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Accuracy and reliability of a 20Hz GPS device for measuring distance and speed of shuttle sprints

Introduction. Many team sports (i.e. rugby, soccer, basketball) are characterized by an "intermittent game model" where players cover distances shorter than 10 m and repeat short runs with acceleration-deceleration actions, changes of direction and sprints separated by short recovery pauses [Hoffman and Maresh 2000]. The most common method to quantify these high-intensity intermittent activities is to determine the distance covered above a specific running speed. Nevertheless, this approach does not consider the energetic cost of accelerations and decelerations during running and a new approach based on the concept of metabolic power has been proposed taking into account the energy demand of accelerated and decelerated running phases [Osgnach et al. 2010]. In the last years global positioning system (GPS) technology has been extensively utilized to estimate the physical demands of training and competition [Aughey et al 2010]. In particular, several studies have demonstrated that GPS devices have a sufficient level of accuracy for monitoring the true demands of intermittent exercise and calculate the mean metabolic power during high-intensity activities [Rampinini et al. 2014]. However, there are several concerns related to the use of GPS devices to measure very high-speed bouts and it has been shown that the sample rate of the devices, as well as speed, effort duration and nature of the task affect the accuracy [i.e. Coutts & Duffield 2010]. Moreover, other studies have shown that reliability of GPS devices gradually decreases in relation to increasing number of direction changes and accelerations [Jennings et al, 2010; MacLeod et al, 2009; Portas et al, 2010].

Aim. The aim of this study was to evaluate the accuracy and reliability of a GPS device with a sampling frequency of 20Hz for measuring distance and speed of shuttle runs. A High-Frequency (HF) video system was utilized as a criterion measure. Moreover, total distance and peak speed recorded by 20Hz GPS device were compared to the same data obtained by a 10Hz GPS device.

Methods. Six amateur soccer players performed 72 shuttle sprints covering different distances: 36 bouts of 4x5m and 36 bouts of 4x10m. During 36 bouts (18 sprints of 5m and 18 sprints of 10m), players wore two portable GPS devices with a sampling frequency of 20Hz (GPEXE, Udine, Italia) for inter-unit reliability assessment. Data for between-device comparisons were obtained from the remaining 36 bouts by a 2 different 10Hz devices (Catapult Minimax S4 Melbourne, Australia; QStarz BT-Q1000EX, Taipei, Taiwan - GPS-10Hz) and one of the two GPS devices previously utilized. GPS devices were positioned on the upper back of the players in a custom-made vest. During the entire testing session, data were also recorded by a high-frequency camera (EXILIM, EX-ZR1000, Casio, Japan) operating at a sampling frequency of 250 fps. The following variables were investigated: total distance (TD) and peak speed. Descriptive statistics were calculated for all variables and reported as mean±SD. To establish the difference between the criterion measures and the GPS devices (10Hz and 20 Hz) a one-way ANOVA test was used (Prism 6.0, Graphpad). Furthermore, validity was estimated by the typical error expressed as a percent of the subject's mean score (coefficient of variation - CV) and relative 95 % confidence limits calculated using Hopkins' spreadsheet [Hopkins 2000]. Significance was set at $P<0.05$.

Results. Table 1 shows TD measured by High-Frequency (HF) Camera, 20Hz and 10Hz GPS devices during 4x5m and 4x10m shuttle sprints. TD obtained from GPS-10Hz was significantly lower than TD obtained from HF camera and GPS-20Hz. No differences were observed between HF camera and GPS-20Hz.

Table 1. Total distance measured in 4x5m and 4x10m shuttle sprint with High-Frequency (HF) Camera, GPS-20Hz and GPS-10Hz

	HF Camera	GPS-20Hz	GPS-10Hz
4x5m (m)	22.18 ± 0.75	22.32 ± 0.89	20.73 ± 1.46*#
4x10m (m)	41.49 ± 0.76	41.46 ± 0.99	40.92 ± 2.15 *#

*significantly different from HF camera; # significantly different from GPS-20Hz

Table 2 shows CV, expressed in percentage, and 95% confidence limits of the total distance covered during shuttle runs comparing the 2 GPS systems with the criterion system. GPS-10Hz showed a higher CV than GPS-20Hz both for 4x5m and 4x10m shuttle runs. Moreover, typical error was higher in 4x5m shuttle runs than in 4x10m.

Table 2. Typical error as CV (95% confidence limits) for total distance in shuttle sprint comparing the 2 GPS devices with criterion system

	4x5m (m)	4x10m (m)
HF Camera vs GPS-20Hz	1.35 (1.09; 1.77)	1.06 (0.85; 1.39)
HF Camera vs GPS-10Hz	3.17 (2.34; 4.96)	2.01 (1.49; 3.07)

As regards intra-device reliability for measuring total distance, we only found small variations between two 20Hz GPS devices, with a CV of 1.6% and 2% in runs of 5 m and 10 m, respectively.

Table 3 reports the mean values of peak speed recorded during sprints. The peak speed of 4x5m shuttle runs recorded by 10Hz GPS device was significantly lower than GPS-20Hz. No difference in peak speed between GPS-20Hz and GPS-10Hz was found during the 4x10m shuttle runs.

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Table 3. Peak speed measured during 4x5m and 4x10m shuttle sprints with GPS-20Hz and GPS-10Hz

	GPS-20Hz	GPS-10Hz
4x5m ($m*s^{-1}$)	3.84 ± 0.24	3.70 ± 0.53 *
4x10m ($m*s^{-1}$)	5.02 ± 0.30	4.97 ± 0.43

* significantly different from GPS-20Hz

The accuracy of 20Hz GPS device for measuring peak speed was higher than 10Hz GPS device both in 4x5m (CV of 5.56% Vs 7.40% respectively) and in 4x10m (CV of 4.14% Vs 5.86% respectively) shuttle sprints. As regards intra-device reliability for measuring peak speed, we found a CV of 1.9% and 3.3% between the two 20Hz GPS devices in runs of 5 m and 10 m, respectively.

Discussion. The purpose of this study was to evaluate the accuracy and reliability of a 20Hz GPS device for measuring distance and speed of several shuttle runs. The main finding was that 20Hz GPS device was more accurate than 10Hz device for measuring both parameters, with an increasing error in relation to distance covered during the shuttle run.

Recent studies have reported that the longer the duration of a measured task, the more precise GPS measured distance becomes. For example, Jennings et al. showed a reduction of the standard error from 25% to 10% when comparing 10 m and 40m sprinting [Jennings et al. 2010]. This is reduced even more dramatically to just 1.5% for 5Hz GPS over a 197m simulated high-intensity soccer activity [Portas et al. 2010]. Moreover, it is known that the higher the sample rate, the more valid GPS becomes for measuring distance. For example, the standard error of the estimate for actual distance was 32.4% for 1 Hz GPS in a 10 m sprint, it reduced at 30.9% by a 5Hz GPS and it was 10,9% in a 15 m sprint in the only published information on 10 Hz GPS to date [Jennings et al. 2010; Castellano et al. 2011]. To our knowledge, this is the first study to investigate the accuracy and reliability of GPS devices operating at a sampling frequency of 20Hz. Our findings showed that accuracy of 20Hz GPS device for measuring total distance of shuttle runs over 5m and 10m was higher than that obtained by a 10Hz GPS device. Indeed, typical error of 20Hz GPS device was 20% and 30% lower than that obtained by 10Hz GPS in 5m and 10m shuttle runs, respectively. Moreover, total distance recorded by 20Hz GPS devices was not significantly different from that obtained by the criterion measure whereas the 10Hz GPS device significantly underestimated total distance. Thus, our results confirm the importance of the sampling rate of GPS devices for measuring distance of high-intensity activities and demonstrate that the utilization of a 20Hz GPS device improves the accuracy of the measure. The high-values of reliability obtained by the comparison of two 20Hz GPS devices demonstrate that it is not always necessary to monitor players with the same device, in contrast to other studies reporting differences between devices [Coutts & Duffield, 2010; Duffield et al. 2010].

Nevertheless, sample rate, velocity, duration of the task, and the type of task each influence the reliability of GPS as outlined above for validity. For example, in linear soccer tasks, the CV was 4.4–4.5% for 1 Hz and 4.6–5.3% for 5 Hz in one study and 0.7–1.3% in 15 and 30 m sprinting respectively with 10 Hz GPS in another study [Portas et al. 2010; Castellano et al. 2011]. Accordingly, caution should be taken in the interpretation of the results of our study when utilizing different GPS models or soccer-specific tasks with many change of directions.
As for speed measures, in our study we evaluated the peak speed during 5m and 10m shuttle runs. We showed no differences in peak speed between 20Hz and 10Hz GPS devices in 4x10m shuttle run, whereas when the distance decrease (4x5m) peak speed determined by 10Hz GPS device was significantly lower than that determined by a 20Hz device. Moreover, the accuracy of the GPS device with a higher sampling rate was 25% and 29% higher than 10Hz GPS in both 5m and 10m shuttle sprints, respectively. These results confirm the importance of the sampling rate of GPS devices in relation to the velocity of a task. In particular, from our results it is evident that an increase of direction changes (and so increase of accelerations and decelerations) reduce the accuracy and reliability of the measure. The absolute values of speed reached in our experiments were below the threshold of $5.56 m.s^{-1}$ usually considered as limit for very high-speed running. Previous studies have demonstrated that GPS systems with a sampling rate up to 10 Hz may not be accurate enough to measure some very high-speed efforts, reporting typical error as CV higher than 10%. Further studies should investigate if a 20Hz GPS device may be able to improve accuracy and reliability for measuring very high-speed activities according to its higher sampling rate.

In conclusion, the main finding of this study was that the 20 Hz GPS device was generally more accurate than GPS-10 Hz for measuring total distance and running speed in shuttle sprints. Thus, a GPS device with a sampling frequency of 20Hz should be used for accurately monitoring the energetic demand of intermittent team-sports activities in order to develop more specific training programs and better estimate physical performance during matches. Nevertheless, we acknowledge that these results are related to the specific GPS devices utilized in the present study. Accordingly, it is not possible to exclude a different result when using different software or GPS hardware not examined in this project. Furthermore, we are aware that high-frequency camera isn't as good as Laser or Radar to verify the accuracy and reliability of GPS technology during sprint or shuttle run [Chelly and Denis, 2001; Rampinini et al, 2015]. Nevertheless, recent studies have used this system to validate GPS device [Duffield et al, 2009] or analyze cinematics of movement [Buglione and Di Prampero, 2013] and the sampling rate of our camera was at least 10% higher than those utilized in that studies.

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