence interval (95 and 99%) of the square root of the error from the regression equation was used to assess confidence in the observed values. To evaluate the existence of proportional bias, the percentage difference between the devices was regressed to their average (Bland et al. 1999). In addition to the test of relationship, a two-tailed paired-sample t-test was used to examine differences between devices. Data was analysed using statistical parametric mapping (spm0d version 0.4) and an alpha level of = 0.05 was utilised. Data analysis was performed in MATLAB (The MathWorks, Massachusetts, USA).

Results

All examined measures demonstrated strong positive correlations between both GPS-1, GPS-2 and TRACAB (> $r^2 = 0.92$), while, significant differences were observed for total distance and HSR between GPS-1 and TRACAB ($p = 0.00$). GPS-2 displayed the stronger correlation to the TRACAB system ($r^2 > 0.96$ vs. $r^2 > 092$). The SEE (expressed in % to mean) was between 5-22% of for GPS-1 and 4-14% for GPS-2. The mean bias was between 6-10% for GPS-1 and 1-4% for GPS-2. No proportional bias was observed ($p > 0.184$). Table 1 and Table 2 report descriptive statistics and analysis for GPS-1 and GPS-2 compared to

TRACAB. The Bland-Altman plot and regression analysis alongside correction calibration equations for GPS-1, GPS-2 are displayed in figure 1.

Discussion

Athlete-tracking technology is commonplace in contemporary sport research and practice (Cummins et al. 2013) and it is important that practitioners are able to make confident comparisons if different devices are used in training and competition.

In the current study, we examined the interchangeability between data for position tracking variables captured by commercial global positioning systems (GPS) and that derived from a semi-automatic HD camera system (TRACAB). Results showed that while there are differences for both total distance and HSR between GPS-1 and TRACAB, both the GPS-1 and GPS-2 were highly correlated with TRACAB ($r^2 > .92$). GPS-1 generally demonstrated higher mean biases compared to GPS-2: total distance (6% vs. 2%), HSR (10% vs. 1%) and sprinting (10% vs. 4%). Furthermore, SEE's ranged from 5-22% for GPS-1 and 4-14% for GPS-2.

Due to the current controversy in the sports science world regarding terminology, statistical approaches and interpretation (Impellizzeri et al. 2019), the authors feel it important to clarify the statistical approach used here to assess interchangeability. Agreement was identified through regression analysis - a statistical technique to examine whether, and how strongly, a pair share variation, which is expressed by correlation coefficient "r" (Giavarina, et al. 2015). The regression analysis also computed a relationship formula that allows the prediction of the magnitude of a measure from one device to another. The accuracy of this equation can be described using the SEE (McHugh, 2008). The Bland-Altman analysis provides information about the mean bias (how much does a device over or underestimate the other) as well as the confidence limits of this bias, which explains potential systematic or random error between tracking technologies (Myles and Cui, 2007). As such, a high correlation between devices (representing the mean association) does not necessarily make it appropriate to use in monitoring individual players, if for example there is also a high mean bias. However, a practitioner could use the regression formula to enable align the data obtained with the two systems.

Previous research investigating interchangeability between GPS and optimal tracking technology (most commonly the Prozone optical tracking system) is limited, with methodological differences accounting for discrepancies in the results reported across studies (Buchheit et al. 2014; Harley et al. 2011; Randers et al. 2010). In agreement with previous findings (Randers et al. 2010), Harley et al. (2011) reported higher total distance travelled using GPS (GPS: 1,755.4 $\pm$ 245.4 m; Prozone: 1,631.3 $\pm$ 239.5 m; p <0.05). Harley et al. (2011) emphasised caution in interchanging sprint distance determined by the two technologies due to a technical error of ~40% (d = 0.68). More recently, Buchheit et al. (2014) highlighted small differences (5.4%) between GPS and optical tracking systems in relation to total distance covered. The optical tracking technology tended to report greater distance covered at higher movement speeds (>19.8 km/h - 26.5%) with a typical error of estimates that was small (>0.2) to moderate (>0.6) (Buchheit et al. 2014). In contrast, smaller differences were observed in the current investigation in relation to both total distance and distances within high-velocity speeds thresholds. Factors such as device sampling rate, satellite connection, data filtering and analysis within the associated software for both GPS and optical tracking systems (Buchheit et al. 2014) could contribute to the differences between the present results and those of previous reports. As such, caution is required when using GPS units without knowing the quality of satellite connections or if there was a poor satellite connection during a specific data collection period.

The present findings show that total distance can be interchanged between augmented 10 Hz GPS (GPS-2) and the TRACAB system with an expected mean error of 4% .. However, it is important to note that HSR and sprinting distance demonstrated larger errors than total distance. Applying corrections through the extrapolation of the Y-intercept demonstrated a SEE of 10% for HSR and 14% for sprinting distance for GPS-2.SEE's were similar for GPS-1 apart from sprinting distance (14% vs 22%). These observed differences are likely due to systematic error with technology used to track positional variables. They may be related to data filtering and/or smoothing of the TRACAB co-ordinate data (X, Y) integrated into GPS analysis software resulting in hysteresis (differences in distance at any measurement value within specified range [speed threshold] recorded using TRACAB compared to raw GPS data). Differences may have also been influenced by measurement error due to loss of satellite connection. As such, the present observations could differ from those in similar future studies due to the prevailing satellite connections, highlighting that data on satellite connection (number of satellites/HDOP) should be included as a time varying covariate within any future GPS study.

From a practical perspective, it is important to consider whether the small differences between technologies reported here are meaningful regarding their influence on decisions made/interpretation of data derived from monitoring concurrent loads (training and match-play). Furthermore, meaningfulness and relevance need to be considered, as relationships between running performance and competitive success are unclear (Carling et al. 2013), whilst the impact of training and match-play upon fatigue (Nedelec, 2014) and fitness (Rollo et al. 2014) is likely to be influenced by a host of factors including periodisation, recovery and training methodology, which makes these relationships difficult to examine in an elite environment. In the present study, applying the GPS-2 calibration equations to a sample player's data set (a full-back); TRACAB – total distance: 11,022m, HSR: 1,220m: sprinting:

341m corrected to GPS-2; total distance: 10,730m, HSR: 1,398m, sprinting: 332m) highlights in practice the magnitude of difference in absolute terms (minimal and maximum error; Figure 1)) between GPS-2 and TRACAB; total distance 292m (15 to 355m) from TRACAB, HSR; 37m (13 to 98m) from TRACAB and sprinting; 9m (8 to 18m) from TRACAB. In real-world elite soccer, the question arises as to whether these differences are meaningful in relation to player management in context of both the team performance and/or rehabilitation. Recently, associations between increased acute loads, changes in week-to-week load and injury risk have been demonstrated (Rogalski et al. 2013). Excessive and rapid increases in load are recognised as an important risk factor for non-contact soft-tissue injuries (Gabbett et al. 2016). Therefore, we can ask the question; are the aforementioned absolute differences meaningful in relation to injury risk?Here, ~292m (less than one lap of an athletic track) and in the context of a weekly micro cycle where players typically accumulate distances of around 30 to 40km, an error of + or - this magnitude would not have any practical influence on the interpretation of the data i.e. not have altered decisions regarding player load management. Similarly, in relation to HSR, one of the commonly measured external load metrics related to intensity, should an approximate error of + or - 37m should be considered in the context of a full-back accumulating ~2000 to 2500m HSR within a weekly micro cycle?

It has been advocated that to determine if change in load within individual players is meaningful, the method proposed by Hopkins et al. (2009) should be used to express relative change to intra-player reliability (Akenhead and Nassis, 2016). In team sport environments, these changes (bandwidth determine by Hopkins method) maybe used to assess changes in week-to-week loads, variations of the acute: chronic ‘workload’ ratio e.g. 7 to 28 days, or more sensitive measures e.g. variations to match-day type specific sessions. From a rehabilitation perspective, we suggest that following injury, retrospective external running loads should be used to formulate a prospective return to chronic loading plan (Taberner et al. 2019).

We observed a lower mean error reported by GPS-2 in comparison to GPS-1, which could be explained by technological enhancements between GPS units. Augmented GPS (GPS-2) utilises a multi-band GNSS receiver capable of acquiring and tracking multiple satellite constellations (e.g. GPS, GLONASS, Galileo, and BeiDou) concurrently, therefore providing more accurate positional data quality (Beato et al. 2018a). Previous research has highlighted that the number of satellites connected to a tracking device plays a pivotal role in GNSS accuracy (Scott et al. 2016) and consequently the enhanced data quality provided by the augmented GPS could explain the lower mean error recorded with TRACAB system compared to GPS-1. Data was also recorded in what could be considered suboptimal conditions due to the experiment being conducted within of high-rise stadiums. Previous research has also reported that satellite pick up near high buildings can affect the validity and reliability of data recorded in such environments (Scott et al. 2016). Hence practitioners should interpret all data with caution in stadia and ensure raw traces of velocity and acceleration are inspected for irregularities generated by the GPS devices, which may include satellite signal loss leading to a delayed detection of locomotion (Malone et al. 2017). Accounting for the satellite connection and horizontal dilution of position would allow the development of formulas that could state when it is 'safe' to interchange or could give a range of possible magnitude for different signal strength to help practitioners fully establish interaction between all components of external load. We suggest professional clubs should do their own diligence investing time and resources to assess their own systems, checking for potential sources of error to ascertain confidence in their dataset when concurrently monitoring training and match data.

Alongside total distance and distance within high velocities (HSR and sprinting), external load in team sports is also characterised by frequent episodes of accelerated and decelerated running actions (Osgnach et al. 2010). Hence, monitoring the demands that require athletes to accelerate, decelerate and rapidly change direction is of high importance (Delaney et al. 2017). As by definition a proportion of these movements are performed at low speed and despite being below the threshold for HSR (>5.5ms^{-1}), have a high mechanical demand with important implications for planning training and recovery strategies (Osgnach et al. 2010; Young et al. 2012). We suggest future research should aim to establish interchangeability between acceleration, deceleration variables recorded by GPS and optical tracking technologies, considering the number of satellites as a time dependent covariate, to help practitioners fully establish interaction between all components of external running load.

Conclusion

The interchangeability between training and match load data is important to help practitioners effectively and confidently monitor and interpret weekly volume of external running loads. Current findings demonstrate that data can be interchanged between the present augmented GPS units and TRACAB system with an expected mean error of 4%, which we estimate to have no practical influence on the interpretation of weekly load data. Since the present commercial GPS and TRACAB systems are used ubiquitously within professional soccer clubs these findings will help enable practitioners to combine training (captured using GPS) and match activity (captured using optical systems) data, to assist with planning of appropriate training and recovery strategies to impact physical performance and potentially reduce injury risk.

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Table and Figure Captions

Table 1. Relationships between GPS-1/TracAb for Total distance, High-speed distance, and Sprint distance.

Table 2. Relationships between GPS-2/TracAb for Total distance, High-speed distance, and Sprint distance.

Figure 1. Correlations between GPS-1/TracAb and GPS-2/TracAb for Total distance, High-speed distance, and Sprint distance.