

The reliability and validity of two different inertial measurement units in youth basketball players

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Abstract

Approach: Technology, such as the inertial measurement unit (IMU), is frequently used in elite sporting environments for monitoring athlete stress and assessing performance. IMUs have been found to be reliable during test-retest in research conducted using adult participants however, there is a lack of information regarding the use of IMU devices with youth athlete sporting teams. **Purpose:** Therefore, this study aimed to evaluate the test-retest reliability and validity of two different IMUs (VX Sport and Blue Trident) for player load analysis in youth athletes. Additionally, a secondary aim was to compare the difference in player load analysis using an IMU (Blue Trident) at two difference locations (2nd thoracic vertebrae and lateral malleolus). **Methods:** Ten state-level youth basketball players participated in this study. Participants performed a multi-directional movement circuit while wearing two IMUs at the 2nd thoracic vertebrae (VX Sport and Blue Trident), and an additional IMU (Blue Trident) at the lateral malleolus on three separate testing sessions. **Results:** Moderate to good reliability was demonstrated for the VX Sport IMU and Blue Trident IMU (ICC = 0.64 to 0.86). There was no difference between sessions for each IMU. The VX Sport IMU at the 2nd thoracic vertebrae resulted in a reduced player load outcome compared to the Blue Trident IMU. Additionally, the Blue Trident IMU at the lateral malleolus had an increased player load outcome compared to the Blue Trident IMU at the 2nd thoracic vertebrae. **Conclusion:** All IMUs used in this study were reliable for testing youth athletes. Practitioners should not compare results between different technological devices without considering the potential sources of error, especially when undertaking cross and longitudinal analyses. Furthermore, where the IMU is placed will provide different analysis of accumulated load.

Keywords: Workload; Youth; Technology; Monitoring

Introduction

Measuring athlete movements during training and competition is important within team sports to evaluate an athlete's readiness, development, and/or need for recovery (McKeown, Taylor-McKeown, Woods, & Ball, 2014; Sawczuk, Jones, Scantlebury, & Till, 2018). The equipment required to conduct these measures varies in cost, user expertise and software. Reliability and validity of this equipment is crucial to understanding whether a change in the athlete's performance results from either the athlete's performance state or measurement error.

One device for measuring athlete movement is the inertial measurement unit (IMU). IMUs are being extensively used to provide objective information on training intensity or competition loads (i.e., accumulated load [AL]) (Chambers, Gabbett, Cole, & Beard, 2015). These devices record the resultant acceleration changes during sporting movements, such as changes in direction and vertical jumps (Montgomery, Pyne, & Minahan, 2010; Russell, McLean, Impellizzeri, Strack, & Coutts, 2021; Schelling & Torres, 2016). Due to the high sampling frequency of IMU products (e.g., Blue Trident I Measure You, sampling up to 1600 Hz), they may be more accurate at identifying various movements and an athlete's training load compared to global and local positioning systems (e.g., Catapult Playertek sampling at 400 Hz) (Russell et al., 2021; Svilar, Castellano, & Jukic, 2018). The VX Sport Log 340b unit is an inexpensive IMU device compared to the Blue Trident IMU however, there is limited research that has investigated the reliability or the validity of the VX Sport IMU (Wylde, Lee, Low, & Callaway, 2018). Additionally, where the IMU is positioned on the body could provide different information regarding accumulated load. Common sites where IMUs are positioned include just above the lateral malleolus (ankle) of the leg or on top of the 2nd thoracic vertebrae (T2) (Armitage, Beato, & McErlain-Naylor, 2021; Burland, Outerleys, Lattermann, & Davis, 2021; Scanlan, Wen, Tucker, & Dalbo, 2014). Research comparing the reliability of IMU location and comparison between locations is also lacking for AL (Armitage et al., 2021; Horsley et al., 2021).

The use of IMUs have typically appeared in adult team sports but as popularity of IMUs have increased, there has been an increased use of IMUs in youth team sports (Izzo, Seccia, Giovannelli, Cejudo, & Hosseini Varde'I, 2022; Palmer, van der Ploeg, Bourdon, Butler, & Crowther, 2023). However, the test-retest reliability and

validity for obtaining accumulating load in youth athletes is limited (Benson et al., 2020; Borges et al., 2017) with evidence for reliability and validity primarily based on adult populations.

Therefore, the aims of this study were to investigate the reliability and validity of the VX Sport IMU compared to the Blue Trident IMU for the assessment of AL during a multi-direction movement circuit and to compare data from two attachment locations (T2 and ankle). It was hypothesised that there would be no difference ($P > 0.05$) between the technology used for AL testing (VX Sport IMU vs Blue Trident IMU) at the same location, however a difference would exist between the two locations ($P < 0.05$).

Material and Methods

Experimental approach to the problem

The study used a randomised crossover design containing three test-retest reliability sessions. In each session, participants completed a multi-direction movement circuit to evaluate the VX Sport IMU (Visuallex Sport International, Lower Hutt, New Zealand) and two Blue Trident IMUs (Vicon Motion Systems Ltd, Oxford, UK) for monitoring AL. Time of day between testing sessions was controlled.

Participants

Ten state-level basketball players (six males, four females; 15.1 ± 1.1 yrs; 1.85 ± 0.08 m; 69.8 ± 6.1 kg) were recruited for the study. A sample size power calculation was performed with an effect size of 1.2, alpha error of 0.05, power of 0.95 and 95% coefficient limits (G*Power 3.1.9.4, Dusseldorf, Germany), which resulted in a calculated sample size of 10 participants required. Inclusion criteria for participants were that they were a current athlete within the Basketball South Australia (BSA) High Performance Program, under 18 yrs of age, pass the requirements for stage 1 of the Exercise and Sport Science Australia Adult Exercise Pre-Screening System and free of any neuromusculoskeletal injuries. Informed consent from each participant and their parent/guardian was obtained prior to their involvement in the study. This study was approved by the University of South Australia Human Research Ethics Committee (203398).

Familiarisation

Each participant received an information sheet outlining the purpose of the study upon arrival to the laboratory. Each participants' height (m) and mass (kg) were measured using a wall mounted stadiometer (SECA 216, SECA, NY, USA) and Tanita scales (TANITA DR-953 Inner Scan, Tanita, Tokyo, Japan), respectively. Participants then performed a familiarisation session of the testing protocol. After completion of the familiarisation session, participants returned within 24 h to complete their first testing session.

Protocol

A VX Log 340b IMU unit (sampling at 100 Hz) was worn on the participant's back, on top of T2 (VX T2), using the manufacturer's vest. Two IMU Blue Tridents (sampling at 800 Hz) were also placed on the body, one above the right lateral malleolus (BT A) and the other directly on top of the VX Sport IMU (BT T2) (Figure 1). The participant then performed a standardized 10 min warm up incorporating jogging, hamstring scoops, hip circles, skipping across 20 m, three submaximal practice countermovement jumps (CMJs) prior to testing (Cormack, Newton, McGulgan, & Doyle, 2008).

Participants were then required to perform the movements listed in Table 1 across a 10 x 5 m open area on a hardwood surface in the laboratory. CMJs were used during the protocol to start and end points for the testing. If the participant failed to reach the marked lines during their movement circuit using their right foot as the pivot foot, the trial was repeated after a 5 min rest interval. Movement of the participant was limited during the rest between each movement event to minimise noise.



Figure 1. Position of the VX Sport IMU and two Vicon Blue Trident IMUs during movement circuit.

Table 1. Movement circuit.

Order	Movement
1.	CMJ
2.	10 s standing rest
3.	10 x consecutive 10 m sprints at 100% intensity
4.	30 s standing rest
5.	10 x consecutive 5 m lateral sprints at 100% intensity
6.	10 s standing rest
7.	CMJ

CMJ – countermovement jump

Cool-down

At the completion of each session, participants were given a 5 min period to conduct a standardized cool down including 10 x walking scoops on each leg, 10 x high knee pulls on each leg and foam rolling (gluteals, hamstrings, quadriceps and calves). Participants had a 48 h period between testing sessions to mitigate the effect of fatigue (Jentjens & Jeukendrup, 2003).

Data analysis

All raw accelerometer data (Fx, Fy and Fz) were exported from the VX Sport and Blue Trident IMUs. Matlab (MATLAB 2020a, The MathWorks, Inc., Natick, MA, USA) was used to remove any data prior to the first CMJ or after the second CMJ before processing. To account for the different sampling rates between devices, all Blue Trident IMU data was down sampled in Matlab to 100 Hz. AL was calculated using the PlayerLoad™ formula (1) most used for assessing changes in movement across all three planes of motion (Barrett, Midgley, & Lovell, 2014; Montgomery et al., 2010; Schelling & Torres, 2016).

$$\text{PlayerLoad}^{\text{TM}} = \sqrt{[(x_n - x_{n-1})^2 + (y_n - y_{n-1})^2 + (z_n - z_{n-1})^2]} \quad (1)$$

Statistical analysis

All statistical analyses were conducted using SPSS statistical software version 25 (IBM Corp, New York, NY, USA). Means and standard deviations (SD) from each session were calculated and box plots were used to test for outliers (no outliers were found). Shapiro-Wilk goodness of fit test was used to assess the data that was normally distributed. Intraclass Correlation Coefficient (ICC_{3,1}) were used to examine inter-session reliability (session 1 vs. session 2 vs. session 3) using the following bandwidths: poor (< 0.5); moderate (0.5-0.75); good (0.75-0.9) and excellent (>0.9) (Koo & Li, 2016; Portney & Watkins, 2000). Effect size (ES) statistics were calculated using a customised spreadsheet and used the following criteria for analysis; trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), very large (2.0–4.0) and nearly perfect (>4.0) (Hopkins, 2015). Typical error (TE) was calculated using the same spreadsheet and reported in raw units. A one-way repeated measure ANOVA was used to determine if there were differences amongst sessions (alpha level set at < 0.05). A post-hoc Bonferroni correction factor was used for the multiple analyses of the same sample data. A paired sample *t*-tests were used to examine differences between IMUs (alpha level set at < 0.05).

Results

The VX T2 demonstrated a mean moderate reliability with a trivial effect size, whilst BT T2 demonstrated a mean good reliability and trivial effect size. The BT A had a mean moderate reliability with a trivial effect size (Table 2). There was no difference ($P < 0.05$) observed between sessions for each IMU. The VX T2 had a reduced ($P < 0.05$) AL compared to BT T2 (diff ~ 20 AU) and BT A had a greater ($P < 0.05$) AL compared to BT T2 for each session (diff ~ 475 AU) (Table 2).

Table 2. Reliability and validity results for the inertial measurement units.

Device	Mean (SD)			ES	Sig.	ICC ^(2,1) mean (95%CI)			ICC ^(2,1) mean (95%CI)	TE (raw) (LL/UL)			TE (raw) mean (LL/UL)	
	Sn. 1	Sn. 2	Sn. 3			2-1	3-1	3-2		2-1	3-1	3-2		
PL (AU)	VX T2	139.5* (16.8)	136.9* (18.0)	143.9* (18.2)	.08	.48	0.80 (0.47-0.93)	0.46 (-0.08-0.79)	0.76 (0.40-0.92)	0.67 (0.41.0.87)	8.7 (6.4-14.4)	13.4 (9.8-22.1)	9.7 (7.2-16.0)	10.8 (8.7-14.6)
	BT T2	159.0† (30.3)	156.7† (29.4)	165.6† (31.7)	.12	.31	0.92 (0.76-0.97)	0.80 (0.49-0.93)	0.86 (0.61-0.95)	0.86 (0.71-0.95)	9.9 (7.2-16.2)	15.3 (11.1-25.2)	13.0 (9.5-21.4)	12.9 (10.4-17.4)
	BT A	623.0 (87.8)	643.2 (70.8)	642.2 (108.4)	.10	.37	0.61 (0.13-0.86)	0.65 (0.20.0.88)	0.56 (0.05-0.84)	0.64 (0.37.0.85)	53.4 (38.9-87.8)	50.2 (36.7-82.7)	49.5 (36.1-81.4)	51.1 (41.0-68.8)

PL = player load; VX T2 = VX Sports 2nd thoracic vertebrae; BT T2 = Blue Trident 2nd thoracic vertebrae; BT A = Blue Trident ankle; Sn = session; SD = standard deviation; CI = confidence interval; ES = effect size; ICC = intraclass correlation coefficient; TE (raw) = typical error; LL = lower limit; UL = upper limit. * < 0.05 vs. BT T2; † < 0.05 vs. BT A.

Discussion

The aims of this study were to assess the reliability and validity VX Sport IMU compared to the Blue Trident IMU for AL analysis in youth athletes during a multi-direction movement circuit and to compare the difference between attachment locations (2nd thoracic vertebrae and ankle). This study demonstrated that the use of the VX Sports IMUs showed moderate reliability whereas the Blue Trident IMU showed good reliability for the 2nd thoracic vertebrae position and moderate reliability for the ankle position during a movement circuit. Differences were found between the two types IMU devices at the 2nd thoracic vertebrae for AL. Additionally, the AL was calculated to be greater at the ankle compared to the 2nd thoracic vertebrae.

The Blue Trident IMU had a higher reliability across the sessions compared to the VX Sport IMU and this may have occurred due to the accelerometer in the Blue Trident IMU having a higher sampling rate than those in the VX Sport IMU. Location of the IMU was also an important factor. When the IMU is positioned on T2 or using the VX Sport bib, the PlayerLoad™ resulted in a reduce AL value compared to the ankle. Given the dramatically increased movement of the ankle compared to the upper segment of the thorax during sprinting, lateral running and vertical jumping, IMU placement at the ankle should only be used to assess discrete movements of the lower limb (Horsley et al., 2021). It is recommended that placement on T2 should occur when assessing PlayerLoad™, as this gross measure assesses the centre of mass change over the duration of training or competition (Camomilla, Bergamini, Fantozzi, & Vannozzi, 2018). Interpreting the results of workload in training or competition requires practitioners to consider the measurement errors on all devices. Total AL results should be taken with further caution, as the measurement error will increase in conjunction with the session duration. Nonetheless, VX player load/min can still be used for sporting teams who need a more cost-effective method than using Blue Trident IMUs. Regardless of the device used, it is vital to focus on the changes in AL over time.

A limitation of this study is the PlayerLoad™ formula is limited despite being a reliable formula for capturing general information regarding an athlete's workload (Barrett et al., 2014), as movements in different planes of motion have varying changes in centre of mass (i.e., 1 x vertical jump compared to 1 x change of direction); the PlayerLoad™ formula does not account for these differences. Where possible, more advance analysis such as the number of rapid changes of direction, total jumps, total high impacts, and total contacts may provide practitioners with applicable data regarding AL.

Conclusion

The VX Sport IMU was found to have a moderate reliability for assessing PlayerLoad in youth athletes. However, the VX Sport IMU was not valid against the Blue Trident IMU at the same location for assessing multi-directional movement accelerations within youth athletes. The Blue Trident IMUs had better reliability between sessions however, this study demonstrated that the location of the IMU can affect the PlayerLoad outcome. Any device's potential sources of error should be considered, especially when undertaking cross-sectional and longitudinal analysis of the same athlete. It is recommended that practitioners use the equipment involved in this study on a comparable population when undertaking reliability measurements on participant groups to ensure they are aware of the magnitude and potential sources of errors.

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