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The reliability of a commonly used (Catapult™ Vector S7) microtechnology unit to detect movement characteristics used in court-based sports

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ABSTRACT

This two-part study evaluated the inter- and intra-unit reliability of Catapult Vector S7 microtechnology units in an indoor court-sport setting. In part-one, 27 female netball players completed a controlled movement series on two separate occasions to assess the inter- and intra-unit reliability of inertial movement analysis (IMA) variables (acceleration, deceleration, changes of direction and jumps). In part-two, 13 female netball players participated in 10 netball training sessions to assess the inter-unit reliability of IMA and PlayerLoad™ variables. Participants wore two microtechnology units placed side-by-side. Reliability was assessed using intraclass correlation coefficient (ICC), coefficient of variation (CV) and typical error (TE). Total IMA events showed *good* inter-unit reliability during the movement series (ICC, 1.00; CV, 3.7%) and training sessions (ICC, 0.99; CV, 4.5%). Inter-unit (ICC, 0.97; CV, 4.7%) and intra-unit (ICC, 0.97; CV, 4.3%) reliability for total IMA jump count was *good* in the movement series, with moderate CV (7.7%) during training. Reliability decreased when IMA counts were categorised by intensity and movement type. PlayerLoad™ (ICC, 1.00; CV, 1.5%) and associated variables revealed *good* inter-reliability, except peak PlayerLoad™ (*moderate*) and $\text{PlayerLoad}_{\text{SLOW}}$ (*moderate*). Counts of IMA variables, when considered as total and low-medium counts, and PlayerLoad variables are reliable for monitoring indoor court-sports players.

KEYWORDS
Reliability; team court-sport; microtechnology; Catapult Vector S7; inertial movement analysis; inertial measurement units

Introduction

Quantifying the movement characteristics of team sport training and match-play is common practice to support athlete monitoring, physical preparation, and injury prevention (Bourdon et al., 2017; Torres-Ronda et al., 2022). Global navigation satellite systems (GNSSs) are widely used to quantify movement characteristics; however, GNSS signals are inaccessible for indoor sports (e.g., netball and basketball) (Duffield et al., 2010). Local Positioning Systems (LPS) can be used indoors but are not widely accessible due to the cost and inability to utilise across multiple environments (Clemente et al., 2021; Mackay et al., 2023). The use of inertial measurement units (IMUs), housed within microtechnology units, provides an alternative method for quantifying movement characteristics. An IMU is comprised of tri-axial accelerometers, gyroscopes and magnetometers (Chambers et al., 2015), and uses software-specific algorithms to detect the frequency and magnitude of specific movement events (e.g., accelerations) and provide 'workload' variables (e.g., PlayerLoad™, a Catapult Sports specific metric) (Luteberget et al., 2018). In court-based sports, players perform repeated short movements (e.g., sudden decelerations), which generate high braking ground reaction forces and impose high mechanical demand (McBurnie et al., 2022). To facilitate optimal athlete preparation and reduce injury risk, it is important for practitioners to be able to reliably monitor the exposure of these movements in indoor settings (Harper & Kiely, 2018). However, research surrounding the reliability of IMUs to quantify movement characteristics (i.e., 'workload' variables [e.g., PlayerLoad™] and movement events [e.g., accelerations]) is limited in court-based sports and is contingent upon the model, manufacturer, movements and variables used (Crang et al., 2021).

Inter-unit reliability is necessary for comparing metrics between units (e.g., to compare data between players from the same training session) (Crang et al., 2022). Accelerometer derived PlayerLoad™ has demonstrated acceptable inter-unit reliability in Australian football matches (Boyd et al., 2011) and handball training sessions (Luteberget et al., 2018) utilising early microtechnology unit models. Specifically, Luteberget et al. (2018) reported Catapult OptimEye S5 units to have a coefficient of variation (CV) of 0.9% and 1.8% for PlayerLoad™ and total inertial movement analysis (IMA) counts (i.e., accelerations, decelerations and changes of direction [COD] combined), respectively. However, when the total IMA count was categorised into the manufacturer's intensity bands (i.e., 'low' [1.5–2.5 m·s^{-1}], 'medium' [2.5–3.5 m·s^{-1}], and 'high'

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[>3.5 m·s^{-1}]), CV increased up to 5.3%. When further categorised into individual movement types and intensity bands, CV increased again, ranging from 4.6% to 21.5%. Boyd et al. (2011) reported PlayerLoad™ to have a CV of 1.9% for Catapult MinimaxX units during Australian football matches, slightly higher than the CV they found during static (1.1%) and dynamic (1.0%) laboratory testing. Both studies utilised applied sports settings (i.e., training sessions or matches) to assess the inter-unit reliability, encapsulating the chaotic nature of team sport, but did not use the more recently developed and widely adopted Catapult Vector S7 units. The inter-unit reliability of Catapult Vector S7 units for acceleration and deceleration counts has been established but was derived from GNSS only (Crang et al., 2022). Therefore, further research to establish the inter-unit reliability of Catapult Vector S7 IMU derived metrics in indoor sports is needed.

Intra-unit reliability is required for comparing metrics recorded by the same unit over time (e.g., to ensure changes in metrics recorded by a player are due to actual differences between training sessions, and not within-unit variability) (Crang et al., 2021). Previous intra-unit reliability research has been completed in controlled laboratory conditions only. Nicolella et al. (2018) reported that most Catapult OptimEye S5 units showed good (Scott et al., 2016) intra-unit reliability for mean peak accelerations (CV = 0.02–5.00%) and PlayerLoad™ (CV = 0.02–5.2%) when assessed across the three planes of motion. However, the intra-unit reliability of the Catapult Vector S7 IMU derived metrics (i.e., IMA variables [accelerations, decelerations, COD and jumps] and PlayerLoad variables) is yet to be investigated in a team-sport setting.

Therefore, this two-part court-based team sport study aimed to evaluate the reliability of Catapult Vector S7 microtechnology units. Part-one aimed to investigate the inter- and intra-unit reliability of IMA variables (i.e., acceleration, deceleration, COD, and jumps) during a controlled movement series. Part-two aimed to establish the inter-unit reliability of IMA and PlayerLoad™ variables during netball training sessions.

Methods

Study design

This two-part study evaluated the inter- and intra-unit reliability of Catapult Vector S7 microtechnology units (Catapult Sports, Melbourne, Australia) in an indoor court-based setting. Netball is a court-based team sport that requires players to perform repeated and frequent short movements (e.g., sudden decelerations and jumps) (Mackay et al., 2024) therefore has been used as an example of an indoor court-based sport in this study. Part-one assessed the inter-unit (i.e., between-unit) and intra-unit (i.e., within-unit) reliability of IMA variables in a controlled movement series. Part-two determined the inter-unit reliability of IMA and PlayerLoad™ variables in netball training sessions. Throughout this paper, the following terminology will be used: 'IMA variables' refers to IMA derived accelerations, decelerations, COD and jumps collectively; 'IMA events' includes IMA accelerations, decelerations, and COD only; and 'IMA jumps' refers to IMA jumps only. The IMA events and IMA jumps are separated due to the different algorithms used for detection. The study was approved by the university ethics committee (118648) and written informed consent was obtained from all participants prior to commencement of the study.

Methodology

Microtechnology units

Catapult Vector S7 microtechnology units, housed with a 100 hz accelerometer, gyroscope and magnetometer, were used for the study. Participants wore two units in a custom-made manufacturer-supplied vest (Catapult Sports, Melbourne, Australia) to determine inter-unit reliability (Figure 1). The units were placed side-by-side in the centre of the participants' back, between the scapulae, as recommended by the manufacturer. The position of the units (left or right) was switched between sessions. Each participant used the same two units throughout the data collection.

Part 1: The inter- and intra-unit reliability of Catapult Vector S7 microtechnology units during a controlled movement series

The inter- and intra-unit reliability of the IMA variables were analysed in a controlled movement series. Twenty-seven female netballers were recruited to participate from the senior ($n = 13$) and under-21 ($n = 14$) squads of one elite netball franchise.

The controlled movement series comprised nine sport-specific movement tasks (modified from Luteberget et al.

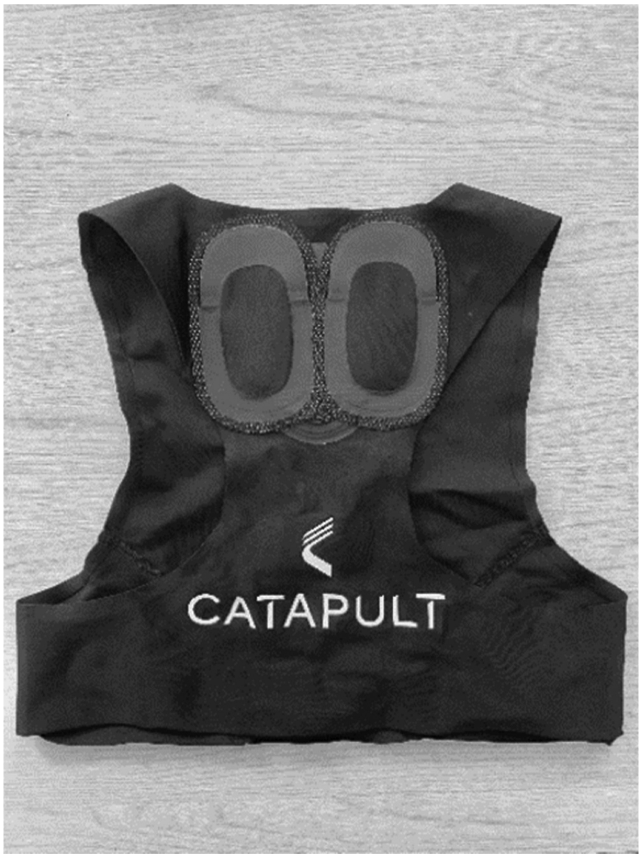

Figure 1. Image of custom-made manufacturer-supplied vest worn.

Table 1. Controlled movement series (Part 1) movement task protocol.

Task Number	Task	Description
Warm-up		5-minutes jogging followed by dynamic stretching and netball specific movements (e.g. accelerations, decelerations, COD, jumps) following the 'RAMP' framework (Jeffreys (2006)).
1	Start/Stop	2 metre (m) forward movement at submaximal effort, with a sudden increase in pace leading into a 2 m sprint. Come to a sudden, complete stop. Facing forwards throughout.
2	Acceleration & 180° turn	2.5 m forward movement with a sharp 180° turn followed by a 2.5 m forward movement, turning the body to the direction of travel. Gradual decline in pace to finish. Always facing direction of travel.
3	90° COD (Left)	2 m forward movement with a sharp 90° COD left, coming to a sudden stop. Always facing direction of travel.
4	90° COD (Right)	2 m forward movement with a sharp 90° COD right, coming to a sudden stop. Always facing direction of travel.
5	Repeated travelling COD	'Zig-zag' COD movement patterns progressively through cones spaced 1.5 m apart. The body should turn with the direction of travel, planting the outside foot at each of the 4 markers to sharply change direction (2 each side). Gradual decrease in pace to finish.
6	Progressive forwards/ backwards running	3 m forward movement followed by 2 m backwards running. Repeated 5 times, progressively travelling forwards, and finishing with a 3 m forward movement gradually decreasing pace to finish. Facing forwards throughout.
7	Multidirectional COD	Starting in the middle of the outlined square, completing 8 'out and back' COD movements from the centre to the outside and back to the middle (around the 'clock'). Facing forwards throughout the task.
8	Vertical jump	Complete 3 countermovement jumps, with self-selected recovery between each jump.
9	Horizontal jump	Complete 3 broad jumps, with self-selected recovery between each jump.

Abbreviations: COD, change of direction.

(2018)), completed on an indoor wooden sprung court surface. The protocol is described in Table 1 and shown in Figure 2. Vertical and horizontal jumps (tasks 8 and 9) were added to the protocol as they are common movements completed in court-sports (e.g., basketball (Ferioli et al., 2020), netball (Mackay et al., 2024), volleyball (Skazalski et al., 2018)).

Participants completed the movement series on two separate occasions (7 days apart), with the same protocol completed on both days. Each participant completed the series four times (Luteberget et al., 2018), with three-minutes recovery between trials and 1-minute recovery between tasks. Participants were familiarised to each movement task on day 1 and instructed to complete each task with maximal effort.

Part 2: The inter-unit reliability of Catapult Vector S7 microtechnology units during netball training sessions

The inter-unit reliability of IMA and PlayerLoad™ variables was assessed across 10 netball training sessions. Thirteen female netball players from the senior squad in one elite netball franchise participated (mean ± SD players per session; 8.7 ± 1.6 [range: 5–11]). All sessions were completed on an indoor court surface and planned by the coach; therefore, the content, intensity and duration of the sessions varied as per a normal training session schedule.

Data processing

PlayerLoad™, its associated variables (PlayerLoad$_{FWD}$, PlayerLoad$_{SIDE}$, PlayerLoad$_{UP}$, PlayerLoad$_{2D}$, PlayerLoad$_{SLOW}$, Peak PlayerLoad, High PlayerLoad, PlayerLoad™ per minute and PlayerLoad maximum intensity intervals [MII]) and IMA variables (accelerations, decelerations, COD and jumps) were extracted from the accompanying propriety software (Openfield v3.4.0, Catapult Sports, Melbourne, Australia). These variables were investigated given their use in the literature and practice (Luteberget et al., 2018; Roe et al., 2016; Torres-Ronda et al., 2022; Whitehead et al., 2018). Further

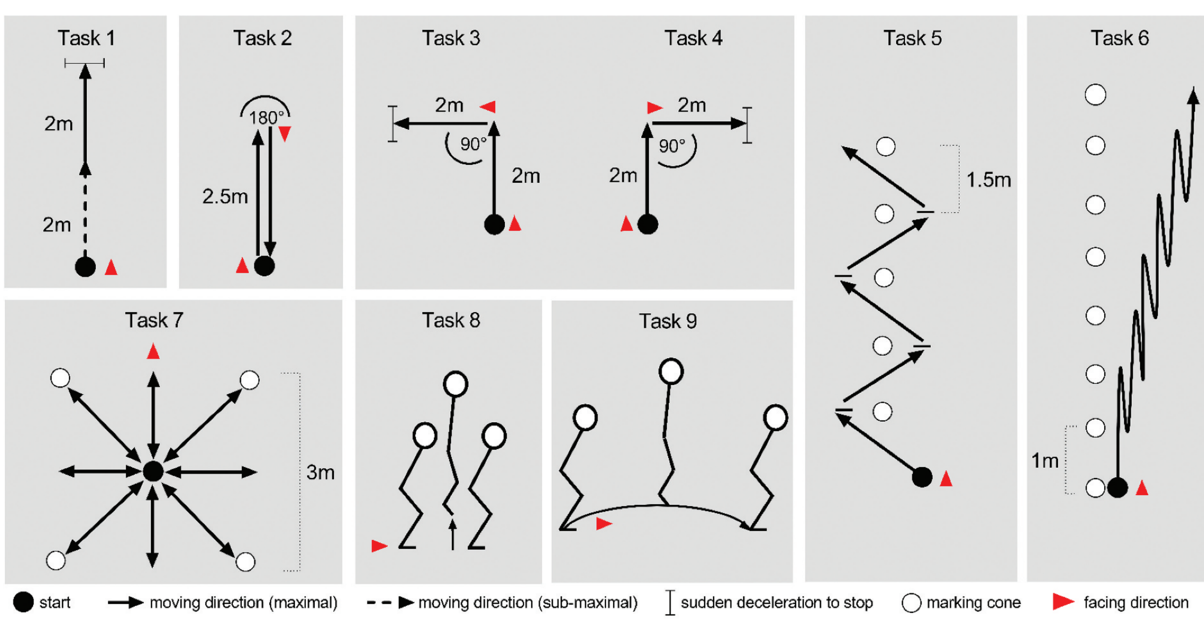

Figure 2. Illustration of tasks 1–9 completed in the controlled movement series (Part 1).

details on the IMU variables and algorithms used are provided as supplementary material (Supplementary document 1) and have been reported previously (Luteberget et al., 2018).

Part 1: The inter- and intra-unit reliability of Catapult Vector S7 microtechnology units during a controlled movement series

Two researchers, with >7 years' experience working with netball athletes, independently assessed the movement quality of each participant across each task using the inclusion criteria (Supplementary Table S1). Tasks that did not reach agreement were reviewed by a third researcher and tasks that did not meet the inclusion criteria were excluded from all analyses. In total, 465 tasks (38.1% of the total dataset) were excluded after this process.

Microtechnology data were downloaded, and the raw accelerometer trace was aligned with the video footage using the OpenField software. Each task that reached the inclusion criteria was individually segmented using the software. The aligned footage was used to ensure only the task duration was included in analysis (e.g., no additional non-prescribed movements performed prior to, or after completion of, the task were included). All IMA jumps and IMA events ≥1.5 m·s^{-1}, Catapult's standard threshold, were included (Luteberget et al., 2018).

Part 2: The inter-unit reliability of Catapult Vector S7 microtechnology units during netball training sessions

Microtechnology data were downloaded (all IMA jumps and IMA events ≥1.5 m·s^{-1}) using the Openfield software. For each training session, one period was created for the whole duration using the known start and end times. Therefore, the analysis was comprehensive of the entire session duration including rest periods.

Data analysis

Part 1: The inter- and intra-unit reliability of Catapult Vector S7 microtechnology units during a controlled movement series

The mean ± standard deviation (SD) for each IMA variable, within each intensity band, was calculated for both microtechnology units (inter-unit reliability) and for both trial days (intra-unit reliability). Acceleration, deceleration and COD values were also combined to give a total IMA event metric (acc-dec-COD) based on previous reliability findings (Luteberget et al., 2018). Inter- and intra-unit reliability was established using the intraclass correlation coefficient (ICC), typical error (TE) and coefficient of variation (CV). The ICC was used to evaluate the consistency between the measurements. The TE expressed the difference between the measurements in absolute terms using the SD of the difference between measurements, while CV assessed this difference in percentage terms (Weir, 2005). Uncertainty was presented as 95% confidence interval (CI) for ICC, TE, and CV. All reliability calculations were completed using Hopkins' reliability spreadsheet (Hopkins, 2017). The ICC was rated as *excellent* (>0.9), *good* (0.75–0.9), *moderate* (0.5–0.75) and *poor* (<0.50) (Koo & Li, 2016). The magnitudes of the CVs used were *good* (<5%), *moderate* (5–10%) and *poor* (>10%) (Scott et al., 2016).

Part 2: The inter-unit reliability of Catapult Vector S7 microtechnology units during netball training sessions

The mean ± SD for absolute, relative, and MII PlayerLoad™ variables, as well as each IMA variable, within each intensity band from the two microtechnology units were calculated. Inter-unit reliability was determined as in part 1.

Results

Part 1: The inter- and intra-unit reliability of Catapult Vector S7 microtechnology units during a controlled movement series

Inter- and intra-unit reliability of IMA variables are presented in Tables 2 and 3, respectively. The ICC for total IMA event counts between units (inter-unit reliability) was *excellent*, ranging from 0.97 (accelerations, decelerations, jumps) to 1.00 (COD, acc-dec-COD). *Good* CV was established for total (CV; 3.7 [3.1–4.7], TE; 2.0 [1.7–2.6]) and low-medium intensity (CV, 4.1 [3.3–5.3]; TE, 2.3 [1.9–3.1]) acc-dec-COD counts, and the total jump count (CV, 4.7 [3.8–6.2]; TE, 1.1 [0.9–1.5]), with *moderate* CV for total decelerations (CV, 8.4 [6.8–11.1]; TE, 1.7 [1.4–2.2]) and total COD (CV, 8.5 [6.9–11.3]; TE, 1.5 [1.2–2.0]). However, the CV increased for all IMA variables when segmented into individual intensity bands (low, medium, and high).

Within the individual unit (intra-unit reliability), the ICC ranged from *excellent* (COD, 1.00 [0.99–1.00]) to *moderate* (accelerations, 0.61 [0.17–0.84]). The CV of jumps was *good* (CV, 4.3 [3.2–6.7]; TE, 1.1 [0.8–1.8]); however, the CV of all other IMA variables was *poor* (Table 3).

Part 2: The inter-unit reliability of Catapult Vector S7 microtechnology units during netball training sessions

The inter-unit reliability of PlayerLoad™ variables and IMA variables during netball training sessions are displayed in Tables 4 and 5, respectively. The inter-unit reliability of PlayerLoad™ within each band is provided in Supplementary Table S2. The ICC between units was *excellent* for all PlayerLoad™ variables, except peak PlayerLoad™ (0.78 [0.69–-0.85]; *good*), with the CV ranging from *good* (CV < 5%) to *moderate* (CV = 5–10%) across all PlayerLoad variables.

All the IMA event counts had excellent ICC (0.91 [0.87–0.94] to 0.99 [0.98–0.99]) when considering the total count. However, the total accelerations (CV, 14.6 [12.6–17.4]; TE, 10.1 [8.7–11.8]) and decelerations (CV, 12.6 [10.9–15.0]; TE, 10.5 [9.1–12.3]) showed *poor* CV but when combined with COD (COD: CV, 5.3 [4.6–6.3]; TE, 19.0 [16.6–22.4]) the CV of acc-dec-COD was *good* (CV, 4.5 [3.9–5.3]; TE, 22.3 [19.4–26.2]).

Discussion

This study aimed to assess the inter- and intra-unit reliability of IMA and PlayerLoad™ variables from Catapult Vector S7 microtechnology units in a court-based team sport. In the controlled movement series, the inter- and intra-unit reliability of IMA

Table 2. Inter-unit (between-unit) reliability for IMA variables, within each intensity band, during controlled movement series (Part 1) (*n* = 36).

IMU Variable (count)	Unit 1 Mean ± SD	Unit 2 Mean ± SD	ICC (95% CI)	ICC qualitative interpretation	TE (95% CI)	CV % (95% CI)	CV % qualitative interpretation
IMA Acceleration							
Low	11.9 ± 6.8	11.5 ± 6.1	0.92 (0.84–0.96)	*Excellent*	1.9 (1.6–2.5)	21.4 (17.0–28.7)	*Poor*
Medium	5.3 ± 5.5	5.2 ± 5.9	0.95 (0.89–0.97)	*Excellent*	1.4 (1.1–1.8)	47.0 (36.7–65.3)	*Poor*
High	1.4 ± 0.9	1.4 ± 0.8	0.79 (0.62–0.88)	*Good*	0.4 (0.3–0.5)	26.8 (21.2–36.3)	*Poor*
Low-Medium	15.8 ± 8.8	16.2 ± 9.7	0.96 (0.92–0.98)	*Excellent*	1.9 (1.6–2.5)	13.4 (10.7–17.8)	*Poor*
Medium-High	5.7 ± 5.9	5.6 ± 6.4	0.94 (0.89–0.97)	*Excellent*	1.5 (1.2–2.0)	50.3 (39.2–70.1)	*Poor*
Total	13.8 ± 9.1	13.8 ± 8.8	0.97 (0.94–0.99)	*Excellent*	1.56 (1.3–2.0)	16.3 (13.3–22.5)	*Poor*
IMA Deceleration							
Low	11.6 ± 5.1	12.3 ± 5.5	0.88 (0.77–0.94)	*Good*	1.9 (1.6–2.5)	20.6 (16.4–27.6)	*Poor*
Medium	12.3 ± 5.5	12.1 ± 5.6	0.88 (0.77–0.94)	*Good*	2.0 (1.6–2.6)	21.2 (16.9–28.5)	*Poor*
High	2.9 ± 2.4	2.4 ± 1.9	0.76 (0.58–0.87)	*Good*	1.1 (0.9–1.4)	39.6 (31.0–54.5)	*Poor*
Low-Medium	22.9 ± 8.7	23.4 ± 8.8	0.95 (0.91–0.99)	*Excellent*	2.0 (1.6–2.6)	9.9 (7.9–13.0)	*Moderate*
Medium-High	14.3 ± 6.5	13.6 ± 6.8	0.92 (0.85–0.96)	*Excellent*	1.9 (1.6–2.5)	20.0 (16.0–26.9)	*Poor*
Total	21.6 ± 9.6	21.9 ± 9.4	0.97 (0.94–0.98)	*Excellent*	1.7 (1.4–2.2)	8.4 (6.8–11.1)	*Moderate*
IMA COD							
Low	18.5 ± 15.0	18.5 ± 14.8	0.97 (0.93–0.98)	*Excellent*	2.8 (2.3–3.7)	23.1 (18.3–31.1)	*Poor*
Medium	17.9 ± 14.5	18.3 ± 14.4	0.97 (0.94–0.98)	*Excellent*	2.6 (2.1–3.4)	26.1 (20.7–35.3)	*Poor*
High	3.4 ± 3.3	3.3 ± 2.9	0.91 (0.84–0.96)	*Excellent*	0.9 (0.8–1.2)	27.0 (21.4–36.6)	*Poor*
Low-Medium	35.4 ± 24.9	35.8 ± 26.1	1.00 (0.99–1.00)	*Excellent*	1.8 (1.5–2.4)	9.8 (7.9–13.0)	*Moderate*
Medium-High	20.3 ± 16.6	20.6 ± 16.0	0.97 (0.95–0.99)	*Excellent*	2.7 (2.2–3.5)	22.9 (14.6–26.3)	*Poor*
Total	32.1 ± 26.1	31.6 ± 24.7	1.00 (0.99–1.00)	*Excellent*	1.5 (1.2–2.0)	8.5 (6.9–11.3)	*Moderate*
IMA Acc-Dec-COD							
Low	39.6 ± 19.4	40.7 ± 20.2	0.97 (0.94–0.98)	*Excellent*	3.6 (2.9–4.7)	10.6 (8.5–14.0)	*Poor*
Medium	33.4 ± 19.9	33.6 ± 19.4	0.97 (0.95–0.99)	*Excellent*	3.4 (2.7–4.4)	13.0 (10.5–17.3)	*Poor*
High	5.8 ± 5.0	5.1 ± 4.4	0.93 (0.86–0.96)	*Excellent*	1.3 (1.1–1.7)	40.8 (31.9–56.2)	*Poor*
Low-Medium	72.1 ± 32.7	73.3 ± 33.9	1.00 (0.99–1.00)	*Excellent*	2.3 (1.9–3.1)	4.1 (3.3–5.3)	*Good*
Medium-High	38.2 ± 23.4	37.7 ± 22.8	0.98 (0.96–0.99)	*Excellent*	3.6 (2.9–4.7)	11.4 (9.1–15.1)	*Poor*
Total	65.5 ± 34.8	65.3 ± 33.5	1.00 (0.99–1.00)	*Excellent*	2.0 (1.7–2.6)	3.7 (3.1–4.7)	*Good*
IMA Jumps							
Low	6.9 ± 5.6	7.2 ± 6.1	0.96 (0.92–0.98)	*Excellent*	1.3 (1.0–1.7)	32.5 (25.6–44.3)	*Poor*
Medium	11.8 ± 5.1	12.1 ± 5.1	0.91 (0.83–0.95)	*Excellent*	1.6 (1.3–2.0)	24.9 (19.8–33.6)	*Poor*
High	7.8 ± 4.5	7.9 ± 4.5	0.86 (0.75–0.93)	*Good*	1.7 (1.4–2.2)	35.6 (28.0–48.8)	*Poor*
Low-Medium	17.9 ± 6.6	18.0 ± 6.9	0.93 (0.87–0.96)	*Excellent*	1.8 (1.5–2.4)	12.8 (10.3–17.0)	*Poor*
Medium-High	19.0 ± 4.4	18.6 ± 4.1	0.82 (0.68–0.91)	*Good*	1.8 (1.5–2.4)	10.3 (8.6–13.6)	*Poor*
Total	24.8 ± 6.3	24.9 ± 6.2	0.97 (0.94–0.98)	*Excellent*	1.1 (0.9–1.5)	4.7 (3.8–6.2)	*Good*

Abbreviations: Acc-Dec-COD; Sum of Accelerations + Decelerations + Change of Directions; ICC, intraclass correlation coefficient; CI, confidence interval; CV, coefficient variation; TE, Typical Error.

Table 3. Intra-unit (within-unit) reliability for IMA variables during controlled movement series (Part 1) ($n = 16$).

IMA Variable (count)	Trial 1 Mean ± SD	Trial 2 Mean ± SD	ICC (95% CI)	ICC qualitative interpretation	TE (95% CI)	CV % (95% CI)	CV % qualitative interpretation
Session Totals (n = 16)							
Acceleration	7.9 ± 3.2	8.6 ± 4.5	0.61 (0.17–0.84)	*Moderate*	2.5 (1.9–3.9)	42.3 (29.8–72.7)	*Poor*
Deceleration	17.3 ± 5.2	15.1 ± 4.8	0.79 (0.49–0.92)	*Good*	2.5 (1.8–3.8)	16.0 (11.6–25.8)	*Poor*
COD	21.8 ± 27.7	20.9 ± 25.5	1.00 (0.99–1.00)	*Excellent*	1.8 (1.3–2.7)	15.3 (11.1–24.7)	*Poor*
Acc-Dec-COD	44.9 ± 30.3	42.6 ± 32.7	0.99 (0.97–1.00)	*Excellent*	3.5 (2.6–5.4)	13.2 (9.6–21.1)	*Poor*
Jumps	19.9 ± 6.3	20.1 ± 6.5	0.97 (0.92–0.99)	*Excellent*	1.1 (0.8–1.8)	4.3 (3.2–6.7)	*Good*

Abbreviations: Acc-Dec-COD; Sum of accelerations + decelerations + change of Directions; COD, change of direction; ICC, intraclass correlation coefficient; CI, confidence interval; CV, coefficient variation; TE, Typical Error.

Table 4. Inter-unit (between-unit) reliability for PlayerLoad™ variables during netball training sessions (Part 2) ($n = 86$).

Variable (AU)	Unit 1 Mean ± SD	Unit 2 Mean ± SD	ICC (95% CI)	ICC qualitative interpretation	TE (95% CI)	CV % (95% CI)	CV % qualitative interpretation
Absolute Variables							
PlayerLoad™	513.0 ± 164.2	511.6 ± 162.4	1.00 (1.00–1.00)	*Excellent*	8.6 (7.5–10.1)	1.5 (1.3–1.8)	*Good*
$\text{PlayerLoad}_{\text{FWD}}$	211.8 ± 70.3	212.4 ± 69.5	0.99 (0.98–0.99)	*Excellent*	8.5 (7.4–10.0)	3.7 (3.2–4.3)	*Good*
$\text{PlayerLoad}_{\text{sideways}}$	209.0 ± 65.2	207.7 ± 64.1	1.00 (0.99–1.00)	*Excellent*	4.0 (3.4–4.6)	1.8 (1.6–2.1)	*Good*
$\text{PlayerLoad}_{\text{UP}}$	338.0 ± 109.8	336.7 ± 108.7	1.00 (1.00–1.00)	*Excellent*	5.9 (5.1–6.9)	1.7 (1.5–2.0)	*Good*
$\text{PlayerLoad}_{\text{2D}}$	331.3 ± 105.6	330.8 ± 104.3	1.00 (0.99–1.00)	*Excellent*	6.6 (5.8–7.8)	1.8 (1.6–2.1)	*Good*
$\text{PlayerLoad}_{\text{SLOW}}$	508.5 ± 161.8	497.1 ± 152.5	0.93 (0.89–0.95)	*Excellent*	42.1 (36.7–49.6)	7.4 (6.4–8.7)	*Moderate*
Peak PlayerLoad	3.4 ± 0.6	3.5 ± 0.6	0.78 (0.69–0.85)	*Good*	0.3 (0.3–0.3)	8.3 (7.2–9.8)	*Moderate*
High PlayerLoad	301.0 ± 131.3	299.1 ± 128.9	0.99 (0.99–0.99)	*Excellent*	11.6 (10.1–13.7)	4.1 (3.6–4.8)	*Good*
Relative Variables							
$\text{PlayerLoad.Min}^{-1}$	5.5 ± 1.2	5.5 ± 1.1	0.99 (0.99–1.00)	*Excellent*	0.1 (0.1–0.1)	1.5 (1.3–1.8)	*Good*
Maximum Intensity Interval Variables							
PlayerLoad 1-min MII	17.1 ± 3.1	17.0 ± 3.0	0.98 (0.97–0.99)	*Excellent*	0.5 (0.4–0.5)	2.5 (2.2–3.0)	*Good*
PlayerLoad 3-min MII	41.2 ± 9.1	40.9 ± 8.7	0.99 (0.98–0.99)	*Excellent*	1.0 (0.8–1.1)	2.0 (1.7–2.4)	*Good*
PlayerLoad 5-min MII	60.4 ± 15.0	60.1 ± 14.2	0.99 (0.99–0.99)	*Excellent*	1.4 (1.2–1.7)	2.0 (1.8–2.4)	*Good*

Abbreviations: AU, arbitrary units; CI, confidence interval; CV, Coefficient of variation; ICC, intraclass correlation coefficient; MMI, Maximum Intensity Interval; TE, Typical Error.

variables varied based on the movement event (i.e., acceleration, deceleration, COD or jump) and intensity band (i.e., low, medium or high). Total jumps and combined acc-dec-COD were found to be the most reliable, but reliability decreased when separated into individual IMA event counts (i.e., acceleration, deceleration or COD) or intensity bands. In netball training sessions, the combined acc-dec-COD variable demonstrated the best reliability alongside PlayerLoad™ and most of its associated variables.

Part 1: The inter- and intra-unit reliability of Catapult Vector S7 microtechnology units during a controlled movement series

The inter-unit (i.e., between-units) reliability observed in this study aligns with the findings reported for Catapult OptimEye S5 microtechnology units during a similar controlled movement circuit (Luteberget et al., 2018). The controlled movement series demonstrated *good* to *excellent* ICC for the count of all IMA variables, regardless of intensity band (Table 2). When presented as total values (e.g., total IMA acceleration count) or grouped into wider intensity bands (e.g., combined low-medium IMA deceleration counts) the ICC was *excellent*, whereas CVs ranged from *poor* to *good* with lower CVs observed when total count was considered. The excellent ICC indicates high consistency between the units in terms of measuring counts. However, when categorised into intensity bands the poor CV suggests there is a wide range of differences between measurements relative to the mean difference. Practitioners should therefore be wary when attempting to monitor IMA variables within intensity bands as any measured differences between players may be influenced by the *poor* between-unit CV.

Table 5. Inter-unit (between-unit) reliability for IMA variables, within each intensity band, during netball training sessions (Part 2) ($n = 86$).

IMA Variable (count)	Unit 1 Mean ± SD	Unit 2 Mean ± SD	ICC (95% CI)	ICC qualitative interpretation	TE (95% CI)	CV % (95% CI)	CV % qualitative interpretation
IMA Acceleration							
Low	55.4 ± 23.5	54.3 ± 24.2	0.90 (0.85–0.93)	*Excellent*	7.7 (6.7–9.1)	17.5 (15.1–20.9)	*Poor*
Medium	17.1 ± 8.0	17.5 ± 8.9	0.79 (0.70–0.86)	*Good*	3.9 (3.4–4.6)	32.1 (27.4–38.7)	*Poor*
High	10.8 ± 5.5	10.9 ± 5.6	0.69 (0.56–0.78)	*Moderate*	3.4 (2.7–3.7)	36.5 (31.0–44.3)	*Poor*
Low-Medium	71.5 ± 29.5	70.8 ± 31.5	0.91 (0.87–0.94)	*Excellent*	9.2 (8.0–10.8)	15.2 (13.1–18.2)	*Poor*
Medium-High	26.9 ± 11.6	27.4 ± 12.5	0.83 (0.75–0.89)	*Good*	5.0 (4.4–5.9)	24.8 (21.3–29.8)	*Poor*
Total	81.3 ± 32.3	80.9 ± 34.5	0.91 (0.87–0.94)	*Excellent*	10.1 (8.7–11.8)	14.6 (12.6–17.4)	*Poor*
IMA Deceleration							
Low	53.7 ± 22.9	56.0 ± 23.8	0.89 (0.83–0.93)	*Good*	7.9 (6.9–9.3)	14.8 (12.8–17.7)	*Poor*
Medium	15.7 ± 8.3	17.1 ± 11.7	0.71 (0.59–0.80)	*Moderate*	5.5 (4.8–6.5)	30.1 (25.6–36.4)	*Poor*
High	6.9 ± 3.8	6.8 ± 4.3	0.78 (0.68–0.85)	*Good*	2.0 (1.7–2.3)	29.8 (25.3–36.3)	*Poor*
Low-Medium	68.4 ± 30.1	72.1 ± 33.1	0.90 (0.85–0.93)	*Good*	10.0 (8.7–11.8)	13.4 (11.5–16.0)	*Poor*
Medium-High	21.6 ± 11.5	22.9 ± 15.0	0.79 (0.70–0.86)	*Good*	6.1 (5.3–7.2)	23.2 (19.9–27.9)	*Poor*
Total	74.3 ± 33.2	77.9 ± 36.2	0.91 (0.87–0.94)	*Excellent*	10.5 (9.1–12.3)	12.6 (10.9–15.0)	*Poor*
IMA Change of Direction							
Low	297.7 ± 120.1	301.9 ± 122.6	0.98 (0.97–0.99)	*Excellent*	17.1 (14.9–20.1)	5.7 (5.0–6.6)	*Moderate*
Medium	58.9 ± 29.6	58.7 ± 26.7	0.95 (0.92–0.96)	*Excellent*	6.7 (5.8–7.9)	12.7 (10.9–15.1)	*Poor*
High	15.8 ± 7.8	17.6 ± 8.6	0.73 (0.61–0.81)	*Moderate*	4.3 (3.8–5.1)	34.1 (29.1–41.2)	*Poor*
Low-Medium	355.5 ± 146.1	359.6 ± 145.1	0.99 (0.98–0.99)	*Excellent*	17.7 (15.4–20.9)	5.3 (4.6–6.2)	*Moderate*
Medium-High	73.7 ± 36.1	75.2 ± 33.1	0.94 (0.91–0.96)	*Excellent*	8.8 (7.6–10.3)	13.2 (11.4–15.8)	*Poor*
Total	370.4 ± 152.3	376.1 ± 151.1	0.98 (0.98–0.99)	*Excellent*	19.0 (16.6–22.4)	5.3 (4.6–6.3)	*Moderate*
IMA Acc-Dec-COD							
Low	404.8 ± 155.8	410.2 ± 159.3	0.99 (0.98–0.99)	*Excellent*	18.0 (15.6–21.2)	4.7 (4.1–5.6)	*Good*
Medium	89.7 ± 41.7	91.2 ± 42.6	0.95 (0.93–0.97)	*Excellent*	9.3 (8.1–11.0)	12.3 (10.6–14.6)	*Poor*
High	31.5 ± 14.1	33.3 ± 15.3	0.83 (0.75–0.89)	*Good*	6.1 (5.3–7.2)	24.1 (20.7–28.9)	*Poor*
Low-Medium	493.5 ± 194.3	500.5 ± 198.0	0.99 (0.98–0.99)	*Excellent*	20.6 (17.9–24.18)	4.6 (4.0–5.4)	*Good*
Medium-High	120.2 ± 54.2	123.5 ± 55.2	0.95 (0.93–0.97)	*Excellent*	12.2 (10.6–14.4)	11.9 (10.2–14.1)	*Poor*
Total	523.9 ± 206.2	532.8 ± 209.9	0.99 (0.98–0.99)	*Excellent*	22.3 (19.4–26.2)	4.5 (3.9–5.3)	*Good*
IMA Jumps							
Low	12.8 ± 7.4	13.4 ± 8.1	0.95 (0.92–0.97)	*Excellent*	1.8 (1.6–2.1)	16.2 (13.9–19.4)	*Poor*
Medium	19.8 ± 9.9	19.6 ± 9.9	0.99 (0.98–0.99)	*Excellent*	1.2 (1.0–1.4)	7.3 (6.3–8.6)	*Moderate*
High	1.7 ± 1.2	1.8 ± 1.4	0.90 (0.85–0.93)	*Good*	0.4 (0.4–0.5)	15.7 (12.3–21.7)	*Poor*
Low-Medium	31.5 ± 15.1	32.0 ± 15.3	0.99 (0.98–0.99)	*Excellent*	1.9 (1.6–2.2)	8.0 (6.9–9.5)	*Moderate*
Medium-High	20.5 ± 10.4	20.3 ± 10.5	0.99 (0.98–0.99)	*Excellent*	1.2 (1.0–1.4)	7.2 (6.2–8.5)	*Moderate*
Total	32.3 ± 15.5	32.7 ± 15.7	0.99 (0.98–0.99)	*Excellent*	1.8 (1.5–2.1)	7.7 (6.7–9.1)	*Moderate*

Abbreviations: CI; confidence interval; COD, change of direction; CV, Coefficient of variation; ICC, intraclass correlation coefficient; TE, Typical Error.

Combining accelerations, decelerations and CODs into a total IMA event metric (acc-dec-COD) resulted in *excellent* ICC between units for all intensity bands, and *good* CV when presented as a total count, in line with previous research (Luteberget et al., 2018) (Table 2). Total IMA jumps also revealed both *excellent* ICC and *good* CV with a TE of 1.1 (0.9–1.5). Therefore, in a controlled environment, Catapult Vector S7 microtechnology units are reliable in their detection of IMA acc-dec-COD and jump counts, specifically when displayed as total count (or low-medium intensity count for acc-dec-COD); however, the reliability decreases when defining each individual type of movement (i.e., acceleration, deceleration or COD separately) and/or intensity band (magnitude). Similar to the GNSS acceleration and deceleration threshold count findings reported by Crang et al. (2022), the *poor* CV values found for the individual intensity band counts are likely influenced by the dichotomising of the continuous variable (i.e., the magnitude of the IMA event) (Altman & Royston, 2006; Crang et al., 2022). That is, devices may record an IMA event at a similar magnitude (e.g., 3.4 and 3.6 $m{\cdot}s^{-1}$) but will get categorised into different groups (e.g., medium intensity band and high-intensity band). Using the total count of IMA variables eliminates this inherent issue, hence the reduction in CV values for total IMA variable counts. The variability is also impacted by the smaller count values within each intensity band compared to the total count. When movements are categorised, there are fewer counts per group (compared to total count), which increases the relative impact of any single count change on the CV (e.g., if the count is 5, a change of 1 represents a 20% difference, whereas if the count is 10, the same change represents only a 10% difference). In line with the recommendations for the use of GNSS-derived variables (Theodoropoulos et al., 2020), it would be recommended that athletes are assigned the same unit for all sessions, particularly if practitioners do choose to use intensity and type of IMA events. However, if using the total count of IMA acc-dec-COD and/or IMA jumps, units could be shared if necessary (e.g., if lacking provision or low battery).

Intra-unit (i.e., within-unit) reliability was *excellent* for total COD, acc-dec-COD and jumps, with jumps also presenting *good* CV (TE = 1.1 [0.8–1.8]) (Table 3). However, acceleration and deceleration reported *moderate* and *good* ICC, respectively, with *poor* CV. Similar to the inter-unit reliability findings, the intra-unit reliability is more limited when defining movement type (i.e., categorising IMA event counts into acceleration, deceleration, and COD separately). However, it should be noted that variation in the count of IMA variables within the unit (between trials) may be influenced by the intensity at which the athlete completed the movement. For example, if in trial one an acceleration was detected with a magnitude of 1.6 $m{\cdot}s^{-1}$, but in trial two the same microtechnology unit detected the acceleration at 1.4 $m{\cdot}s^{-1}$, this would cause a discrepancy in the total IMA acceleration count due to the manufacturers minimum threshold for detection being ≥1.5 $m{\cdot}s^{-1}$. Athletes were requested to complete all movements with maximum effort; however, it is recognised that differences in the exact intensity (magnitude) at which movements were completed would naturally vary between trials. Practitioners should consider combining acceleration, deceleration, and COD movements for a total IMA event count (acc-dec-COD) and utilise this in conjunction with total IMA jump count to ensure reliability when monitoring player movement characteristics across sessions.

Part 2: The inter-unit reliability of Catapult Vector S7 microtechnology units during netball training sessions

When measured in a sport-specific environment (i.e., training sessions), a similar trend to the controlled movement series was identified for inter-unit reliability and is in line with previous research on Catapult OptimEye S5 units (Luteberget et al., 2018). The inter-unit reliability was *excellent* when considering the total count for each IMA variable (Table 5), yet when divided into intensity bands, reliability decreased. The CV for total acceleration and deceleration counts was *poor* but improved when combined with COD, showing *good* reliability for total and low-medium intensity counts of acc-dec-COD. The ability to categorise each movement (i.e., acceleration, deceleration and COD) reliably would be valuable to practitioners. Decelerations in particular impose high mechanical demand (McBurnie et al., 2022) and occur more frequently than accelerations during intermittent multi-directional sports (Harper et al., 2019), including basketball (Vázquez-Guerrero et al., 2018). Therefore, reliable quantification of deceleration counts could be beneficial in informing training prescription and helping to reduce injury risk, however, would not yet be recommended based on current findings. The *moderate* to *poor* CVs identified for total IMA acceleration, deceleration and COD counts during the controlled movement series and training sessions could result from the temporal proximity of movements completed, causing count discrepancies between the units (e.g., detecting one movement with a large magnitude versus detecting two consecutive movements at lower magnitudes) (Luteberget et al., 2018). In court sports, where movements are performed in sequence (Sweeting et al., 2017) with frequent changes in movement activity (Taylor et al., 2017), this could present issues. As found in the controlled movement series, current results show caution is warranted when segregating IMA event counts into movement types (e.g., deceleration only) and/or intensity bands. Instead, the total count of IMA acc-dec-COD is a more reliable metric to use in practice. These recommendations are consistent with previous research using Catapult OptimEye S5 microtechnology units (Luteberget et al., 2018).

PlayerLoad™, during training sessions, was found to have an *excellent* inter-unit reliability and *good* CV. All PlayerLoad™ associated variables, except Peak PlayerLoad (ICC; *good*) resulted in *excellent* ICC and only Peak PlayerLoad and $\text{PlayerLoad}_{\text{SLOW}}$ presented a CV > 5.0% (Table 4). The low CV found for PlayerLoad™ and its variables align with previous research in Australian football matches (CV; 1.9% between-units [Catapult MinimaxX] (Boyd et al., 2011)), and handball training sessions (CV; 0.9% between-units [Catapult OptimEye S5] (Luteberget et al., 2018)). Therefore, similar to earlier models, PlayerLoad™ in an absolute, relative or MII (i.e., maximum intensity interval) form recorded by Catapult Vector S7 microtechnology units can confidently be used as a monitoring tool and detect differences in movement characteristics irrespective of the microtechnology unit used. Individual athlete comparisons however should be approached with caution given the large between-athlete variability in PlayerLoad™ (Barrett et al., 2014). This may stem from the individual movement style and/or the units' potential to move based upon the garment fit on different athletes (Malone et al., 2017).

Limitations and future research

Previous research exploring the inter-unit reliability of earlier Catapult microtechnology unit models has placed units on top of each other, with the unit positioned distally to the body recording larger PlayerLoad™ values (Boyd et al., 2011; Luteberget et al., 2018). In this study, units were worn side-by-side as suggested by the manufacturer for research purposes. However, this may have impacted the results as the non-central positioning of each unit could have influenced the type of movement the IMA event was classified as. Additionally, whilst match-play situations were embedded in the training sessions analysed, the inter-unit reliability specifically during competition match-play was not assessed in this study. It is suggested that microtechnology units be evaluated under the specific type and intensity of activity (Welk, 2005) and so future research should focus on evaluating the reliability of Catapult Vector S7 microtechnology units during match-play with the intended population. In addition to reliability, the validity of the Catapult Vector S7 microtechnology units in detecting IMA variables during indoor court-based sports is important. Accurate detection of movement events would assist practitioners in monitoring and preparing athletes for competition, yet the validity is currently unknown. Therefore, future research should investigate the accuracy of Catapult Vector S7 microtechnology units in detecting IMA variables.

In conclusion, this is the first study to evaluate the inter- and intra-unit reliability of Catapult Vector S7 microtechnology unit IMU derived variables in indoor court-based sports. The findings demonstrate that during training sessions of an indoor court-based sport, PlayerLoad™ and its associated variables are reliable metrics in quantifying movement characteristics. The total IMA event count (acc-dec-COD) is a reliable variable when presented as a total or combined low-medium intensity count, as is the total IMA jump count, particularly in a controlled setting. Increases in CV values were established when categorising IMA events into movement types (i.e., acceleration, deceleration, or COD separately) and intensity bands, and as a result, should be used with caution. The findings of this study can be applied to other similar indoor court-based sports and allow practitioners to understand which Catapult Vector S7 microtechnology unit variables can be used to reliably monitor athletes.

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