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New variables and new agreements between 10 Hz global positioning system devices in tennis drills

Carlos Galé-Ansodi[1], Argia Langarika-Rocafort[2], Oidui Usabiaga[1] and Julen Castellano Paulis[1]

Abstract

The knowledge about physical demands in different sports has increased, thanks to the application of global positioning system devices. The reliability and validity of 10 Hz global positioning system devices have been assessed by some authors. The majority of the studies only addressed the reliability of the devices or, in other words, the ability of scores of global positioning system device to differentiate among subjects or objects. The reliability is based on correlations (such as the intraclass correlation coefficient) which do not give the researcher information that can be interpreted in a practical way. In this way, the aim of this study was to assess the grade of agreement among repeated measurements made on the same subject using two global positioning system devices simultaneously. Four trained male tennis players participated in the study. The participants completed tennis-simulated point-games (n = 32), each player wearing two devices at the same time. Global indicators, such as Player Load (PL), Exertion Index (EI) and Equivalent Distance Index (EDI) per minute, were monitored through the use of global positioning system devices (MinimaxX v4.0; Catapult Innovations, Melbourne, Australia) operating at the above-mentioned sampling frequency of 10 Hz. The systematic error is that there is tendency of the global positioning system devices to measure systematically different from others V_{mean} ($-1.03\,m \cdot min^{-1}$), V_{peak} ($-10.31\,m \cdot min^{-1}$), Equivalent Distance Index (0.63 ratio), PL_{min} ($0.35\,UA\,min^{-1}$) and EI_{min} (-0.01) variables. As for random error (limit of agreement), we would expect that in PL_{min}, the global positioning systems would differ in 95% of the cases between 2.12 and $-1.42\,m \cdot min^{-1}$; any value out of the limits of agreement would result relevant for the practical point of view. We concluded that the global positioning system devices produce systematically different results from one another; therefore, the bias from one global positioning system to another should be subtracted to compare the results between the global positioning systems.

Keywords

Reliability, accuracy, racquet sport, global positioning system devices, physical demands

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Currently, micro-technology is being applied in some sports to assess external loads and players' performances. Modern global positioning system (GPS) devices, which are made up by accelerometers, magnetometers and gyroscopes, allow the recording of variables such as accelerations and velocities, or even other variables like turns, jumps or tackles, performed by players in both trainings and match-play.[1]

The knowledge about physical demands in different sports has increased, thanks to the application of certain indicators such as the Player Load (PL), which involves accelerations produced in three planes of body movement; the Exertion Index (EI), which shows the resulting velocities developed by players (both calculated in arbitrary units (AU) and finally, the Equivalent Distance Index (EDI), which represents the ratio between estimated distance (considering the acceleration and energy cost) and the total distance (actual) that the athlete has travelled. The reliability and validity of 10 Hz GPS devices have been assessed by a number of authors.[2–5] However, it would be interesting to

[1]Faculty of Physical Activity and Sport Sciences, University of the Basque Country (UPV/EHU), Vitoria-Gasteiz, Spain
[2]Faculty of Psychology and Education, University of Deusto, Bilbao, Spain

Corresponding author:
Julen Castellano Paulis, Faculty of Physical Activity and Sport Sciences, University of the Basque Country (UPV/EHU), C/Lasarte 71, 01007 Vitoria-Gasteiz, Alava, Basque Country, Spain.
Email: julen.castellano@ehu.es

improve the knowledge about the reliability[6] of these global indicators that are integrated in GPS devices.[4] In relation to speed, increasing the sampling frequency of GPS devices might decrease measurement errors and increase the reliability of values involved in speed categories.[2,3,7,8] However, it may be difficult to accurately measure higher speeds ($5.8\,m\,s^{-1}$).[2] On the other hand, the accelerations >4 and decelerations $<-4\,m\,s^{-2}$ should be taken into account carefully.[9] Therefore, it might be adequate to assess the reliability and agreement of global indicators involving velocities and accelerations.

Most statistical analyses used by researchers to assess accuracy, reliability/agreement and validity of the GPS devices revealed certain deficiencies. The majority of the studies only addressed the reliability of the devices or, in other words, the ability of GPS devices to differentiate among subjects or objects.[6] The reliability is based on correlations (such as the intraclass correlation coefficient or ICC) which do not give the researcher information that can be interpreted in a practical way. When studying a measurement, it is also essential to know the measurement error or agreement[6] which is more practical and easy to interpret. The measurement error given is the amount of inherent error produced by the device in the same units (e.g. distance in metres, time in seconds, speed in $km\,h^{-1}$ or $m\,s^{-1}$) in which the device makes the measurements. The measurement error gives the researcher or practitioner the necessary information as to what constitutes a meaningful change in a score. Only differences that are higher than the measurement error should be considered real differences (among participants, devices, etc.). The method proposed by Bland and Altman[10] has been used recently to assess the measurement error of the acceleration.[9] This method is based on the individual differences among each pair of observations, from which measurement errors, systematic errors (bias) and random errors (limits of agreement) are calculated. One of its main advantages is that it is also a graphical method that provides a lot of information to the researcher to assess the agreement among measurements.

In this way, the aim of this study was to assess the grade of agreement among repeated measurements made on the same subject[11] using two GPS devices simultaneously. To study the degree of agreement proposed, the Bland and Altman method[10] was used, where the limits of agreement, systematic errors (bias) and confidence intervals were calculated at 95%.

Four trained male tennis players participated in the study. The participants completed two simulated tennis matches on a hard surface and obtained 32 point-games, each player wearing two devices at the same time. The players wore a special harness that enabled both devices to be fitted to the upper part of their backs. Global indicators were monitored through the use of GPS devices (MinimaxXS4.0, firmware 6.75; Catapult Innovations, Melbourne, Australia) operating at the above-mentioned sampling frequency of 10 Hz. The MinimaxX S4 device contains a tri-axial piezoelectric linear accelerometer (Kionix: KXP94) sampling at a frequency of 100 Hz. Data were collected during what were considered to be good GPS conditions in terms of the weather and satellite conditions. The mean ± standard deviation (SD) number of connected satellites and horizontal dilution of position (HDOP) for 8 GPS devices were 9.0 ± 0.3 and 1.0 ± 0.2, respectively.

According to the analysis performed to study the systematic error (Table 1), there is some tendency of the GPS devices to systematically measure differently from others V_{mean} ($-1.03\,m \cdot min^{-1}$), V_{peak} ($-10.31\,m \cdot min^{-1}$), EDI (0.63 ratio), PL_{min} ($0.35\,AU\,min^{-1}$) and EI_{min} ($-0.01\,AU\,min^{-1}$) variables. According to the paired t-Student analysis (Table 1), this tendency was significant in all the variables but not in V_{mean}. As for random error (limits of agreement), we would expect (Table 2) that in PL_{min}, the GPSs would differ in 95% of the cases between 2.12 and $-1.42\,AU\,min^{-1}$. Likewise, in the other variables, the GPS units would differ from one another in 95% of the cases between the upper (limits of agreement (LOA) sup.) and lower (LOA inf.) limits of agreement (Table 2). On the other hand, the regression analysis revealed that the mean value and SD of all the variables, except PL_{min}, were constant in all ranges of the measurements.

From a practical standpoint, any value out of the LOAs should be considered meaningful or interpreted as real differences. For example, when comparing tennis players, or the same tennis player in different conditions, only values out of LOA should be interpreted as real. In V_{mean}, any value within the 4.68 and $-6.73\,m \cdot min^{-1}$ range should be interpreted as an

Table 1. Inter-unit systematic error of GPS devices for measuring global indicators in play game.

Variable	χ GPS1	χ GPS2	Bias	Bias 95% CI	p T-S (paired)
V_{mean} ($m \cdot min^{-1}$)	47.32	48.34	−1.03	−2.02/−0.03	ns
V_{peak} ($m \cdot min^{-1}$)	167.81	178.13	−10.31	−19.39/−1.24	0.03
EDI (ratio)	4.91	4.28	0.63	0.36/0.91	0.00
PL_{min} ($AU\,min^{-1}$)	6.99	6.64	0.35	0.04/0.66	0.04
EI_{min} ($AU\,min^{-1}$)	0.17	0.17	−0.01	−0.01/−0.01	0.02

$AU\,min^{-1}$: arbitrary units per minute; V_{mean}: velocity average in $m \cdot min^{-1}$; V_{peak}: velocity peak in $m \cdot min^{-1}$; EDI: Equivalent Distance Index; PL_{min}: Player Load per min in $AU\,min^{-1}$; EI_{min}: Exertion Index per min in $AU\,min^{-1}$; Bias: systematic error; Bias 95% CI: 95% confidence interval of the Bias; p T-S: paired sample t-Student test significance level. χ (mean).

Table 2. Inter-unit random error of GPS devices for measuring global indicators in play game.

Variable	LOA sup.	95% CI LOA sup.	LOA inf.	95% CI LOA inf.	R	R p
V_{mean} ($m \cdot min^{-1}$)	4.68	2.96/6.41	−6.73	−8.46/−5.01	0.01	ns
V_{peak} ($m \cdot min^{-1}$)	41.01	25.5/56.53	−61.64	−77.15/−46.12	−0.05	ns
EDI (ratio)	2.14	1.69/2.6	−0.88	−1.33/−0.42	0.08	ns
PL_{min} ($AU\,min^{-1}$)	2.12	1.59/2.66	−1.42	−1.96/−0.89	0.51	0.03
EI_{min} ($AU\,min^{-1}$)	0.03	0.02/0.05	−0.05	−0.07/−0.04	−0.03	ns

$AU\,min^{-1}$ is arbitrary units per minute; V_{mean}: velocity average in $m \cdot min^{-1}$; V_{peak}: velocity peak in $m \cdot min^{-1}$; EDI: Equivalent Distance Index; PL_{min}: Player Load per min in $AU\,min^{-1}$; EI_{min}: Exertion Index per min in $AU\,min^{-1}$; LOA: limit of agreement; INF: inferior; SUP: superior; 95% CI: 95% confidence interval; R: regression; R p: regression significance level. χ (mean).

inherent error (random error) of the units of the GPS device and not by real differences between tennis players or a real change in a tennis player.

As for the systematic errors, the GPS units used in this study produced systematically different results from one another. There might be two main causes for this systematic error. The GPS units might have produced systematically different results because they were not placed in the exact same location but were instead next to one another. However, there was only a slight difference in the location. The systematic error might also be due to a calibration issue among the units of the same GPS device. Nevertheless, we cannot discuss this as the previous literature[1,3–5] has only analysed random errors of GPS devices, ignoring the systematic errors. Further literature should focus on clarifying this regard because GPS could be a perfect tool to quantify the external load and performance of tennis players and other kinds of athletes.

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