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The validation of a novel camera-based system for measuring linear sprint performance

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ABSTRACT

Sprinting is a vital part of many locomotive sports. Furthermore, sprint profiling is essential for the development of bespoke training solutions to improve performance. The aim of this research, therefore, was to validate a new technology, Photon Sports, against a validated system, 1080 Sprint. 56 academy football players each performed two 30 m sprints whilst simultaneously collecting time-series data from both devices. The two systems were synchronized using a single machine vision camera to align repetition detection methods. Limits of agreement (LOA) (systematic bias ± random error) and coefficient of variation (CV) was calculated for each 1 m split. LOAs revealed very low systematic bias between devices (-0.014 to 0.002) and very low CVs (< 1.5%). In conclusion, Photon Sports is a valid system for measuring 30 m linear sprints.

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INTRODUCTION

Sprinting is a vital part of most locomotive sports, including court, invasion, track and field, and some winter sports. Higher speeds often result in greater technical or competitive success, for example, first over the finish line, a further or higher jump, more goals or tries, or returning more shots (6,9,12). Physical performance coaches and sport scientists will therefore make speed development a key priority when designing phases of training.

Football is a sport that requires high levels of speed during competition (8), with research reporting speeds of almost 39.0 km/h within senior matches (1). Indeed, with the changes in technical priorities within football, the need to achieve higher speeds is vital for competitive advantage, given the intensity of match play is increasing and predicted to continue to increase over time (8). To address the physical demands of these high-intensity actions, individualizing training interventions for players can only be effective with valid and reliable profiling.

Speed profiling has advanced over recent years due to extensive developments to technology, evolving testing and monitoring to more advanced methods than the traditional timing or light gate (5). Various systems are now available to practitioners, including radar, lidar, global positioning units, camera-based, and pulley (5). With these advancements, comes more sophisticated data options and more efficient functions to increase practitioner's understanding of sprint performance, ensuring more bespoke interventions are put in place to maximise adaptations.

The 1080 motion sprint is a system that has become popular with sport science practitioners (3,17). This motorized pulley system provides highly valid and reliable data such as distance, time, velocity, force, acceleration, and power, in addition to force-velocity characteristics first devised by Morin and colleagues (10,14,15,18). Nevertheless, this system is very expensive, retailing at around €18,000, creating a gap in the market for technology that can offer similar data accuracy, but with a reduced price point.

Photon Sports is a new 3D camera-based system that utilises a time-of-flight camera to track the coordinates of a reflective vest worn by an individual. By doing so, the system can measure time-series data to then calculate, much like the 1080 Sprint, a variety of options to assess sprint performance such as distance, velocity, acceleration etc. Force-velocity profiling is possible, with an added option of overlaying 2D video against a time-speed trace to map technical and mechanical performance. Importantly, prior to assessing these more complex mechanical computations, evaluating the system's ability to measure time-series data is vital. To

date, no studies have assessed the validity of this technology, and therefore, the aim of this research is to validate the Photon Sports system against the already validated 1080 motion sprint.

METHOD

Research Design

A repeated measures, within-participant design was implemented to compare the Photon Sports system against the 1080 motion sprint (criterion measure). Testing was performed at two separate football academies across three days. Data was collected simultaneously on both systems, providing a direct comparison. Testing took place either mid-morning or mid-afternoon, based on the training times of the two academies, with club practitioner led warm-ups undertaken prior to testing. The warm-ups consisted of floor-based mobility, dynamic movements, technical sprint drills, and submaximal efforts over 20-30 m. Both academies performed the testing prior to a technical session, and as a result, combined it as part of their maximal velocity day pre-training preparations. Ethical approval was granted by the institutions ethics board, in conjunction with the seventh iteration of the declaration of Helsinki (ER56984873).

Participants

56 participants (age: 18.04 years ± 1.46 years; mass: 72.26 kg ± 7.66 kg; stature: 178.67 cm ± 7.13 cm) from the two academies U18 and U21 squads took part in the study. Participants consisted of a mix of positions, including defenders (*n* = 22), midfielders (*n* = 18), and forwards (*n* = 16). Goalkeepers were not asked to take part given the distance being performed. All players were passed fit by the club's medical department and gave informed consent to take part in the study and were given the option to withdraw at any time.

Protocols

Sprint testing

Each participant was asked to perform two 30 m sprints, each separated by a minimum of five minutes rest. Players were asked to set-up in a split stance position on the 0 m (start) line, 2 m in front of both systems. Participants were instructed to ensure there was no slack in the 1080 cable and could begin their run "when they were ready", after Photon Sports had calibrated and was ready to collect the run. Players were also instructed to provide a maximal effort and to

"not slow down" or "run through the cones" to prevent deceleration before the 30 m point. Verbal encouragement was provided before and during each sprint.

Equipment set-up

The set-up can be seen in Figures 1-3. The 1080 motion was situated on the ground in front of the Photon, with the cable calibrated to 1.67 m protraction to ensure players began directly on the 0 m start line, 2 m in front of the Photon system. The 1080 cable was attached to the central point of the participants backs to ensure a more representative comparison to the Photon. To achieve this, a harness was worn with cable ties attached to some hooks in the central part of the back which then attached to the 1080 cable via a carabiner. Photon Sports was set up 2 m behind the start point and set to a height of 1.5 m for all trials. Participants wore a reflective vest provided by the manufacturer, with a small hole cut out the back to attach the 1080 Sprint to the harness.



Figure 1. Photographs showing the set-up of the 1080 Sprint, Photon Sports, and Basler camera.

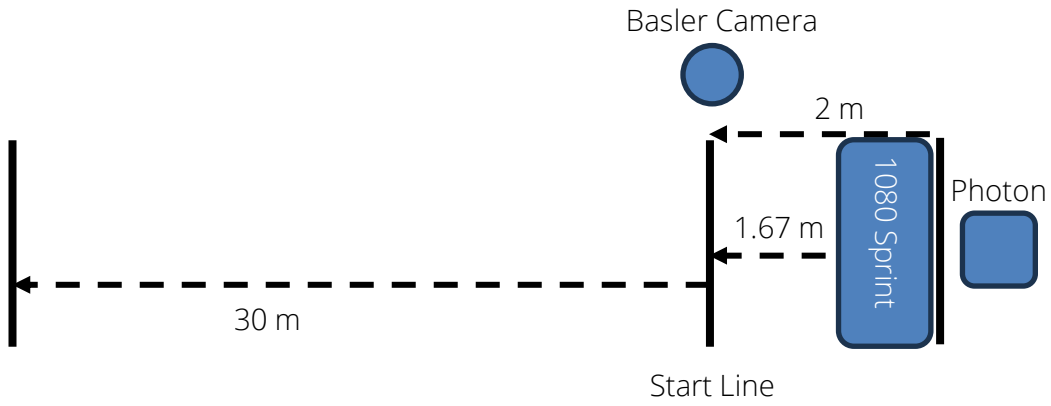


Figure 2. Schematic showing equipment set-up

Data collection

All devices were operated as per the manufacturer's recommendations. The 1080 Sprint used a servo motor (2000 RPM OMRON G5 Series Motor, OMRON Corporation, Kyoto, Japan) to apply a resistance to a cable, measuring time and displacement of the cable as it unraveled. The 1080 Sprint was set to 1 kg resistance and the 'no flying weight' setting to minimize slack in the line as each player accelerated. The 1080 Sprint collected data at a sampling rate of 333 Hz. Photon Sports used 3D depth technology to create a 3D image based on a reflective vest worn by the participant. This 3D image generated a centroid that defines the x, y, and z coordinates used to measure time, displacement, and velocity at 60 Hz. Both systems detected the start of a repetition based on an initial velocity greater than 0.2 $m.s^{-1}$.

To address the different technologies employed by the 1080 and Photon Sports, an additional single machine vision camera (Basler, Ace 1920-50-gc color) was set up perpendicular to the start line to capture the initial point of movement from the participant (Figure 3). This camera captured images at a resolution of 1920 x 1100 pixels and at a frame rate of 50 Hz, with an exposure time of 3000 microseconds. Movement of the 1080 Sprint was synchronized to the camera capture system through a hall-effect sensor on the rotating wheel of the device. A signal from the line out of the Basler camera was set to output on frame exposure. Both the camera frame exposure and rotation signals were collected on a single National Instruments device, USB-6008 and logged to the capturing PC. A custom camera capture application was created to enable the direct saving of frames and log signals onto a laptop device connected to the camera via an ethernet cable. The camera capture and signal logging were started and stopped manually by a researcher monitoring the laptop and testing protocol. The camera field of view, captured the start of the sprinting effort, as shown in Figure 3.



Figure 3. Typical field of view captured by the machine vision camera.

Further to this, a secondary synchronization method was adopted based on a one-dimensional monotonical linear interpolation of the Photon raw data to match the sampling rate (333 Hz) of the 1080 Sprint. Once this was applied, a time delay function was developed to align the two sets of data at the 1 m split, which was then cross-refenced against the time delay calculated by the camera and hall-effect sensor.

Statistical Analysis

Data were checked for normal distribution following a process of outlier removal via the calculation of the interquartile range (IQR) based on the difference between the 25th and 75th percentile. Once found, a lower (25th percentile minus 1.5 times the IQR) and upper (75th percentile plus 1.5 times the IQR) boundary was calculating, removing any data outside of this threshold as an outlier. 1 m split times were then calculated for each participant, with means and SDs subsequently calculated for each split across all repetitions performed. Systematic bias between the two devices was then calculated in addition to limits of agreement (LOA) and represented via Bland-Altman plots. These were calculated per 1 m split using the accumulative

split times, and then all splits combined using the interval splits. Finally, coefficient of variation (CV) was calculated for each 1 m split using the following formula:

$$CV(\%) = \frac{SD\ (differences)}{mean\ of\ criterion\ (1080\ Sprint)}\ x\ 100$$

All statistical analysis was conducted via RStudio (*R*, 2024.04.0+735).

RESULTS

All data were normally distributed following the removal of outliers based on the IQR. In total, 105 repetitions were used for analysis. Means and SDs for both devices, and LOA's across the 30 m splits can be seen in table 1. Systematic bias between devices was low across all splits, ranging from -0.014 s to 0.002 s, with random error ranging from 0.002 s to 0.029 s. The absolute differences between the two devices can be seen in Figure 4. Figure 5 shows the LOA's for all splits across all participants. Systematic bias between the two devices across all splits was 0.000 ± 0.015. Figure 6 displays the CV across all 30 m splits, ranging from 0.30 to 1.46%.

Table 1. Means, SD's, systematic bias, upper and lower limits of agreement (LOA) for both devices across all 30 m splits.

Split (m)	1080 (s)	1080 (SD) (s)	Photon (s)	Photon (SD) (s)	Systematic Bias (s)	LOA (lower) (s)	LOA (upper) (s)
1	0.397	0.069	0.397	0.069	0.000	-0.003	0.002
2	0.656	0.075	0.659	0.074	0.002	-0.016	0.021
3	0.872	0.078	0.872	0.078	0.000	-0.020	0.020
4	1.064	0.081	1.058	0.081	-0.006	-0.028	0.017
5	1.241	0.085	1.239	0.083	-0.003	-0.027	0.021
6	1.405	0.087	1.402	0.085	-0.003	-0.027	0.020
7	1.561	0.088	1.556	0.087	-0.006	-0.029	0.018
8	1.715	0.091	1.704	0.089	-0.010	-0.035	0.014
9	1.860	0.093	1.846	0.091	-0.014	-0.037	0.009
10	2.003	0.094	1.990	0.093	-0.013	-0.036	0.010
11	2.142	0.098	2.132	0.095	-0.010	-0.037	0.016
12	2.278	0.099	2.271	0.098	-0.007	-0.033	0.019
13	2.413	0.101	2.403	0.099	-0.010	-0.035	0.016
14	2.543	0.105	2.536	0.102	-0.007	-0.032	0.018
15	2.675	0.107	2.668	0.105	-0.007	-0.031	0.017
16	2.803	0.109	2.797	0.107	-0.006	-0.030	0.018
17	2.930	0.112	2.925	0.110	-0.005	-0.028	0.019
18	3.056	0.116	3.053	0.113	-0.003	-0.028	0.023
19	3.182	0.118	3.176	0.115	-0.005	-0.028	0.018
20	3.306	0.121	3.301	0.118	-0.005	-0.030	0.020
21	3.429	0.125	3.426	0.122	-0.003	-0.027	0.022
22	3.552	0.128	3.546	0.124	-0.005	-0.032	0.022
23	3.674	0.131	3.669	0.127	-0.005	-0.032	0.022
24	3.796	0.134	3.794	0.130	-0.002	-0.028	0.024
25	3.917	0.138	3.915	0.134	-0.002	-0.028	0.025
26	4.038	0.141	4.036	0.137	-0.003	-0.029	0.024
27	4.159	0.144	4.158	0.141	-0.001	-0.028	0.027
28	4.280	0.148	4.278	0.144	-0.002	-0.029	0.026
29	4.400	0.152	4.400	0.148	0.000	-0.029	0.029
30	4.536	0.159	4.523	0.151	0.000	-0.027	0.027

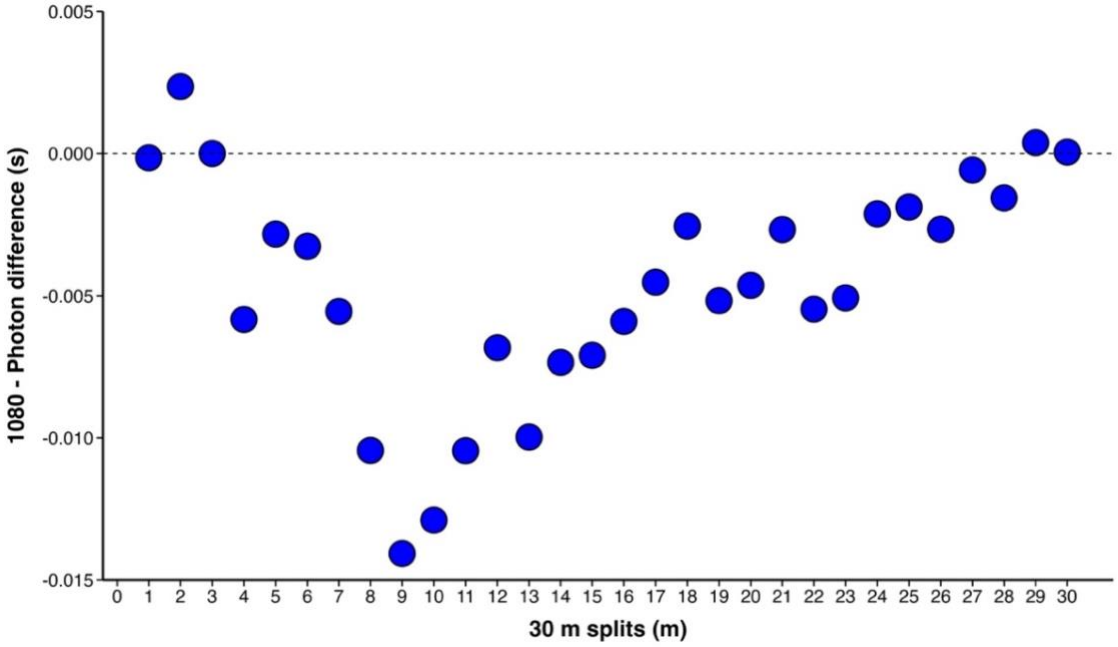


Figure 4. A graph showing the difference between 1080 motion sprint and Photon Sports across 30 1-meter splits.

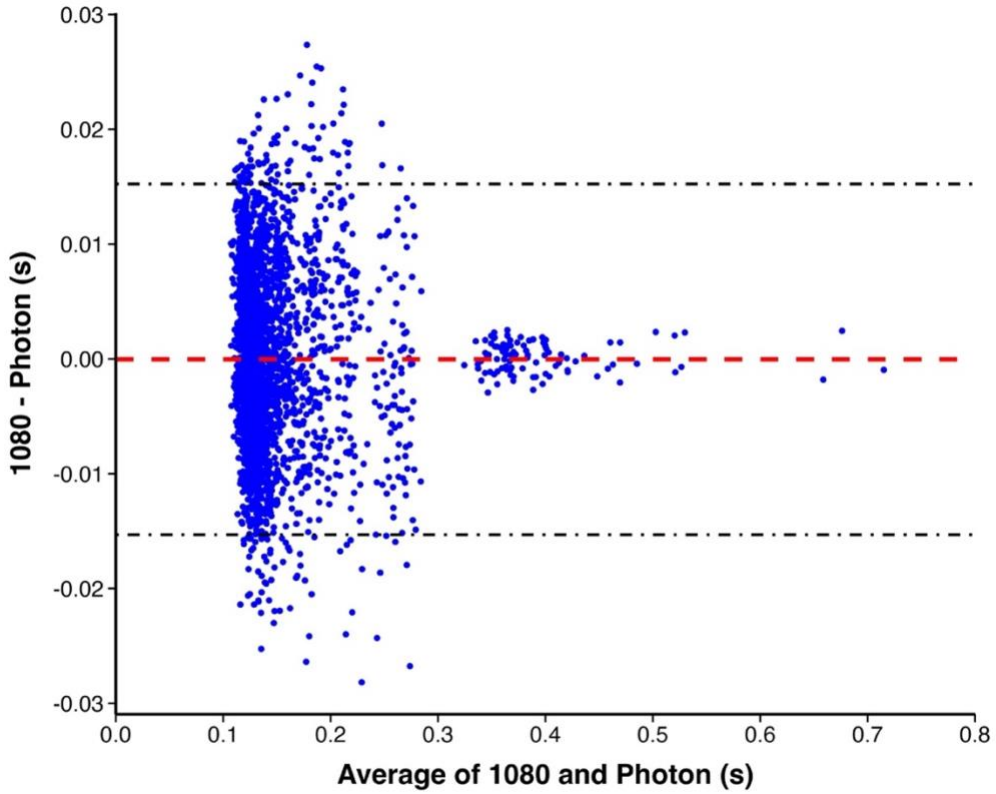


Figure 5. Bland-Altman plot showing the difference between 1080 motion sprint and Photon Sports across all repetitions.

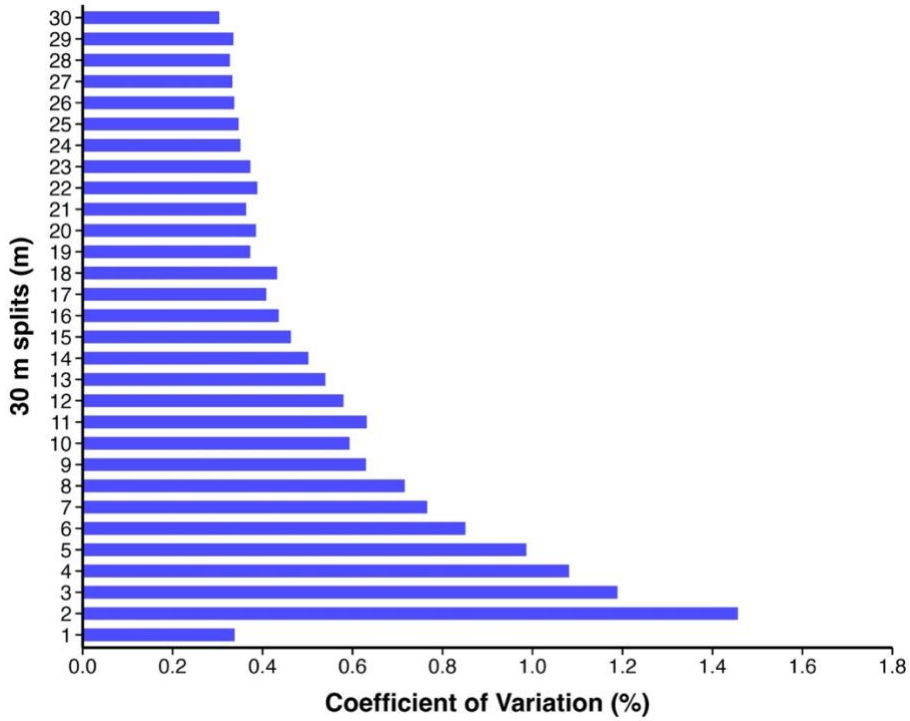


Figure 6. Coefficient of Variation (CV) for all 30 1-meter splits between 1080 motion sprint and Photon Sports

DISCUSSION

The aim of this research was to validate Photon Sports against the criterion measure, 1080 Sprint. The main findings of this study were that 25 out of the 30 1 m splits had a systematic bias of less than one hundredth of a second (0.010), with the remaining five splits ranging from 0.010 to 0.014. Similarly, all coefficient of variations across all 30 1 m split times were less than 2%. Finally, when combining all splits across all participants, the systematic bias of the total system was 0.000 ± 0.015, with no evidence of heteroscedasticity.

Our results demonstrate a very low systematic error between Photon Sports and the 1080 Sprint, ranging from -0.014 to 0.002, highlighting good agreement between the two systems. Photon Sports is a new technology that has previously never been validated and therefore, this research will be of interest to sport science and strength and conditioning

practitioners who require regular sprint profiling. Our data aligns closely to previous research validating other technologies, such as the 1080 Sprint, used as the criterion measure here. Studies have reported low CV's (0.74% to 5.97%), high correlation coefficients (r = 0.48 to 0.95), and low systematic biases (0 to 6%) when comparing the 1080 Sprint against the MuscleLab timing system and a Radar Gun (7,17). Interestingly, Rakovic et al., (2022) reported large measurement error between the 1080 and MuscleLab timing system in the 0 to 5 m split across various resistances (CVs = 19.76% to 20.54%, bias = 0.34 s). It was suggested that these large errors were evident due to the different types of technology (motorized cable-based system vs. a mat-based timing trigger system), meaning that initiation of the start of each repetition occurred at different times, impacting the initial 5 m split. Importantly, in this study, synchronization occurred to align the start times of both devices, recalculating each split post-process to provide a more valid comparison of the two different technologies.

In addition to recent reports of the 1080 Sprint having good validity (hence the choice to use it as the criterion measure within this study), researchers have also found it to have good level of test-retest reliability. Buchheit and Eriksrud (2024) reported very low CVs (1.2% to 3.3%) and typical errors (0.05 to 0.09) (TE) across key time (0-40 m and 0-5 m) and speed (max speed) metrics during a 40 m sprint in professional football players (3). This excellent level of reliability supports the decision to use the 1080 Sprint as the criterion measure. Given the very close agreement between Photon Sports and 1080 Sprint, it would be sensible to assume good levels of test-retest reliability will also be evident within Photon Sports. Future research should therefore look to analyse the reliability of linear sprinting in Photon Sports, in addition to the validity and reliability in common change of direction tests.

Practically, both systems have strengths and some limitations. The 1080 motion sprint offers resisted and assisted sprinting, which has been shown to be effective in improving acceleration and change of direction performance, both acutely and chronically (4,11,13,16). Despite this obvious benefit, 1080 Sprint is a very expensive device and can be limited when wanting to utilise in training with a squad of athletes. Whilst Photon doesn't offer a resistance function, combining other methods such as pulley systems (e.g., Exergenie) or weighted sleds with the load-velocity profiling protocol in the system could address this limitation. Additionally, Photon offers a variety of testing options, including the S-MAS (2) and video integration to better align kinetic and kinematic data. Most importantly, both devices offer valid data, and therefore practitioners must understand their sprint priorities before deciding which device to invest in.

CONCLUSION

Photon Sports sprint profiling technology is a valid device for assessing 30 m sprint times, with a degree of accuracy to a 1 m split. The system demonstrated a low level of systematic bias across all splits following a process of synchronization with the 1080 Sprint (criterion measure). Additionally, low measurement error (< 1.5%) was evident across all splits. This provides sport scientists with the confidence to invest in such a system to utilise for their speed profiling requirements.

Contributions

Contributed to conception and design: SWT, LF
Contributed to acquisition of data: SWT, EK
Contributed to analysis and interpretation of data: ST, LF
Drafted and/or revised the article: ST, LF, EK
Approved the submitted version for publication: ST

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Data and Supplementary Material Accessibility

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