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The Reliability of the Titan 1+ 10 Hz Global Positioning System for Measures of Distance and Distance within Speed Zones

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ABSTRACT

Introduction: This experiment was designed to investigate the inter and intra-unit reliability of the Titan 1+ 10 Hz global positioning system (GPS) for measures of distance and distance within speed zones during straight-line and change of direction running at varying distances and speeds, as well as during a team-sport simulated circuit.
Methods and Materials: 16 male NCAA DI collegiate soccer players completed running protocols of varying distances and speeds, including long and short duration straight-line running (100m Run and SLR), tight and gradual change of direction running (COD T and COD G), and a team-sport simulated circuit (TSSC).
Results: Between Titan 1+ devices, good to moderate interunit reliability was established for distance measures during the 100m run (%CV = 1.31%). Moderate to high-speed movements for 20m SLR (5.2 – 7.4%), and all movements speed across the 40m SLR (3.5 – 4.5%). Good interunit reliability for distance measures was also established during both COD courses (2.04 – 3.6%). Good to moderate interunit reliability for distance within speed zones was established for COD G speed zone 4 (%CV = 6.8%) and COD T in speed band 3 (%CV = 7.1%). Moderate to excellent intraunit reliability was reported for distance within speed zones 2 and 3 during SLR ($p < 0.05$), with moderate intraunit reliability for 10m (.605 ICC, $p = .004$) and 40m (.620 ICC, p = .007). During the COD G, distance intraunit reliability was moderate for jogging and sprinting (.649 ICC, $p = .004$; .649 ICC, $p = .002$, respectively). Distances within speed zones 2 and 3 during COD G intraunit reliability was excellent for zone 2 (.956 ICC, $p < .001$) and zone 3 (.905, $p < .001$). During the TSSC, intraunit reliability was good for lap distance (.805 ICC, $p < .001$). Good intraunit reliability was reported for distance in speed zone 2 (.840 ICC, $p < .001$) and excellent for zone 3 (.919 ICC, $p < .001$) and zone 4 (.901 ICC, $p < .001$).
Conclusions: The present study is known to be the first to investigate the intra-unit reliability of distance measures during a team-sport simulated circuit. The findings suggest that the Titan 1+ provides good intraunit reliability for measures of distance and good to excellent intraunit reliability for measures of distance within speed zones during the TSSC. Further, the Titan 1+ produced reliable distance measures across all running protocols both within and between devices.

Keywords: Global positioning systems, GPS, Titan 1, Reliability, Inter-unit reliability, Intra-unit reliability, Distance, Speed zone

INTRODUCTION

The use of GPS technology has enabled the collection of real-time data on human locomotion,[1] providing

valuable information on sports performance with convenience, efficiency, and precision.[2] GPS technology objectively quantifies player movements (external training load),[3] which can be used in combination with data on athlete physical stress measurements (internal training loads).[4] This information is vital for strength and conditioning coaches and sports scientists to understand the relationship between an athlete's internal and external load,[4] data derived from GPS technology may allow for enhanced planning and periodization of training and recovery sessions.[3] With the ability to tailor external training loads, coaches and scientists can shape performance preparation to better mirror the specific demands athletes may face during match-play.[3, 5] These specialized training sessions provide the possibility for increased performance and reduction in injury occurrence.[4,6,7]

Cummins et al.[1] indicates that the optimal amount of training should not exceed an individual's exercise tolerance and capability of recovery. The practice of using GPS monitoring to adequately prescribe training loads should create a balance between preparing the individual for specific and positional demands involved in team sports, and the maximum training load that can be sustained by the individual before a significant increase in the likelihood of injury occurs.[8] Therefore, it is imperative that GPS technology provides accurate and reliable data, to ensure that all players are monitored and safely prescribed training volume and intensities to best prepare them for match-play while also preventing the incidence of injury.

Because GPS technology provides data that is important for the overall health and safety of the individuals wearing the devices, it is equally as important to ensure that these devices measure individuals metrics accurately and reliably. Historically, 10 Hz GPS devices have demonstrated increased reliability for measuring movement demands when compared to previous 1 and 5 Hz GPS devices.[9-12] Specifically, Castellano et al.[13] reported good intraunit reliability (%CV < 5%) for distance measures during 15m and 30m sprinting, however, greater measurement stability was observed during 30m sprinting compared to 15m sprinting. Additionally, the authors[13] reported good interunit reliability for distance measures during 15m (1.3%) and 30m (0.7%) sprinting. These results indicate that 10 Hz GPS devices are capable of capturing reliable distance measures during high-speed movements – a quality that both 1 Hz and 5 Hz GPS devices lack.

However, during a team-sport simulated circuit, Johnston et al.[12] reported good interunit reliability for distance measures during all movement speeds except very high-speed running (TEM = 11.5%). Given the variability in interunit reliability for distance measures, it is suggested that practitioners use caution when comparing very high-speed movement data between devices.[4] However, because 10 Hz GPS devices have demonstrated good intraunit reliability for distance measures across short distances, it is advised that for the purposes of comparability devices should be worn by the same individual for every training and match-play session.[4]

Through a robust battery of field-based tests, including short and long-distance movements, movements including changes of direction, and a team-sport simulated circuit, the present study aims to establish device intra and interunit reliability for measures of distance and distance within speed zones. The metrics will shed light on session volume and intensity, which allow practitioners to adequately monitor player workload. Reliable distance measures are a key component for quantifying of external training load,[14] allowing coaches and training specialists to adequately monitor the amount of physical stress experienced by the individual. Further, distance metrics are vitally important in the comparison of work intensity across different sports.[1] By establishing device reliability for distance and distance covered in speed zones, Titan 1+ data can be utilized to safely monitor the individual wearing the device and provide reliable data that may be used in sport activity profiles compared between field-based sports.

This study is a replication of previous investigations,[7, 12] focusing specifically on the inter and intraunit reliability of a novel GPS device that has not been previously evaluated. The present study is known to be the first to investigate intraunit reliability of a 10 Hz GPS device during a team-sport simulated circuit. The establishment of this level of reliability will not only add to the available body of literature surrounding GPS technology, but will provide insight on the reliability of a cost-effective GPS device.

METHODS

Experimental Approach to the Problem

The Titan 1+ is a novel device that samples data at 10 Hz with triple a Global Navigation Satellite System (GNSS), including GPS, GLONASS, and Gaelileo

capabilities.[15] However, there is no available data to confirm that the Titan 1+ is accurate or reliable. To determine the reliability of the Titan 1+ device for measures of distance and distance within speed zones, participants completed five running tasks designed to replicate the various movements observed during training and match-play. Reliability will be established both within and between the Titan 1+ devices.

Subjects

Participants included 16 male, men's NCAA Division I soccer players from a university in southeast Texas (age: 20 ± 1.3 years, height: 175.73 ± 5.9 cm, mass: 71.55 ± 7.83 kg). During the study, three participants were removed, two participants sustained an injury and one tested positive for covid-19. A total of 20 Titan 1+ a were used throughout the study. GPS devices that were assigned to participants who were removed from the study were paired with remaining participants.

All data was de-identified for the protection of the participants identities. Study design and methods approval were granted by the Houston Baptist University and Rocky Mountain University of Health Professions Institutional Review Boards. Additionally, all participants were required to complete a written informed consent form, following a complete explanation of all procedures.

Procedures

Data collection was conducted over the course of 10 days during September and October of 2020. Due to covid-19 social distancing protocols and time restrictions, each running procedure required two sessions to include all subjects and devices. All data were collected on a natural grass surface at a university in southeast Texas.

GPS devices were turned on 30 minutes before testing and set out in an open area to allow for the adequate acquisition of satellite signals.[7,9,16,17] Devices were not inserted into customized garments until participants were ready to begin each running task. The devices were aligned along the midline of the back between the scapulae, spaced approximately 3cm apart.[7] Previous studies,[7,12,18,19] have used similar methods for wearing multiple devices; none referenced any technological deficiencies regarding proximity of devices.

Running Protocols

This study included a series of running protocols that were designed to mimic different movement demands of field-based sports, including straight-line jogging, striding, and sprinting, change of direction in gradual and tight conditions, and a circuit composed of all list movements.[7, 20-22] Course distances were measured with tape measure, marked with cones (height = 11cm), and turns were measured by goniometer.[20]

100m Run. Participants were instructed to complete a series of three, 100m movements at a self-selected fast but comfortable pace. (Figure 1). Participants were allowed 30 seconds of stationary rest and were given a verbal cue to begin the next trial.

Straight-Line Running

Participants completed three trials of jogging, striding, and sprinting at self-selected speeds over distances of 10, 20, and 40m. (Figure 2). Participants would complete each movement speed

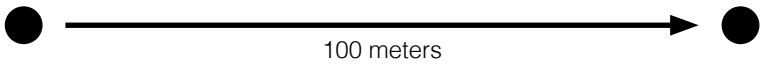

Figure 1. 100m Run Protocol

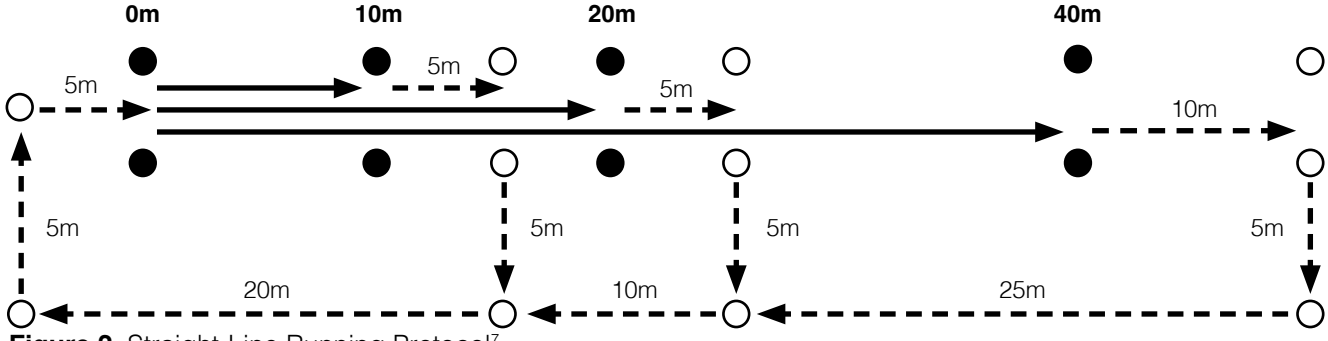

Figure 2. Straight-Line Running Protocol[7]

and distance in consecutive order. For example, participants completed three 10m jogs, followed by three 10m strides, followed by three 10m sprints, before moving to the 20m distance where the pattern would be repeated.[7] Participants were given 15 seconds between trials to rest, stationary at the start line.[10] A total of 27 straight-line running trials were completed, with a total distance of 630m.

Change of Direction Running

Each participant completed two change of direction (COD) courses at the same self-selected speeds of jogging, striding, and sprinting, totaling 18 trials and 720m. Both courses measured 40 total meters in distance. The gradual condition change of direction course (COD G) included three 90° turns. The tight condition change of direction course (COD T) included seven 90° turns (Figure 3).[7,20,22] Participants were given 15 seconds to rest stationary at the start line before beginning the next trial.[10]

Team Sport Simulated Circuit

Participants completes five individual trials of a 140m team-sport simulated circuit (TSSC), including two maximal sprints, a period of COD, three instances of walking, three jogs, one striding effort, and deceleration to complete stop (Figure 4).[7,20] Before starting the circuit, participants were given the opportunity to familiarize themselves to the course pattern of movements. Most participants needed three complete familiarization laps, before they were ready to begin. Participants were instructed to complete each lap of the circuit in one minute[20] and were given 15 to 30 seconds of rest between trials.[21]

STATISTICAL ANALYSIS

All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS, Version 27.0.1.0). Reliability comparisons were made between Titan 1+ 10 Hz GPS devices worn during each running protocol. Statistical significance was set at $p < 0.05$. Data are presented as mean ± SD.

Two-way mixed-effects interclass correlation (ICC) and 95% confidence interval (CI) were used to compare intraunit reliability of the Titan 1+ 10 Hz GPS devices for measures of distance and distance covered within each speed zone.[10,23,24] ICC scores were interpreted as poor (< 0.5), moderate (0.5-0.75), good (0.75-0.90), and excellent (>0.90).

Interunit reliability was tested via the measurement error or %CV.[23] %CV was categorized as good (<5%), moderate (5-10%), and poor (>10%).[3,7] Internal consistency was established using Cronbach's Alpha (α) ranging from 0.00 to 1.00, values approaching .90 were considered high, indicating good reliability.[25]

RESULTS

Satellite Data and Environmental Conditions

Daily satellite acquisition for the Titan 1+ 10 Hz GPS devices for all trials ranged from 16 to 22 satellites with a mean of 19 ± 2.16 satellites. This availability is significantly greater than previously reported satellite acquisition, where the average number of satellites ranged from 6 to 14.[12,17,18,20,24,26] Environmental conditions ranged from fair to partly cloudy, with temperatures ranging from 62-72°F (provided by the National Weather Service Forecast Office).

Distance inter- and intraunit reliability data are depicted in Table 1. Distance within speed zone for the SLR, COD G, COD T, and TSSC are depicted in Tables 2 and 3.

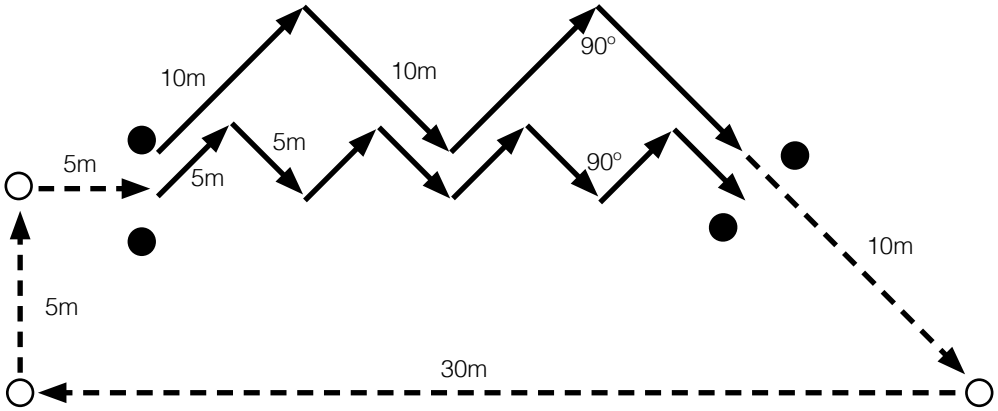

Figure 3. Change of Direction - Gradual and Tight Protocols[7]

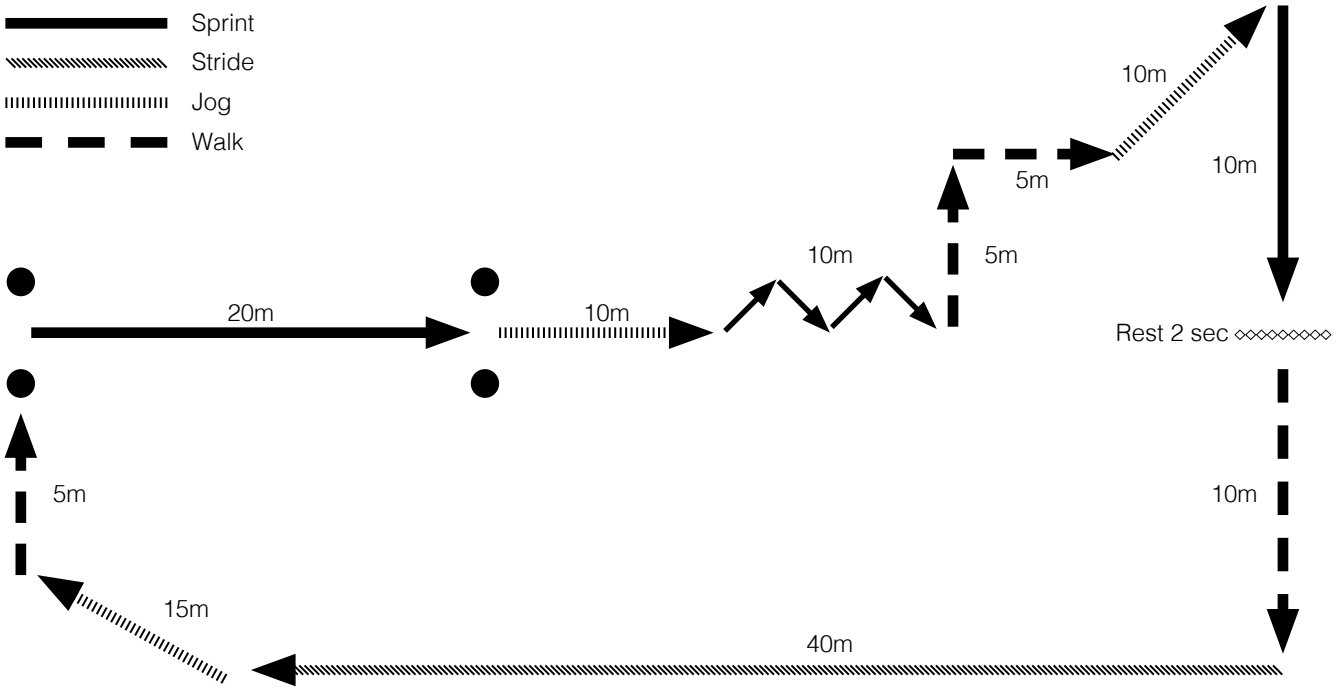

Figure 4. Team-Sport Simulated Circuit Protocol[20]

Table 1. Titan 1+ Inter and Intraunit Reliability

	%CV	ICC	95% CI	*p*	α
100m Run	1.31				
10m SLR					
Jog	7.5	.41	-.268, .749	.088	.401
Stride	7.9	.46	-.151, .772	.055	.454
Sprint	11.3	.55	.068, .803	.017	.555
20m SLR					
Jog	11.5	.78	.521, .902	< .001	.821
Stride	5.2	.20	-.466, .631	.240	.230
Sprint	7.4	.32	-.399, .706	.149	.324
40m SLR					
Jog	3.5	.52	-.031, .800	.030	.511
Stride	4.0	.58	.144, .817	.009	.594
Sprint	4.5	.35	-.451, .728	.135	.340
COD G					
Jog	3.6	.649	.246, .854	.004	.645
Stride	2.6	.486	.082, .784	.042	.491
Sprint	3.1	.649	.276, .851	.002	.671
COD T					
Jog	3.2	.648	.342, .864	.001	.686
Stride	2.5	.639	.252, .845	.003	.643
Sprint	2.0	.133	-.874, .635	.347	.130
TSSC	1.3	.805	.630, .912	< .001	.810

Interunit Reliability

A good interunit reliability was found for the Titan 1+ devices for the distance measured during the 100m run trials (%CV = 1.31%). During the SLR good interunit reliability was also found for the distance measured during all 40m trials (3.5 – 4.5%). Moderate interunit reliability was found for 10m jog and stride (7.5 and 7.9%, respectively) and the 20m stride and sprint (5.2 and 7.4%, respectively). Good interunit reliability was found for the Titan devices for the distance measured during all 40m trials (3.5 – 4.5%). Moderate interunit reliability was found for 10m jog and stride (7.5 and 7.9%, respectively) and the 20m stride and sprint (5.2 and 7.4%, respectively).

Good interunit reliability was found for distance measured during all COD G and COD T trials (2.6% – 3.6% and 2.0% – 3.2%, respectively). Moderate interunit reliability was found for distance measured in speed band 3 (%CV = 7.1). Good interunit reliability was also found for distance during the TSSC (%CV = 1.3).

Intraunit Reliability

A moderate intra-unit reliability was found for the Titan 1+ 10 Hz GPS devices for distance during the 10m sprint (ICC = .545, p = .017, 95% CI .068; .803), 40m jog (ICC = .524, p = .030, 95% CI = -.031; .800), and 40m stride (ICC = .579, p = .009, 95% CI .144; .817). Good intra-unit reliability was also found for measures of distance during the 20m jog (ICC = .776, p < .001, 95% CI .521; .902).

For distance within speed zone 2, excellent intra-unit reliability was found at 10m (ICC = .924, p <.001, 95% CI .842; .968), good intra-unit reliability was found at 20m (ICC = .726, p < .001, 95% CI .437; .881), and moderate intra-unit reliability was found at 40m (ICC = .515, p = .025, 95% CI .011; .790). Distance measured in speed zone 3 revealed moderate intra-unit reliability at 10m (ICC = .685, p = .002, 95% CI .325; .867) and 40m (ICC = .692, p = .001, 95% CI .346; .869), and good intra-unit reliability for 20m (ICC = .787, p < .001, 95% CI .559; .908).

For distance measured during the COD G, moderate intra-unit reliability was found during jogging (ICC = .649, p = .004, 95% CI .246; .854) and sprinting (ICC = .649, p = .002, 95% CI .276; .851). Excellent intra-unit reliability was found for distance within speed band 2 (ICC = .956, p < .001, 95% CI .906; .982; Table 5) and speed band 3 (ICC = .905, p <.001, 95% CI .796; .961). Moderate interunit reliability was found for distance measured in speed band 4 (%CV = 6.8).

During the COD T, moderate intra-unit reliability for distance were found for jogging (ICC = .684, p = .001, 95% CI .342; .864) and striding (ICC = .639, p = .003, 95% CI .252; .845). Moderate intra-unit reliability was found for distance measured within speed zone 4 (ICC = .695, p < .001, 95% CI .361; .869). Good intra-unit reliability was found for distance measures within speed zone 2 (ICC = .896, p < .001, 95%CI .778; .956) and speeds zone 3 (ICC = .798, p < .001, 95% CI .580; .913).

Good intra-unit reliability was found for distance measured during the TSSC (ICC = .805, p < .001, 95% CI .630; .912). Good intra-unit reliability was found for distance within speed zone 2 during the team-sport simulated circuit for the Titan 1+ 10 Hz GPS devices (ICC = .840, p < .001, 95% CI .694; .929). Excellent intra-unit reliability was found for speed zone 3 (ICC =.919, p < .001, 95% CI .846; .964) and speed zone 4 (ICC = .901, p < .001, 95% CI .811; .956).

DISCUSSION

Interunit reliability

The present study suggests that the Titan 1+ provides good to moderate interunit reliability for distance during SLR and COD running protocols. Two important patterns were observed in the data across all straight-line running protocols. First, as the distance of a specific movement increased, device interunit reliability increased. Second, as movement speed increased for a specific distance, interunit reliability decreased but remained acceptable overall. These findings suggest that the Titan 1+ reported increased measurement variability as movement speed increased for straight-line activities. However, overall distance interunit reliability remained within acceptable measures.

The only two exceptions to the SLR observations are 10m sprinting (11.3 %CV) and 20m jogging (11.5 %CV) distances. Previous authors have identified comparable high-speed running distance reliability measures,[23,27] suggesting that the Titan 1+ will exhibit higher measurement variability for short distances during high-speed movements. This variability results from GPS technology lacking the ability to capture short burst accelerations over short distances.[27] Meanwhile, low-speed distance

Table 2. SLR Protocol Inter and Intraunit Reliability – Distance Within Speed Zone

	%CV	ICC	95% CI	p	α
Zone 2					
10m	97.5	.924	.842, .968	< .001	.922
20m	68.7	.726	.437, .881	< .001	.752
40m	65.2	.515	.011, .790	.025	.526
Zone 3					
10m	40.0	.685	.325, .867	.002	.674
20m	42.9	.787	.559, .908	< .001	.794
40m	20.5	.692	.346, .869	.001	.684
Zone 4					
10m	24.1	.605	.208, .827	.004	.635
20m	31.3	.211	-.687, .666	.264	.208
40m	29.2	.620	.183, .840	.007	.609

Table 3. COD G, COD T, and TSSC Protocol Inter and Intraunit Reliability – Distance within Speed Zone

	%CV	ICC	95% CI	p	α
COD G					
Zone 2	85.3	.956	.906, .982	<.001	.955
Zone 3	29.4	.905	.796, .961	<.001	.901
Zone 4	6.8	.427	-.274, .766	.084	.415
COD T					
Zone 2	75.2	.896	.778, .956	<.001	.907
Zone 3	7.1	.798	.580, .913	<.001	.801
Zone 4	107.7	.695	.361, .869	<.001	.693
TSSC					
Zone 2	18.3	.840	.694, .929	<.001	.862
Zone 3	23.4	.919	.846, .964	<.001	.921
Zone 4	30.2	.901	.811, .956	<.001	.900

measures of 20m were likely due to participants continuing past the 20m end-line without a proper deceleration for the GPS to measure low-speed distance definitively. Interestingly, previous studies have cautioned against utilizing interunit reliability for distance measure comparisons during high-speed running;[7,12,16] due to increased measurement variability as movement speeds increased.[12] However, the present study provides adequate interunit reliability for high-intensity speeds over 20 and 40m straight-line running. The results indicate that the Titan 1+ can provide comparable high-speed running distances.

Interunit reliability remains good (<5%) across both COD running protocols at all movement speeds. Interestingly, during these protocols, as movement speed increased, the Titan 1+ interunit reliability also increased. Further, as the change of direction exercises moved from gradual to tight turns, the Titan 1+ exhibited increased interunit reliability for each movement speed. Coupled with good 100m run and TSSC distance interunit reliability (1.3% and 1.3%, respectively), the study findings suggest that the Titan 1+ is a reliable tool to produce consistent distance measures.

While the Titan 1+ displayed acceptable interunit reliability across all running protocols for distance measures, the devices could not consistently measure distance within speed zones. Overall, the Titan 1+ measured only COD G sprinting (6.8 %CV) and COD T striding (7.1 %CV) with acceptable interunit reliability. There was evidence of decreasing measurement error through the present study as movement speeds increased during the 100m run

and SLR protocols, suggesting that device accuracy will increase with high-speed linear movements, thus reducing measurement variability.

During the TSSC protocol, device interunit reliability decreased as speed zones increased (18.3 - 30.2 %CV). However, total distance measures within each speed zone, during this protocol were estimated similarly with known distances of corresponding movement speeds of jogging, striding, and sprinting, indicating that the Titan 1+ is capable of measuring reliable distances but speed zone thresholds may not have matched the participant's movements properly.

Intraunit Reliability

The Titan 1+ showed good intraunit reliability for the distance measured within speed zones during SLR, COD, and the TSSC running protocols. Overall, moderate to excellent intraunit reliability was observed during all SLR movements. In speed zone 2, there is a decrease in reliability and internal consistency as distances increased. However, this pattern was not observed in speed zone 3 or 4. High-speed, speed zone 4 movements, were poor for 20m SLR (ICC = .21), and the COD G (ICC= .43), indicating low reproducibility within devices. While COD G, speed zone 4 distance measures were poor, corresponding sprinting distance showed moderate intraunit reliability (ICC = .65, p = .004). All other COD G and COD T protocols and the TSSC protocol had moderate to excellent intraunit reliability and good to excellent internal consistency for distance within speed zones.

Intraunit reliability for distance measures during straight-line running was moderate to good across only 4 movements. Both the 10m sprint and 20m jog showed acceptable intraunit reliability consistency but were the only two movements above acceptable measurement accuracy (11.3% and 11.5%, respectively). Suggesting distance data for these types of movements should only be compared within devices not across all Titan 1+ devices. Additionally, with only 40m jogging and striding showing acceptable intraunit reliability, all other straight-line movements between 10 and 40m should be compared across all Titan 1+ devices and not within devices.

Change of direction distance intraunit reliability was considerably better than SLR results. Except the COD T sprint, all COD protocols, produced moderate intraunit reliability and good internal consistency for distance measures. Curiously, the COD T sprint had the best measurement accuracy (2.0%), across all COD protocols. These results indicate that high-speed change of direction running is best compared between Titan 1+ devices and should not be compared within devices. Additionally, intraunit reliability during the TSSC was good with good internal consistency (ICC = .81, p < .001, α = .81).

The results of this study suggest that the Titan 1+ was able to produce reliable distance measures across all running protocols both within and between devices. Additionally, the Titan 1+ provided reliable distance measures in speed zones within devices, with good to excellent internal consistency for all running protocols. These results indicate that distance within speed zones should only be compared within Titan 1+ devices, not compared across a group. However, it is important to highlight that while the Titan 1+ did not measure distance within speed zones accurately, the data was reliable with strong internal consistency, indicating that the Titan 1+ can replicate measures. Therefore, the device may lack interunit reliability due to the preset speed zone thresholds established before data collection.

The primary investigator's opinion is that adjustment to speed zone thresholds should be made better to investigate the reliability of distance within speed zone measures. The fourth speed zone should be changed to have an upper limit of 6.7 $m \cdot s^{-1}$, which would still correspond with sprinting speeds, and a fifth speed zone, corresponding with very high-speed sprinting (>6.7 $m \cdot s^{-1}$), should then be added. These thresholds would better align with upper-level speed zones that have been observed in professional soccer players and professional AFL players.[28-31]

PRACTICAL APPLICATIONS

The present study is the first to investigate the intra-unit reliability of distance measures during a team-sport simulated circuit.4 The findings suggest that the Titan 1+ 10 Hz GPS devices provide good intraunit reliability for distance measure and good to excellent measures of distance within speed zones during activities designed to replicate prolonged field-based sports activities. Additionally, the internal consistency of these metrics was good to excellent. Therefore, the Titan 1+ 10 Hz GPS devices can provide reliable data during team-sport competition activities. However, due to variability in interunit reliability during low-speed movements, it is still

suggested that individuals wear the same device during all training sessions and competitions.

With the conclusion of this study, it is evident that the Titan 1+ 10 Hz GPS device is a reliable technology that can be compared to more popular GPS brands. The main benefit of implementing Titan Sensor technology compared to similar technology from companies such as Catapult is pricing. The Titan 1+ 10 Hz GPS device and subsequent software costs considerably less than similar devices. Therefore, the availability of reliable, lower cost GPS technology would allow for smaller budgeted field-based sports programs to invest in technology that will only improve their training sessions and match preparations.

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