A comparison of two global positioning system devices for team-sport running protocols.

Running Title: Comparability in GPS devices for team-sports

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Abstract Word Count: 200

Text-Only Word Count: 1938

Number of Figures and Tables:
1 Figure
2 Tables

Abstract

The comparability and reliability of global positioning system (GPS) devices during running protocols associated with team-sports was investigated. Fourteen moderately-trained males completed 690 m of straight-line movements, a 570 m change of direction (COD) course and a 642.5 m team-sport simulated circuit (TSSC); on two occasions. Participants wore a FieldWiz GPS device and a Catapult MinimaxX S4 10-Hz GPS device. Typical error of measurement (TE) and coefficient of variation (CV%) were calculated between GPS devices, for the variables of total distance and peak speed. Reliability comparisons were made within FieldWiz GPS devices, between sessions. Small TE were observed between FieldWiz and Catapult GPS devices for total distance and peak speed during straight-line (16.9 m [2%], 1.2 $km \cdot h^{-1}$ [4%]), COD (31.8 m [6%], 0.4 $km \cdot h^{-1}$ [2%]) and TSSC protocols (12.9 m [2%], 0.5 $km \cdot h^{-1}$ [2%]), respectively, with no significant mean bias ($p>0.05$). Small TE were also observed for the FieldWiz GPS device between sessions ($p>0.05$) for straight-line (9.6 m [1%], 0.2 $km \cdot h^{-1}$ [1%]), COD (12.8 m [2%], 0.2 $km \cdot h^{-1}$ [1%]) and TSSC protocols (6.9 m [1%], 0.6 $km \cdot h^{-1}$ [2%]), respectively. Data from the FieldWiz GPS device appears comparable to established devices and reliable across a range of movement patterns associated with team-sports.

Keywords: GPS, team-sports, training load, performance analysis.

Introduction

Recent advances in player-tracking technology, notably global positioning system (GPS) devices, enable measurement of athlete movement patterns and physical demands during training and competition[4,6,16,19]. Applied sport practitioners can use these data to monitor external training loads and quantify competition demands[8,9]. Data collected using GPS devices facilitates objective planning of periodised training and managing injury risk in an attempt to optimise future performances[8,13,16]. Moreover, live transmission of these data can facilitate real-time feedback[16], for pro-active training load management and/or tactical decisions during competition. Consequently, the use of GPS technology within different sports and across ability levels is increasing[5], as well as in non-sporting industries who monitor physical performance (e.g. military)[12].

There are high purchasing and subscription costs associated with implementing GPS devices for player monitoring, which are likely reasons why GPS monitoring is less widespread across sporting and research environments, where financial constraints are evident. The use of GPS monitoring in sport, exercise, clinical, and research settings is an expanding market and therefore, simpler and more affordable GPS devices are becoming available, although it is unclear how such technologies compare against established brands.

The FieldWiz GPS device provides retrospective analysis of key performance metrics, which include total distance and peak speed, and therefore offers less data than other more complex GPS devices. However, it is currently unclear if there is comparable accuracy of the FieldWiz device, to other existing devices commonly utilised in similar applications. Consequently, establishing the comparability to current GPS devices and the reliability of FieldWiz GPS devices is necessary to enable users to be confident in their ability to interpret small differences in key performance metrics[11,16]. Therefore, the aim of this study was to investigate the comparability and reliability the FieldWiz GPS device during a range of movement patterns associated with team-sports.

Methods

Participants:

Fourteen, moderately-trained males (mean ± standard deviation [SD]: age: 23 ± 3 years, body mass: 75.1 ± 9.2 kg, stature: 1.78 ± 0.06 m and body fat: 15.7 ± 3.1 %) volunteered and provided written and informed consent for this study. Ethical approval was obtained from the Institution's Research Ethics and Governance Committee, and experimental procedures conformed to the Declaration of Helsinki (2013). Participants refrained from exhaustive exercise and alcohol (24-hours), and, heavy eating and caffeine (2-hours) prior to testing.

Experimental design:

Participants completed three running protocols, including: three straight-line runs of 10, 20 and 40 m (Figure 1a), two change of direction (COD) runs (4 x 10 m and 8 x 5 m at 90° [Figure 1b])[8,9], and a team-sport simulated circuit (TSSC) (Figure 2), as found in Coutts and Duffield[4]. The TSSC included: two maximal sprints, a COD section, three periods of walking, two periods of jogging, one striding effort and two decelerations. These protocols were completed on two occasions (session 1 and 2) and separated by 72-hours. During each session participants wore a FieldWiz unit (UNA Sports Medicine, UK) and a Catapult MinimaxX S4 unit (Catapult Innovations, Australia), with the same device used for both sessions. Devices were inserted vertically, in-line and separated by approximately 1 cm, into a purpose designed garment on the upper-back of the participant with the antennas fully exposed. Analyses for comparability were made between FieldWiz and Catapult GPS devices, while intra-unit reliability analysis were made between the same FieldWiz GPS device worn for session 1 and 2.

[Figure 1 and 2 near here]

Global positioning system devices and experimental procedures:

FieldWiz measures GPS derived data at 10-Hz and provides peak speed and distance covered. Catapult is an established GPS device brand and its 10-Hz device, such as the OPTIMAX S4 has been shown to have measurement errors of <9% and <1% for speed and distance metrics, respectively[10,17]. Despite demonstrating limitations in validity when protocols involve short distances[3], acceleration[1] and high velocities[10], they are one of the most widely used devices, indicating they are deemed sufficiently accurate and reliable to be used in team sport analysis, and suitable as a comparative measure in this study. All running protocols began following a 10-minute stabilization period to ensure each device had a satellite lock. After a 10-minute warm up, participants were familiarised to each running protocol during both sessions. Each straight-line and COD protocol began from a stationary position and was completed three times comprising self-selected walking, jogging and sprinting. Testing occurred outdoors, in an open area, on a 4G synthetic turf pitch, in similar conditions (visit 1: 18.7 ± 0.9°C, 51 ± 5 % relative humidity and 4.7 ± 0.9 km·h^{-1} wind speed *vs.* visit 2: 18.1 ± 1.7°C, 55 ± 5 % and 3.9 ± 1.6 km·h^{-1}). Environmental conditions were assessed using a heat stress meter (HT30, Extech instruments, USA) and airflow anemometer (LCA 6600, UK).

The data collected via the GPS devices included total distance, peak speed, and the distance covered across six speed bands, which were; 1.0-<5.0 km·h^{-1} (walking), 5.0-<10.0 km·h^{-1} (low jogging), 10.0-<15.0 km·h^{-1} (high jogging), 15.0-<20.0 km·h^{-1} (striding), 20.0-<25.0 km·h^{-1} (low sprinting) and >25 km·h^{-1} high sprinting). Total distances for straight-line (690 m) and COD (570 m) protocols were measured and participants followed the marked circuit as closely as possible. Timing gates (Brower, USA) were set up at 10, 20 and 40 m to measure movement times. Participants also completed five laps of the 128.5 m TSSC (total 642.5 m), where performance measures included; total distance, peak speed and the distance covered at a low (<14.5 km·h^{-1}), high (14.5-<20.0 km·h^{-1}) and very high (>20.0 km·h^{-1}) intensity, as per Coutts and Duffield[4].

Statistical analyses:

Data was assessed for normality and sphericity prior to further statistical analysis. Data is reported as mean ± SD, with statistical significance accepted as $p < 0.05$. Comparability for total distance during each protocol were initially made against fixed distances, as measured using a trundle wheel (Rabone Chesterman, England). Further comparability of distance and peak speed were made using data from the FieldWiz and Catapult GPS devices that were worn simultaneously throughout the protocol. Reliability comparisons were made between the same FieldWiz GPS device, worn for both sessions (i.e. intra-unit). Relative (Pearson's correlation coefficients and intraclass correlation [ICC]) and absolute (coefficient variation [CV] and ± 95 % limits of agreement [LOA]) statistical measures were calculated[2]. Mean bias was calculated as the mean of the individual differences between GPS measures. Typical error of measurement (TE) was calculated from the SD of the mean difference between measures, divided by √2[7], and is expressed in absolute (TE) and relative terms (CV). CV was categorised as '*good*' (<5%), '*moderate*' (5-10%) or '*poor*' (>10%)[16].

Results

Comparability:

Table 1 displays TE and CV between FieldWiz and Catapult GPS devices across all protocols and speed intervals. Total distance was not different between the trundle wheel and FieldWiz for straight line ($p = 0.30$), COD ($p = 0.33$) or TSSC ($p = 0.11$) protocols, but was different between mean lap distance during the TSSC ($p < 0.001$) (Table 1). Total distance and peak speed did not differ during straight-line ($p = 0.49$ and $p = 0.82$), COD ($p = 0.10$ and $p = 0.10$) or TSSC ($p = 0.20$ and $p = 0.12$) protocols between FieldWiz and Catapult units, displaying an overall low-moderate bias and a '*good*' CV (Table 1). There were high ICC (>0.8) between GPS units for all performance measures, in each protocol.

[Table 1 near here]

Reliability:

Table 2 displays TE and CV between sessions in FieldWiz GPS units across all protocols and speed intervals. Total distance and peak speed did not differ during straight-line (p = 0.79 and p = 0.16), COD (p = 0.18 and p = 0.65) or TSSC (p = 0.54 and p = 0.90) protocols between FieldWiz GPS units, displaying low-moderate bias and a '*good'* CV (Table 2). There were high ICC (> 0.9) between FieldWiz units for all performance measures, in each protocol.

[Table 2 near here]

Discussion

The aim of this study was to investigate the comparability and reliability the FieldWiz GPS device during a range of movement patterns associated with team-sports. The FieldWiz GPS device demonstrated moderate agreement (CV <10 %) compared to criterion measures and the Catapult device. Moreover, the FieldWiz GPS device demonstrated low-moderate bias and high ICC for key performance metrics (e.g. distance covered and peak speed) between repeated sessions (e.g. intra-unit), across each team-sport running protocol. The potential errors and variations in data are not dissimilar to those previously reported for other GPS devices when examining total distance and different speeds during the straight-line and TSSC protocols[4,8,9,11,13-16,18]

The moderate comparability and reliability of the FieldWiz during a COD activity (CV 5-10 %), is partly attributable to bias from biological variation, namely, differences in participant displacement as they run the course. Previous research highlights similar difficulties when participants are required to repeatedly follow a marked course whilst running at high speeds and with COD at tight angles[4]. Consequently, measurement accuracy may decrease as speed increases during the COD course, requiring further investigation, although the CV remained <10% for all FieldWiz movement speeds.

During straight line movements and the COD, a moderate CV (2-10 %) was displayed for the FieldWiz when compared to the Catapult unit across all distances and speeds. This was similarly found in the TSSC, where distance covered demonstrated '*good'* (4.4 %) accuracy for low intensity and '*moderate'* (7-8 %) accuracy for medium-high intensity running when comparing GPS devices. The moderate-high relationship (ICC 0.6-0.8) between 20 m sprint times collected using timing gates and FieldWiz peak speed during the TSSC, indicates the FieldWiz can be used to track sprint performance in team-sports and potentially differentiate between players.

When assessing FieldWiz intra-unit reliability, there were no statistical differences ($p > 0.05$) in distance covered or movement speed between sessions. Total distance and peak speed demonstrated a low CV (0.9-1.3 %, '*good'*) between FieldWiz GPS units during the straight-line movements. Moreover, as speed increased from 1.0-4.9 $km \cdot h^{-1}$ (walking) to >25 $km \cdot h^{-1}$ (high sprinting), the CV for distance covered reduced from 9.5 to 5.3 %, respectively (Table 2). Similar to straight-line movements, a low CV in total distance (2.2 %) and peak speed (0.8 %) between FieldWiz units occurred during the COD protocol. In contrast to the reductions in variability observed as speed increased during straight-line movements, a '*moderate'*, albeit larger, CV was observed for distance data as speed increased from 1.0-4.9 $km \cdot h^{-1}$ (6.5 %) to >15 $km \cdot h^{-1}$ (9.7 %). This is in line with other studies, who report similar patterns[8,9,18]. As found in the COD course, and reported elsewhere for this type of test[4], the CV for distance covered during the TSSC worsened (e.g. more variable) as running speeds increased, as demonstrated from the low (e.g. <14.5 $km \cdot h^{-1}$) (3.3 %) to very high intensity categories (e.g. >20.0 $km \cdot h^{-1}$) (7.2 %). Therefore, practitioners should be aware the most accurate data appear to derive from lower intensity exercise when using the FieldWiz device. Further investigation into intermittent sprints at various speeds and during different courses is recommended, to facilitate the detection of small, but meaningful differences[4] and help distinguish between technical error of the device and variation in human performance. The reliability of the FieldWiz GPS device between both sessions during the TSSC, displayed low bias and '*good'* CV for total distance covered (1.6 m [1.1 %]) and peak speed (0.6

km·h^{-1} [2.3 %]), respectively, indicating suitability for FieldWiz to track pertinent team-sport variables.

Practical applications:

This study indicates that the FieldWiz GPS device measures key performance metrics at a comparable level to other leading GPS devices, although it offers less overall data analysis to other GPS devices. Nonetheless, the FieldWiz GPS device provides reliable data between sessions when used in certain activities involving walking and running at varying speeds, replicating that of team-sport movement patterns (e.g. football). Moreover, the lower consumable cost may make it a more affordable option for sports and teams with less funding, and studies with less demanding data results.

Acknowledgements

The authors would like to thank the participants for their time and commitment during this study.

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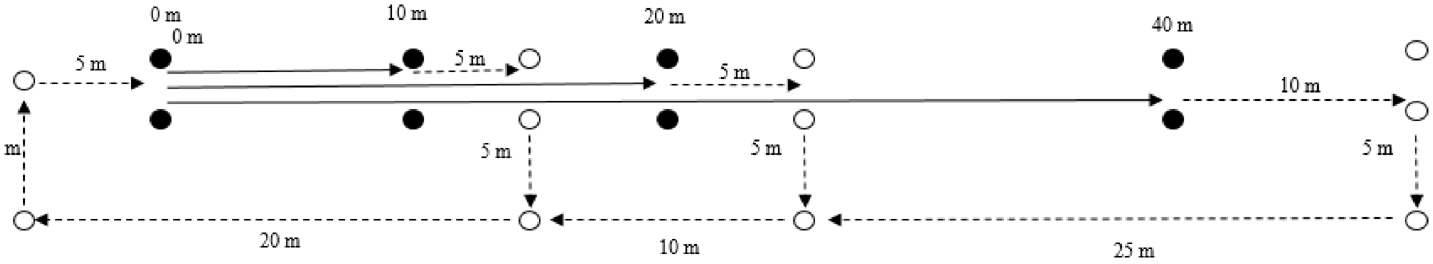
Figures:

Figure 1a



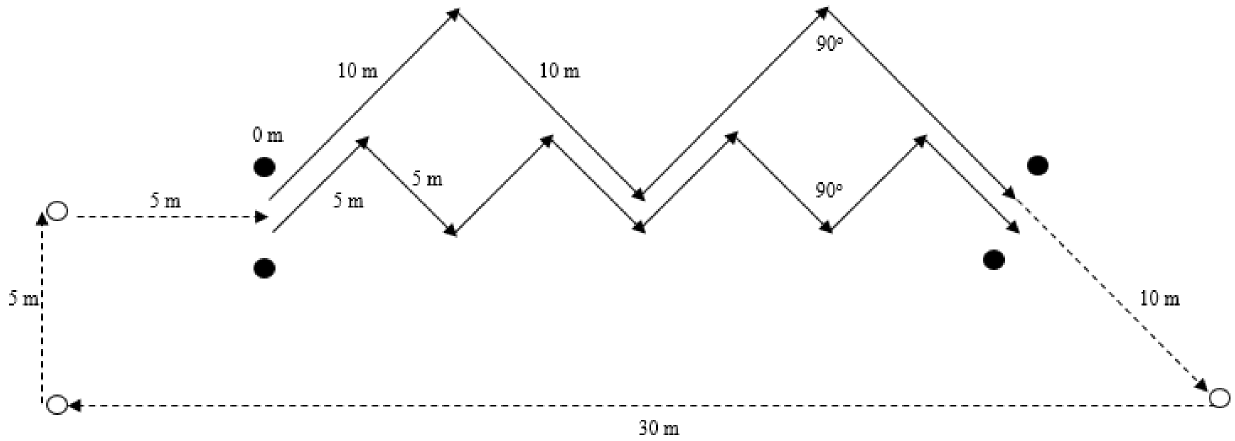


Figure 1b

Figure 1. A) Straight line distances (10, 20 and 40 m, solid lines), following a walking course after each drill (dotted lines). Timing gates (black circles) and set cones (white circles). **B)** Change of direction (COD) course: (top) gradual 10 m COD. 4 × 10 m straights with 3 × 90° COD, (bottom) tight 5 m COD. 8 × 5 m straights with 7 × 90° COD. Timing gates (black circles) and set cones (white circles).

Figure 2

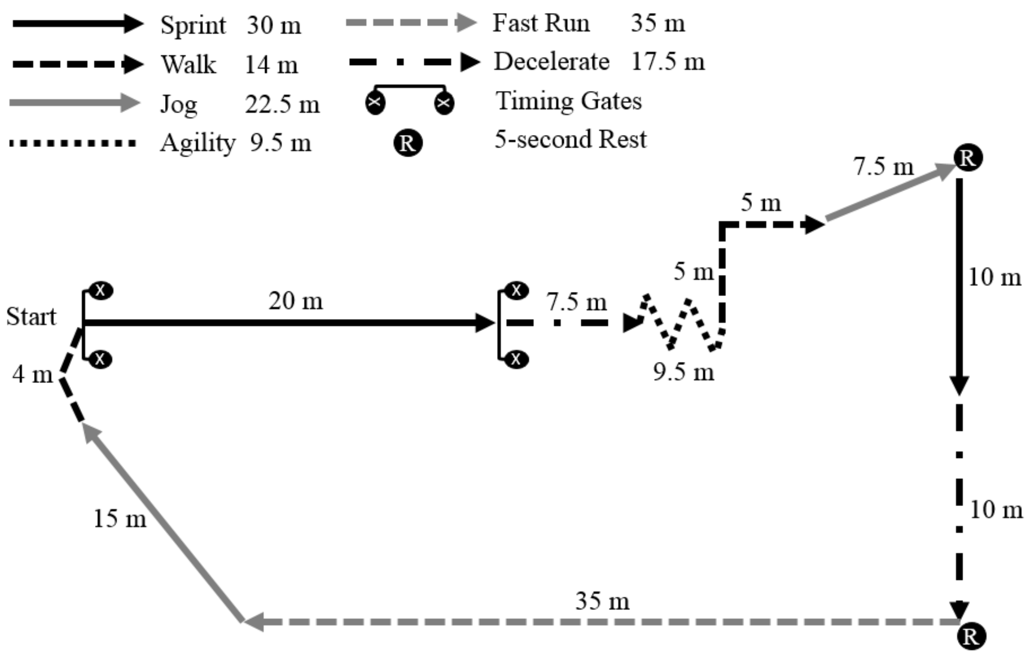


Figure 2. Team-sport stimulation circuit (TSSC), as per Coutts and Duffield[4].

Table 1. Comparability between FieldWiz and Catapult GPS devices

Performance metrics	Straight line Catapult	Straight line FieldWiz	Straight line Mean bias (95 % LoA)	Straight line TE (CV %)	COD Catapult	COD FieldWiz	COD Mean bias (95 % LoA)	COD TE (CV %)	TSSC Catapult	TSSC FieldWiz	TSSC Mean bias (95 % LoA)	TSSC TE (CV %)
Total distance (m)	727.1 ± 33.6	731.7 ± 40.1	4.6 (46.9)	16.9 (2.3)	553.5 ± 42.3	576.4 ± 58.8	21.2 (88.1)	31.8 (5.6)	646.4 ± 22.9	653.0 ± 22.8	6.5 (35.7)	12.9 (2.0)
Peak speed (km·hr^{-1})	27.7 ± 1.7	27.6 ± 2.2	0.1 (3.2)	1.2 (4.2)	19.9 ± 1.85	20.2 ± 1.6	0.3 (1.1)	0.4 (2.0)	24.7 ± 1.2	25.0 ± 1.4	0.3 (1.4)	0.5 (2.1)
Walking (m) 1.0-<5.0 km·h^{-1}	267.1 ± 94.7	276.8 ± 92.5	9.8 (55.3)	20.0 (7.3)	205.9 ± 83.5	213.7 ± 77.3	7.8 (38.7)	13.9 (6.6)				
Low jogging (m) 5.0-<10.0 km·h^{-1}	239.1 ± 127.5	237.8 ± 117.9	1.3 (60.3)	21.8 (9.1)	217.3 ± 88.5	209.7 ± 79.3	7.6 (50.8)	18.3 (8.6)				
High jogging (m) 10.0-<15.0 km·h^{-1}	53.5 ± 14.9	52.2 ± 15.8	1.3 (13.2)	4.8 (9.0)	78.2 ± 19.1	83.1 ± 21.2	4.9 (21.8)	7.9 (9.8)				
Striding (m) 15.0-<20.0 km·h^{-1}	38.5 ± 19.9	40.1 ± 22.9	1.5 (9.9)	3.6 (9.1)	24.8 ± 8.1	26.1 ± 8.0	1.2 (6.2)	2.3 (8.8)				
Low sprinting (m) 20.0-<25.0 km·h^{-1}	27.4 ± 11.2	27.5 ± 9.5	0.1 (6.3)	2.3 (8.3)								
High sprinting (m) >25 km·h-1	21.1 ± 14.9	22.3 ± 15.5	1.2 (5.2)	1.9 (8.6)								
Low (m) <14.5 km·h^{-1}									330.9 ± 59.4	330.8 ± 55.6	0.1 (40.3)	14.5 (4.4)
High (m) 14.5-<20.0 km·h^{-1}									158.1 ± 46.7	153.4 ± 45.9	4.7 (36.3)	13.1 (8.4)
Very High (m) >20.0 km·h-1									112.8 ± 44.4	113.6 ± 46.8	0.8 (23.1)	8.3 (7.4)
Validity measures between FieldWiz GPS device and trundle wheel												
	Trundle wheel	**FieldWiz**	**Mean bias (95 % LoA)**	**TE (CV %)**	**Trundle wheel**	**FieldWiz**	**Mean bias (95 % LoA)**	**TE (CV %)**	**Trundle wheel**	**FieldWiz**	**Mean bias (95 % LoA)**	**TE (CV %)**
Total protocol distance (m)	690	731.7 ± 40.1	41.7 (78.6)	28.4 (3.9)	570	576.4 ± 58.8	16.4 (115.3)	41.6 (7.3)	642.5	653.0 ± 22.8	10.5 (44.6)	16.1 (2.5)
Total lap distance (m)									128.5	131.4 ± 2.0	2.9 (3.9)	1.4 (1.1)

Note. TE = typical error, CV % = coefficient variation, LOA = limits of agreement, COD = change of direction, TSSC = team sport simulation circuit.

Table 2. Reliability between session 1 and 2 for FieldWiz GPS device

Performance metrics	Straight line Session 1	Straight line Session 2	Straight line Mean bias (95 % LoA)	Straight line TE (CV %)	COD Session 1	COD Session 2	COD Mean bias (95 % LoA)	COD TE (CV %)	TSSC Session 1	TSSC Session 2	TSSC Mean bias (95 % LoA)	TSSC TE (CV %)
Total distance (m)	731.7 ± 40.1	730.7 ± 33.3	1.0 (26.7)	9.6 (1.3)	569.2 ± 55.0	576.4 ± 58.8	7.2 (35.5)	12.8 (2.2)	651.3 ± 22.9	653.0 ± 22.8	1.6 (19.2)	6.9 (1.1)
Total lap distance (m)									131.4 ± 2.0	132.3 ± 2.6	0.9 (4.4)	1.6 (1.2)
Peak speed (km·hr^{-1})	27.6 ± 2.2	27.5 ± 2.1	0.1 (0.7)	0.2 (0.9)	20.2 ± 1.6	20.2 ± 1.7	0.0 (0.5)	0.2 (0.8)	25.0 ± 1.4	25.0 ± 1.1	0.0 (1.6)	0.6 (2.3)
Walking (m) 1.0-<5.0 km·h^{-1}	276.8 ± 92.5	284.5 ± 95.0	7.7 (73.7)	26.6 (9.5)	213.7 ± 77.3	215.7 ± 71.6	1.9 (38.8)	14.0 (6.5)				
Low jogging (m) 5.0-<10.0 km·h^{-1}	237.8 ± 117.9	225.9 ± 113.6	12.0 (61.7)	22.2 (9.6)	209.7 ± 79.3	201.2 ± 77.0	8.5 (31.2)	11.2 (5.5)				
High jogging (m) 10.0-<15.0 km·h^{-1}	52.2 ± 15.8	52.6 ± 15.3	0.4 (13.2)	4.8 (9.1)	83.1 ± 21.2	82.0 ± 23.9	1.1 (15.8)	5.7 (6.9)				
Striding (m) 15.0-<20.0 km·h^{-1}	40.1 ± 22.9	37.8 ± 23.4	1.8 (8.8)	3.2 (8.1)	26.1 ± 8.0	26.4 ± 8.3	0.3 (7.1)	2.5 (9.7)				
Low sprinting (m) 20.0-<25.0 km·h^{-1}	27.5 ± 9.5	28.2 ± 7.8	0.6 (6.3)	2.3 (8.2)								
High sprinting (m) >25 km·h-1	22.3 ± 15.5	22.0 ± 15.6	0.2 (3.2)	1.2 (5.3)								
Low (m) <14.5 km·h^{-1}									330.8 ± 55.6	328.5 ± 59.4	2.2 (30.3)	10.9 (3.3)
High (m) 14.5-<20.0 km·h^{-1}									153.4 ± 45.9	151.2 ± 48.0	2.3 (9.2)	3.3 (2.2)
Very High (m) >20.0 km·h-1									113.6 ± 46.8	114.8 ± 38.2	1.0 (22.8)	8.2 (7.2)

Note. TE = typical error, CV % = coefficient variation, LOA = limits of agreement, COD = change of direction, TSSC = team sport simulation circuit.