Short Communication

# Reliability and validity of GPS-embedded accelerometers for the measurement of badminton specific player load

Matthew J. Wylde, Marcus B.C. Lee, Low Chee Yong, Andrew J. Callaway

***Objectives***: The aim of this study was twofold, firstly to assess the reliability of the VX Sport Log GPS-based accelerometer, and secondly the validity of the same device compared to a Catapult Optieye S5 (considered a gold standard) recording at 100 Hz.
***Design & Methods***: A total of 15 participants were recruited to take part in two separate trials of a Badminton specific endurance test. Reliability and validity assessments were conducted using coefficients of variation, intra-class correlation coefficient, Bland-Altman plots per axis (Vertical, Antero-posterior and Medio-lateral) and for vector magnitude (player load).
***Results***: Reliability results demonstrate high levels of agreement between devices. Validity results also demonstrate high levels of agreement. However, there were issues with sample rate agreement between manufacturers of 0.25%.
***Conclusion***: This study re-emphasises the need for sports utilising GPS-based accelerometers to conduct reliability and validity studies to ensure the consistency between data collection systems.
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Key words: Accelerometers ■ Badminton ■ Reliability ■ Wearable Technology

## INTRODUCTION

Elite level badminton is characterised by periods of high intensity effort, interspersed with short rests[1] which requires both aerobic and anaerobic energy systems[2]. A review of Badminton research[3] highlighted that there have been numerous studies of the temporal structure of game play. However, there have been few attempts to quantify the movements of athletes during badminton match-play and/or training. One such study attempted to quantify the distance covered by Badminton players in match conditions by dividing the court into 0.5 metre segments.[4] Based on this method it was estimated that an elite male badminton player would cover 1.8km in a singles match and 1.1km in a doubles match under the old scoring system. Another attempt to quantify Badminton movement was used by Robinson and O'Donoghue.[5] In these examples, movement classification was conducted using video-based time-motion analysis, where matches are observed and athlete movement subjectively classified into one of a list of pre-defined categories. While video-based time-motion analysis is convenient, practical and inexpensive there are issues with the reliability of the data, especially if matches are being notated by different observers.[6] In addition, this method of movement analysis can be labour intensive[7] and time-consuming[8]. Due to the limitations of video-based time-motion analysis the use of global positing system (GPS) technology has become increasingly prevalent in a range of team sports.[9] However, the use of GPS technology has been predominantly limited to field-based team sports as the technology can only be used in an outdoor setting with sufficient satellite coverage.[10] A number of local position system (LPS) and semi-automated camera solutions are available but these are restrictive due to the additional hardware requirements[11] and the prohibitively high cost[12].

Many of the commercially available athlete tracking systems have inbuilt tri-axial accelerometer functionally which is used to supplement the GPS data towards calculating player load information. Tri-axial accelerometers offer a light, portable, inexpensive, easy to set up and rapid means evaluating of a large number of athletes[13]. Despite the widespread use of GPS-embedded accelerometers, there have been few published reliability studies of this technology. However, the accelerometers within the MinimaxX S4 units (Catapult Innovations, Melbourne, Australia) have been shown to be reliably for use with Australian Football[14] and the Optimeye S5 units (Catapult Innovations, Melbourne, Australia) have been shown to be reliable for tracking athlete loading in ice hockey[15].

While the validity of the GPS functionality of the VX Sport athlete tracking system has been assessed[16], there is currently no published studies assessing the reliability or validity of the tri-axial accelerometer functionality which is important if player load is to be calculated in future studies. Therefore, the purpose of this study is to assess the reliability and validity of the tri-axial accelerometers embedded within the VX Sport Log units to assess Badminton specific movements. Firstly, the reliability will be assessed between two VX Sport Log units. Secondly, the validity will be assessed between the VX Sport Log and Catapult Optimeye S5 units.

## METHODS

With institutional ethical approval, 15 participants were recruited for the data collection (age 26.7 ± 5.6 yr, height 167.5 ± 7.7 cm, mass 61.6 ± 4.7 kg). Each participant was a

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From the National Youth Sports Institute, Singapore (M.J.W., M.B.C.L., L.C.Y.) and Bournemouth University, Department of Sport and Physical Activity, Bournemouth, United Kingdom (M.J.W., A.J.C.)
Communicated by Takashi Abe, PhD
Correspondence to: Matthew Wylde, National Youth Sports Institute, 1 Champions Way, Singapore, 737913. Email: matthew_wylde@nysi.org.sg
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recreational Badminton player with a minimum of 5 years playing experience. Each participant was provided with a participant information sheet and was required to complete informed consent form. The testing was conducted over two separate days. On day one, 8 participants were tested wearing two VX Sport Log units (Visuallex Sport International, Lower Hutt, New Zealand) each placed between the scapulae in the manufacturer's purpose-built vest. On day two, 9 participants (including 2 who had taken part in the previous data collection) were tested wearing one VX Sport Log unit and one Catapult Optimeye S5 unit (Catapult Innovations, Melbourne, Australia) each placed between the scapulae in the manufacturer's purpose-built vest. For each test the accelerometers embedded within these units had a sampling frequency of 100 Hz.

Each participant was asked to perform a warm up of their choice prior to the commencement of the test. Immediately before starting the test the participants were instructed to perform three vertical jumps to aid with the synchronisation of the data.[17] The participants were instructed to perform the Badminton specific incremental test[3] in one half of a Badminton court. From a central point the participant started moving following a signal given as a computer generated beep. The participant moved 3 m forward at a 45 degree angle to a marker at the right side of the court, touched the top of the net with their badminton racket and moved immediately back to the central point. On the next signal the participant moved to a second marker at the left side of the court, touched the top of net with their racket and moved back to the central point. On the next signal the participant moved backwards to a third marker 3 m behind the central point, performed a simulated smash then returned to the central marker. Once the participant returned to the central point the procedure repeated and continued until voluntary exhaustion. Signals were given from a pacer with the velocity at the beginning of the test being 0.60 $ms^{-1}$, with six signals per minute. The velocity increased every minute by 0.10 $ms^{-1}$, with one additional signal per minute.

Upon completion of the test protocol the data was extracted using the accompanying software of the two systems. The raw data was filtered in Matlab (MathWorks, Natick, MA, USA) at 10 Hz using a 3rd order Butterworth filter. The filtered data was mean centred in Microsoft Excel (Redmond, WA, USA) and manually synchronised by aligning the three vertical jumps within the datasets.

Each axis has a contribution towards the calculation of player load which could be influenced with differences in max and minimum values, the reliability of individual axis is important to understand. The maximum positive and negative accelerations for each axis were used as the first point of comparison. In addition, the load of each separate axis was calculated using the Player Load calculation (vector magnitude) to identify any errors in a particular axis. This was calculated as the square root of the sum of activity counts squared.[14] The equation for the Vertical axis (Equation 1):

$$Load = \sqrt{\frac{(ay_1\, ay_{-1})^2}{100}}$$

**Equation 1**. Vertical load calculation (vector magnitude)

To assess the reliability and validity, coefficients of variation (CV%) and intra-class correlation coefficient (ICC) calculations were selected.[18] The following descriptors were used for the ICC: "Poor" < 0.40, "Fair" 0.40 - 0.59, "Good" 0.60 - 0.74, "Excellent" 0.75 - 1.00.[19]

## RESULTS

A high level of agreement between the two VX Sport Log units with 8 out of 9 CV% under 5% and "Excellent" ICC observed for all measures (Table 1).

An acceptable level of agreement was observed between the

**Table 1** Reliability between VX Sport Log units (N = 8)

| | | Max Acceleration ($m/s^2$) | Max Deceleration ($m/s^2$) | Vector Magnitude (AU) |
|---|---|---|---|---|
| Vertical | Unit 1 | 2.06 ± 0.25 | -1.48 ± 0.16 | 119.42 ± 29.13 |
| | Unit 2 | 2.12 ± 0.22 | -1.49 ± 0.18 | 123.03 ± 30.84 |
| | CV% | 1.5 | 1.6 | 1 |
| | ICC | 0.980 | 0.988 | 0.996 |
| Antero-posterior | Unit 1 | 1.12 ± 0.27 | -1.68 ± 0.24 | 81.26 ± 15.45 |
| | Unit 2 | 1.15 ± 0.31 | -1.66 ± 0.22 | 77.41 ± 14.14 |
| | CV% | 5.1 | 1.9 | 2.3 |
| | ICC | 0.980 | 0.961 | 0.979 |
| Medio-lateral | Unit 1 | 1.28 ± 0.26 | -1.22 ± 0.24 | 50.88 ± 6.85 |
| | Unit 2 | 1.33 ± 0.24 | -1.23 ± 0.22 | 54.03 ± 8.36 |
| | CV% | 3.2 | 3.5 | 2.3 |
| | ICC | 0.975 | 0.977 | 0.958 |

VX Sport Log and Catapult Optimeye units. For all comparison CV% below 10% were recorded and "Excellent" ICC values were recorded.

## DISCUSSION

Based on these results in can be determined that the accelerometers within the VX Sport Log units demonstrate high reliability and offer a valid means to compare acceleration and Player Load of Badminton specific movements between different athletes or the same athlete over multiple training sessions. For the validity test between the VX Sport Log and Catapult Optimeye S5 units there was a higher degree of variability as compared to the reliability test between the same units. There are a number of explanations for this poorer level of agreement. Firstly, the two units used have different dimensions, meaning that the exact positioning of the accelerometer within the respective unit would be different between the two systems.

Secondly, in the design of the data collection, the participants were required to wear two vests, one vest for each unit. One vest was worn over the top of the other and in most cases the outer vest was a size larger than the inner vest. For example, if the inner vest was size "Small" the outer vest would be size "Medium". While this was necessary for the comfort of the participants, it may have resulted in addition incidental movement of the outer unit which was placed in the larger vest. This is consistent with findings from a study of Rugby League in which data obtain from units worn in the manufacturer's purpose-built vest were found to have higher construct validity than data obtained from a unit worn in a pouch in the player's jersey, due to the latter causing greater incidental unit movement.[20] The highest CV% were observed in the media-lateral axis during the validity tests. In the reliability assessment the media-lateral axis also demonstrated the poorest reliability for 2 of the 3 measures. This would suggest that the outer units experienced greater movement from body rotations during the reliability assessment.

Notwithstanding the issues mentioned above, the main cause of the poorer level of agreement in the validity assessment would be the different sample rates observed between the two systems. While at the outset of the data collection there was not difference between the two units, a disparity become apparent as the data collection progressed. While the drift did not lead to unacceptable level of difference, this may have been due to the relatively short duration of the validity assessment. The drift between the two units could result in more significate differences if used for longer duration, such as for the duration of a Badminton match. While it was not possible to ascertain which of the systems was not recording at a true 100 Hz, it was observed that there was a 0.25% difference between the two sampling frequencies. Once this error was established, it was possible to resample the data using MatLab so that both datasets were sampled at the same frequency.

Such an approach should be considered when seeking to compare data collected from different brands of athlete tracking system to ensure accurate comparison of data obtained from the systems. It should also be noted that this difference in sample rate between devices would not affect the player load data produced, it is only the time axis which is affected.

## CONCLUSION

Based on the results from this study, it is preferable to use the same brand of athlete tracking system to make comparisons of accelerations and Player Load for Badminton specific movements. The reliability for the VX Sport Log system was high with CV% of below 5% in 8 of our 9 comparisons and "Excellent" ICC for all measures. While the validity between the VX Sport Log and Catapult Optimeye S5 systems was acceptable, with CV% below 10% and "Excellent" ICC values, there was a larger difference compared to the reliability assessment. This difference may be due to the relative size of

**Table 2** Validity between VX Sport Log and Catapult Optimeye S5 units (N = 9)

| | | Max Acceleration ($m/s^2$) | Max Deceleration ($m/s^2$) | Vector Magnitude (AU) |
|---|---|---|---|---|
| Vertical | VX Sport | 1.98 ± 0.20 | -1.49 ± 0.15 | 106.55 ± 24.88 |
| | Catapult | 2.05 ± 0.21 | -1.52 ± 0.17 | 108.15 ± 25.55 |
| | CV% | 3.3 | 2.8 | 3.8 |
| | ICC | 0.897 | 0.937 | 0.970 |
| Antero-posterior | VX Sport | 1.04 ± 0.20 | -1.58 ± 0.21 | 70.85 ± 20.43 |
| | Catapult | 1.05 ± 0.19 | -1.54 ± 0.24 | 70.66 ± 22.79 |
| | CV% | 5.2 | 4.4 | 6.1 |
| | ICC | 0.934 | 0.925 | 0.956 |
| Medio-lateral | VX Sport | 1.32 ± 0.18 | 1.13 ± 0.25 | 42.31 ± 7.91 |
| | Catapult | 1.33 ± 0.24 | 1.22 ± 0.24 | 48.57 ± 7.56 |
| | CV% | 7.3 | 4.5 | 7.1 |
| | ICC | 0.785 | 0.965 | 0.828 |

the units, the placement of the units within two vests which resulted in greater incidental unit movement and drift due to one or both systems not sampling at a true 100 Hz. In circumstances where different systems are used and longer data collection duration are required, resampling the data so that data from both systems is at the same sampling frequency would provide improved reliability.

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