Validity and Reliability of the FlightScope Mevo+ Launch Monitor for Assessing Golf Performance

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Abstract

Brennan, A, Murray, A, Coughlan, D, Mountjoy, M, Wells, J, Ehlert, A, Xu, J, Broadie, M, Turner, A, and Bishop, C. Validity and reliability of the FlightScope Mevo+ launch monitor for assessing golf performance. *J Strength Cond Res* XX(X): 000–000, 2023—The purpose of this study was to (a) assess the validity of the FlightScope Mevo+ against the TrackMan 4 and (b) determine the within-session reliability of both launch monitor systems when using a driver and a 6-iron. Twenty-nine youth golfers, with a minimum of 3 years of playing experience, volunteered for this study. All golfers completed 10 shots with a 6-iron and a driver, with 8 metrics concurrently monitored from both launch monitor systems in an indoor biomechanics laboratory. For both clubs, Pearson's r values ranged from small to near perfect (r range = 0.254–0.985), with the strongest relationships evident for clubhead speed (CHS) and ball speed ($r \geq 0.92$). Bland-Altman plots showed almost perfect levels of agreement between devices for smash factor (mean bias ≤ −0.016; 95% CI: −0.112, 0.079), whereas the poorest levels of agreement was for spin rate (mean bias ≤1,238; 95% CI: −2,628, 5,103). From a reliability standpoint, the TrackMan showed intraclass correlation coefficients (ICCs) ranging from moderate to excellent (ICC = 0.60–0.99) and coefficient of variation (CV) values ranged from good to poor (CV = 1.31–230.22%). For the Mevo+ device, ICC data ranged from poor to excellent (ICC = −0.22 to 0.99) and CV values ranged from good to poor (CV = 1.46–72.70%). Importantly, both devices showed similar trends, with the strongest reliability consistently evident for CHS, ball speed, carry distance, and smash factor. Finally, statistically significant differences ($p < 0.05$) were evident between devices for spin rate (driver: d = 1.27; 6-iron: d = 0.90), launch angle (driver: d = 0.54), and attack angle (driver: d = −0.51). Collectively, these findings suggest that the FlightScope Mevo+ launch monitor is both valid and reliable when monitoring CHS, ball speed, carry distance, and smash factor. However, additional variables such as spin rate, launch angle, attack angle, and spin axis exhibit substantially greater variation compared with the TrackMan 4, suggesting that practitioners may wish to be cautious when providing golfers with feedback relating to these metrics.

Key Words: accuracy, consistency, golf, radar technology

Introduction

In modern sporting environments, technological advances are often combined with natural athletic ability to produce the best possible sporting outcomes (14). This is no different in golf, where advancements in technology include launch monitor systems (e.g., TrackMan and FlightScope), equipment updates (e.g., aerodynamic clubheads, graphite shafts, and golf ball advancements), and golf range finders (e.g., Bushnell Tour V6 and Nikon Coolshot Pro II). With the influx of new technologies, understanding the data that comes with it is essential for players and coaches alike, with the underlying aim of using said data to help guide decision making. For example, launch monitors can provide an in-depth understanding of how a golf shot has been achieved by providing data on a range of shot metrics. These include outcome measures (e.g., distance and accuracy), metrics relating to the interaction between the clubhead and golf ball—coined "impact factors" (e.g., attack angle and dynamic loft), and subsequent "launch characteristics" of the golf ball (e.g., ball speed and spin rate) (6). Collectively, all these shot metrics are theoretically of interest because they determine the outcome of any given shot. Thus far, however, the majority of golf research in strength and conditioning has focused on clubhead speed (CHS) (15,19,20). Although the importance of this is not being downplayed, many launch monitors use radar technology, which searches for objects flying through the air. Put simply, ball metrics are more appropriate to monitor for such technologies (as opposed to the golf club that never leaves a player's hands) and have shown greater levels of agreement than club-based data compared with a laboratory-based criterion method (12). Finally, a further benefit of launch monitors is their ability to provide instantaneous feedback, which has been documented to improve motor skill acquisition (8). In turn, this suggests that feedback, and therefore, the use of a launch monitor is likely to be beneficial for a skill-based sport such as golf (11).

Many players, technical coaches, and support staff practitioners consider the TrackMan launch monitor system to be the

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Journal of Strength and Conditioning Research 00(00)/1–8 the Journal of Strength and Conditioning Research™

"benchmark standard" (13), which is used on the professional tours (e.g., PGA Tour and DP World Tour). To the authors' knowledge, only one study has aimed to determine the validity of the TrackMan, in addition to another system named the Foresight GC2 + HMT (12). Leach et al. (12) investigated the validity of ball parameters (e.g., ball speed, launch angle, and launch direction) and club parameters (e.g., CHS, attack angle, and club direction) using a (a) TrackMan Pro IIIe and (b) Foresight GC2 + HMT, against a high-speed camera system. The findings demonstrated that levels of agreement between launch monitors and the high-speed camera system was stronger for ball parameters, with clubhead parameters demonstrating slightly greater variability. Collectively though, it seems that these launch monitor systems are largely accurate. Despite these positive findings, the TrackMan system is expensive, with the newest model (TrackMan 4) available for approximately \$25,500–30,500 or £20,000–24,000. Consequently, these systems are often only available at the elite level, providing accessibility issues, even for high-level amateur players.

With this in mind, cheaper alternatives have been manufactured such as the FlightScope Mevo+ for approximately \$2,500 or £2,000, which offers similar features and data as the TrackMan, and for a 10th of the price. Similar to the TrackMan though, a limited amount of research has been conducted using the FlightScope Mevo+. For example, Villarrasa-Sapina et al. (19) investigated the test-retest reliability of multiple metrics from the FlightScope Mevo+ launch monitor, with a total of 15 metrics analyzed using a driver and a 6-iron. The driver showed intraclass correlation coefficient (ICC) values ranging from 0.08 (lateral distance) to 0.98 (CHS), and the 6-iron showed similar results ranging from −0.11 (launch direction) to 0.97 (carry and total distance). Read et al. (15) investigated the association between commonly measured strength and power field-based tests and their association with CHS, using a FlightScope launch monitor. However, from a reliability standpoint, the authors only reported the metric of CHS, which showed an ICC of 0.87. Therefore, from the limited body of evidence, it seems that some metrics exhibit strong within- and between-session reliability when using the FlightScope Mevo+. However, as useful as this is, to the authors' knowledge, no study has been conducted that validates the FlightScope system against the benchmark standard of TrackMan. Thus, we currently have no means of knowing how accurate the data are from this cheaper launch monitor system. With this in mind, the purpose of this study was to (a) assess the validity of the FlightScope Mevo+ against the TrackMan 4 and (b) determine the within-session reliability of both launch monitor systems when using both a driver and a 6-iron.

Methods

Experimental Approach to the Problem

Initially, all Subjects were instructed to bring their own driver and 6-iron. All testing took place in an indoor biomechanics laboratory with Subjects conducting their own desired golf-specific warm-up routine, relative to how they practice and compete (20). This was done to ensure that we did not interfere with any well-established golf warm-up practices, which may have impacted subsequent data. Data collection consisted of 10 maximal effort shots using a 6-iron and a driver, with all trials taken during a single session and all 6-iron shots completed first. This was done because golfers typically swing irons differently to a driver and the decision was taken that this order was least likely to impact the subsequent driver data in a negative way. Subjects were provided with 60 seconds of rest between swings and 3 minutes of rest between clubs. All shots that presented data on both the Mevo+ and the TrackMan 4 were analyzed, regardless of impact location or shot outcome, and an average of all 10 shots (for both clubs) were used for subsequent data analysis. If any data were missing, shots were retaken, ensuring that all metrics had a reported value from both launch monitors. The specific shot metrics that were analyzed are presented in Table 1, with an accompanying definition for each.

Subjects

Twenty-nine high-level youth golfers ($n = 25$ male golfers, $n = 4$ female golfers, age: 16.85 ± 0.55 years, height: 176.0 ± 7.2 cm, body mass: 75.0 ± 13.2 kg, mean handicap: 6.7 ± 4.7) volunteered for the current study, with all players being right-handed except for one. Each player had on average, a minimum of 3 years of regular (i.e., minimum of one practice session and one general practice round per week) playing experience. A priori power analysis using G*Power (Version 3.1, University of Dusseldorf, Germany) showed that 21 golfers were needed to implement a statistical power of 0.8, a type 1 alpha level of 0.05, and an effect size of 0.5. Owing to the age of golfers, written informed consent was provided by each parent or guardian, in addition to subject ascent. Ethical approval was granted by the Middlesex University Research and Ethics Committee.

Procedures

Equipment Setup. A schematic of the testing set-up is provided in Figure 1, with both launch monitors set up in accordance with their respected manufactures' guidelines. The golf ball

Table 1
Common launch monitor metrics analyzed from the TrackMan and FlightScope Mevo+ with accompanying definitions.*†

Metric	Units	Description
Launch characteristics		
Ball speed	mph	The speed of the golf ball's center of gravity immediately after separation from the club face
Spin rate	rpm	The rate of rotation of the golf ball around the resulting rotational axis of the golf ball immediately after the golf ball separates from the club face
Spin axis	degrees	The tilt angle relative to the horizon of the golf ball's resulting rotational axis immediately after separation from the club face (post impact)
Launch angle	degrees	The vertical angle relative to the horizon of the golf ball's center of gravity movement immediately after leaving the club face
Impact factors		
Clubhead speed	mph	The linear speed of the clubhead's geometric center just before the first contact with the golf ball
Attack angle	degrees	The vertical direction of the clubhead's geometric center movement at maximum compression of the golf ball
Additional		
Smash factor	—	The ratio between ball speed and clubhead speed
Carry distance	yards	The straight-line distance between where the ball started and where it first hits the ground

*mph = miles per hour; rpm = revolutions per minute.
†Table has been modified from Brennan et al. (6). Smash factor has no units of measurement because it is a ratio metric.

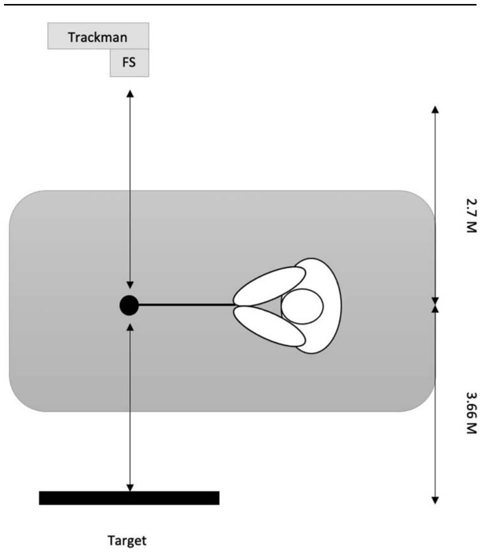

Figure 1. Setup of indoor shot monitoring testing. FlightScope being the smaller of the 2 launch monitor systems was set up in front of the TrackMan 4, aligning cameras to the golf ball. FS = FlightScope Mevo+.

was placed in the same tee spot each shot to enable consistency with the distance between the netting (3.66 m) and the 2 launch monitors (2.7 m). Players were given the option of 3 different rubber tee heights (for the driver) or no tee (for the 6-iron) but were required to keep consistent protocols for all shots. When using a driver, trying multiple tee heights during practice attempts was allowed before deciding on one for data collection. Golfers were instructed to aim for a "target" that lay in the center of the 8 × 8-foot netting, which was also calibrated for each launch monitor, before data collection. To gain the most accurate measurements, Titleist Pro V1x Radar Capture Technology golf balls were used, which have been specifically built for indoor use with radar-based launch monitors, so that reflective markers are no longer required on the golf ball. Both manufactures reported that the TrackMan 4 and FlightScope Mevo+ were 2 launch monitors used to validate the golf balls in previous indoor testing sessions (17).

Trackman 4 Setup. A TrackMan 4 launch monitor is a dual-doppler radar (Interactive Sports Games, Denmark) and was one of 2 launch monitor systems used to monitor shot data. An aerial view of the setup is shown in Figure 1, showing its position set up behind the participant. TrackMan advise optimal placement of the TrackMan to be 8–10 feet behind the tee and placed so the system is in line with the intended target (18). The launch monitor was calibrated and set to a "normalized" setting for all testing sessions, which is recommended for indoor use. If an error occurred and the TrackMan did not record all the recorded metrics, participants were asked to retake the shot and, in turn, the recorded data for the Mevo+ were also discarded.

FlightScope Mevo+ Setup. The FlightScope Mevo+ is a 3D doppler tracking radar (EDH, Inc., Orlando, FL) and was positioned directly in front of the TrackMan (Figure 1—noting that the size of it did not impact with the camera view of the TrackMan), which enabled it to concurrently measure the same data. Manufactures advise a minimum distance of 2.13 m (7) between the golfer and the FlightScope; therefore, to maintain consistency between both launch monitors, a distance of 2.7 m was selected.

Table 2
Mean ± *SD*, reliability data, and effect sizes showing differences between mean launch monitor data with a driver.*†

Variables	Mevo+				TrackMan				
	Mean ± *SD*	ICC (95% CI)	CV (95% CI)	*SEM*	Mean ± *SD*	ICC (95% CI)	CV (95% CI)	*SEM*	Cohen's *d*
Clubhead speed	108.21 ± 8.57	0.99 (0.98, 0.99)	1.57 (1.17, 1.98)	0.90	106.48 ± 8.47	0.99 (0.99, 1.00)	1.31 (0.97, 1.65)	0.71	0.20 (−0.33, 0.73)
Ball speed	154.04 ± 15.01	0.98 (0.97, 0.99)	2.83 (2.10, 3.56)	2.12	153.09 ± 14.90	0.98 (0.97, 0.99)	2.76 (2.05, 3.47)	2.11	0.06 (−0.46, 0.59)
Carry distance	236.88 ± 30.56	0.93 (0.88, 0.96)	7.07 (5.25, 8.89)	8.03	243.10 ± 35.76	0.94 (0.90, 0.97)	6.68 (4.96, 8.40)	8.69	−0.18 (−0.71, 0.34)
Smash factor	1.42 ± 0.06	0.88 (0.80, 0.94)	2.63 (1.95, 3.30)	0.02	1.44 ± 0.04	0.78 (0.62, 0.88)	2.36 (1.76, 2.97)	0.02	−0.28 (−0.81, 0.25)
Spin rate	4,403.38 ± 977.54	0.12 (−0.53, 0.54)	39.61 (29.42, 49.81)	918.05	3,165.84 ± 943.28	0.82 (0.69, 0.90)	22.91 (17.02, 28.81)	403.52	**1.27 (0.69, 1.85)**
Launch angle	12.94 ± 3.65	0.82 (0.69, 0.91)	21.01 (15.61, 26.42)	1.55	11.32 ± 2.04	0.63 (0.36, 0.80)	22.77 (16.91, 28.63)	1.25	**0.54 (0.00, 1.08)**
Attack angle	−2.53 ± 3.99	0.97 (0.95, 0.98)	39.51 (29.34, 49.68)	0.70	10.75 ± 36.03	0.94 (0.88, 0.98)	230.22 (170.97, 289.47)	8.75	**−0.51 (-1.05, 0.02)**
Spin axis	5.73 ± 9.99	0.79 (0.64, 0.89)	68.73 (50.21, 87.25)	4.56	5.33 ± 10.79	0.74 (0.46, 0.90)	16.65 (12.36, 20.94)	5.54	0.04 (−0.17, 0.25)

*Units of measurement: clubhead speed and ball speed = miles per hour; carry distance = yards; spin rate = revolutions per minute; launch angle, attack angle and spine axis = degrees.
†Effect size values in bold signify a significant difference ($p < 0.05$) between measurement devices.

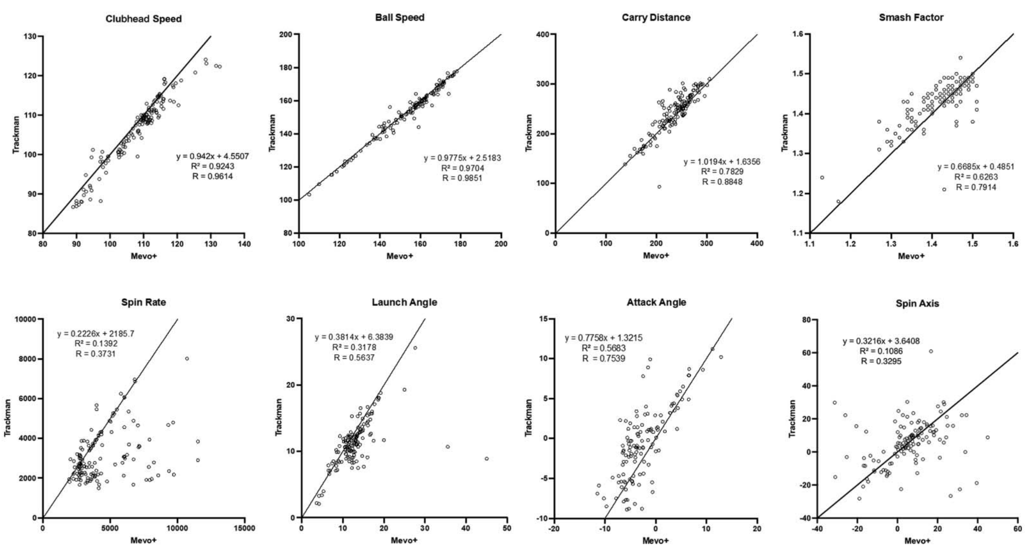

Figure 2. Scatter plot presenting relationships between Mevo+ and TrackMan for all driver shot data.

Statistical Analyses

All data were analyzed using SPSS and Microsoft Excel, with mean and *SD* for each individual shot metric calculated for both the driver and the 6-iron. Initially, all data were checked for and showed normal distribution ($p > 0.05$). Within-session reliability was computed for both launch monitors using the coefficient of variation (CV), ICC with 95% confidence intervals (CIs), and standard error of the measurement (*SEM*). Coefficient of variation values were considered good if <5%, moderate if between 5 and 10% and poor if >10% (1). Intraclass correlation coefficients values were interpreted in accordance with guidelines from Koo and Li (10) where: >0.90 = excellent, 0.75–0.90 = good, 0.50–0.74 = moderate, and <0.50 = poor.

Levels of agreement between the FlightScope Mevo+ and TrackMan 4 were determined from Bland-Altman plots with 95% upper and lower limits (5). Paired samples *t*-tests were computed to determine statistical significance between launch monitor data, with significance set at $p < 0.05$. Cohen's *d* effect sizes with 95% CI were also computed to depict practical differences between launch monitors and interpreted as <0.2 = trivial, 0.2–0.49 = small, 0.5–0.79 = moderate, and ≥0.8 = large (16). Finally, to determine the validity between launch monitors, Pearson's correlation coefficients (*r*) were calculated and interpreted as follows: <0.1 = trivial, 0.1–0.29 = small, 0.3–0.49 = moderate, 0.5–0.69 = large, 0.7–0.89 = very large, and >0.9 = nearly perfect (9).

Results

Driver

Reliability and Differences. Table 2 shows mean ± *SD* data, within-session reliability statistics, and Cohen's *d* effect size data for both launch monitors. For the TrackMan, ICC data ranged from moderate to excellent (ICC = 0.63–0.99) and CV values ranged from good to poor (CV = 1.31–230.22%). For the Mevo+ device, ICC data ranged from poor to excellent (ICC = 0.12–0.99) and CV values ranged from good to poor

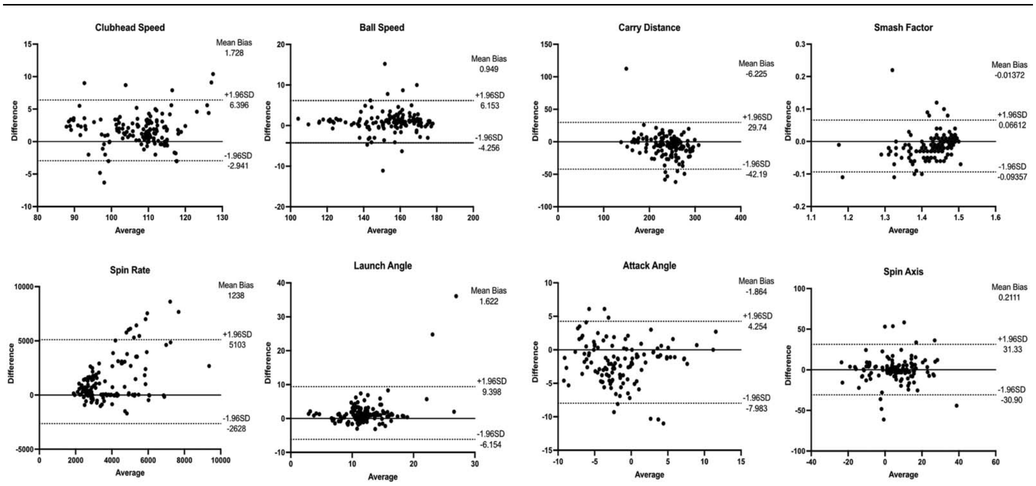

Figure 3. Bland-Altman plot depicting levels of agreement for Mevo+ and TrackMan for all driver shot data, including mean bias estimate and both lower and upper limits of agreement.

(CV = 1.57–224.77%). When assessing differences, statistically significant differences were evident between devices for spin rate (d = 1.27), launch angle (d = 0.54), and attack angle (d = −0.51).

Relationships and Levels of Agreement. Figure 2 shows Pearson's r values for all 8 launch monitor metrics, which ranged from moderate to near perfect (r range = 0.329–0.985), with the strongest relationships evident for CHS and ball speed ($r \geq 0.96$). Figure 3 shows Bland-Altman plots for all metrics. Almost perfect levels of agreement between devices were evident for smash factor (mean bias = −0.014; 95% CI: −0.094, 0.066), whereas the poorest levels of agreement was for spin rate (mean bias = 1,238; 95% CI: −2,628, 5,103).

6-Iron

Reliability and Differences. Table 3 shows mean ± *SD* data, within-session reliability statistics, and Cohen's d effect size data for both launch monitors. For the TrackMan, ICC data ranged from moderate to excellent (ICC = 0.60–0.99) and CV values ranged from good to poor (CV = 1.38–79.68%). For the Mevo+ device, ICC data ranged from poor to excellent (ICC = −0.22 to 0.99) and CV values ranged from good to poor (CV = 1.46–72.70%). When assessing differences, statistically significant differences were evident between devices for spin rate (d = 0.90).

Relationships and Levels of Agreement. Figure 4 shows Pearson's r values for all 8 launch monitor metrics, which ranged from small to near perfect (r range = 0.254–0.939), with the strongest relationships evident for CHS and ball speed ($r \geq 0.92$). Figure 5 shows Bland-Altman plots for all metrics. Almost perfect levels of agreement between devices were evident for smash factor (mean bias = −0.016; 95% CI: −0.112, 0.079), with the poorest levels of agreement again, evident for spin rate (mean bias = 862.6; 95% CI: −3,489, 5,214).

Discussion

The purpose of this study was to (a) assess the validity of the FlightScope Mevo+ against the TrackMan 4 and (b) determine the within-session reliability of both launch monitor systems when using both a driver and a 6-iron. Pearson's r correlations showed near-perfect correlations between launch monitors for CHS and ball speed, and very large correlations for carry distance and smash factor, with both clubs. Mean bias for smash factor was minimal, indicating near-perfect levels of agreement between devices, whereas spin rate showed the largest mean bias estimate and poorest levels of agreement. From a reliability standpoint, results indicated that CHS, ball speed, carry distance, and smash factor taken from a driver and a 6-iron exhibited acceptable levels of variability (CV < 10%) when measured across both launch monitors. Launch angle was deemed to have low levels of variability when shots were taken using the 6-iron (CV < 10%), but this was not consistent with the driver (CV > 10%). All other shot metrics displayed high levels of variability for both clubs and launch monitor devices (CV > 10%).

When viewing the Pearson's r values, the strongest associations with the TrackMan were evident for CHS, ball speed, carry distance, and smash factor, regardless of whether a driver or a 6-iron

Table 3
Mean ± *SD*, reliability data, and effect sizes showing differences between mean launch monitor data with a 6-iron.*†

Variables	Mevo+				TrackMan				
	Mean ± *SD*	ICC (95% CI)	CV (95% CI)	*SEM*	Mean ± *SD*	ICC (95% CI)	CV (95% CI)	*SEM*	Cohen's *d*
Clubhead speed	92.41 ± 6.84	0.99 (0.98, 0.99)	1.46 (1.08, 1.83)	0.72	90.37 ± 6.87	0.99 (0.98, 1.00)	1.38 (1.03, 1.74)	0.65	0.29 (−0.24, 0.82)
Ball speed	121.32 ± 10.29	0.91 (0.84, 0.95)	4.87 (3.61, 6.12)	3.14	120.31 ± 9.73	0.90 (0.83, 0.95)	4.81 (3.57, 6.05)	3.03	0.10 (−0.43, 0.63)
Carry distance	169.20 ± 18.37	0.87 (0.77, 0.93)	7.72 (5.73, 9.71)	6.67	170.59 ± 18.21	0.88 (0.79, 0.94)	6.93 (5.14, 8.71)	6.34	−0.07 (−0.60, 0.45)
Smash factor	1.32 ± 0.06	0.68 (0.41, 0.82)	4.80 (3.57, 6.04)	0.03	1.33 ± 0.05	0.60 (0.31, 0.79)	2.36 (1.76, 2.97)	0.03	−0.30 (−0.83, 0.23)
Spin rate	6,425.62 ± 938.13	−0.22 (−1.11, 0.37)	31.03 (23.05, 39.02)	1,034.93	5,562.99 ± 943.73	0.72 (0.52, 0.85)	17.97 (13.34, 22.59)	502.93	**0.90 (0.35, 1.46)**
Launch angle	16.04 ± 2.46	0.89 (0.82, 0.94)	9.61 (2.47, 7.14)	0.81	15.87 ± 2.61	0.91 (0.85, 0.95)	9.73 (7.22, 12.23)	0.78	0.06 (−0.46, 0.59)
Attack angle	−5.54 ± 4.92	0.98 (0.96, 0.99)	26.67 (19.81, 33.53)	0.73	−4.17 ± 2.28	0.88 (0.77, 0.95)	37.83 (28.09, 47.57)	0.79	−0.35 (−0.88, 0.18)
Spin axis	4.28 ± 7.30	0.90 (0.83, 0.95)	72.70 (53.99, 91.41)	2.33	3.37 ± 7.10	0.94 (0.87, 0.97)	79.68 (59.17, 100.18)	1.81	0.12 (0.03, 0.22)

*Units of measurement: clubhead speed and ball speed = miles per hour; carry distance = yards; spin rate = revolutions per minute; launch angle, attack angle and spine axis = degrees.
†Effect size values in bold signify a significant difference ($p < 0.05$) between measurement devices.

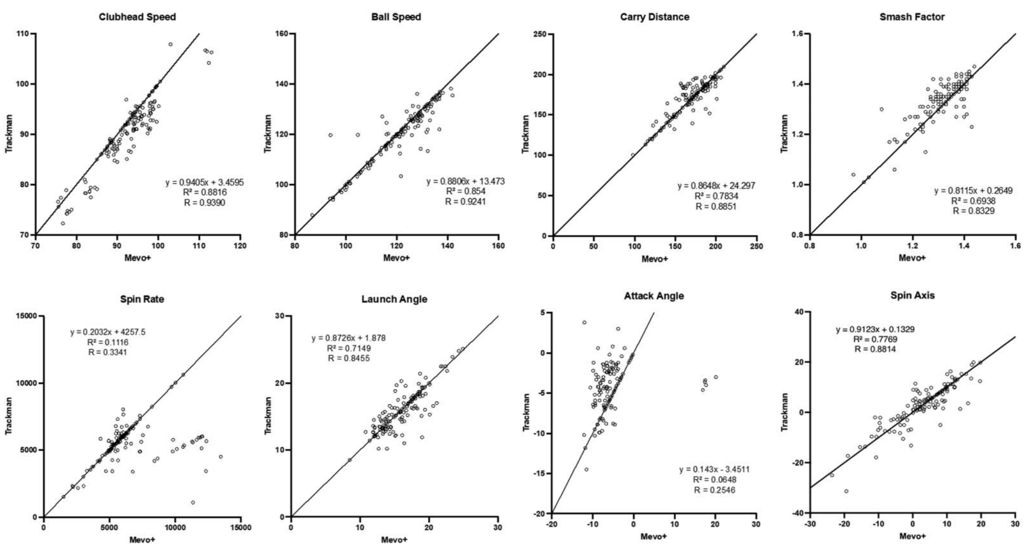

Figure 4. Scatter plot presenting a relationship between Mevo+ and TrackMan for all 6-iron shot data.

was used. To the authors' knowledge, this is the first study of its kind in golf, thus drawing conclusions from comparable literature is not possible. However, these findings are not entirely unsurprising. Previous literature has outlined that all these metrics (with the exception of smash factor) can be considered an "outcome measure" for a given golf shot (6), which tend to exhibit consistency if golfers are provided with the same set of instructions for each subsequent shot. In contrast, metrics such as spin rate, launch angle, attack angle, and spin axis can be considered "strategy metrics" (i.e., they help to explain the outcome of a given shot) and often exhibit much greater inconsistency (19). In an attempt to explain this, we must consider key differences in the way that these devices capture data to truly elucidate why these strategy metrics typically showed lower relationships between devices.

The FlightScope Mevo+ utilizes phased array radar technology to track golf shots. Put simply, it emits radar signals and measures the time it takes for the signals to travel to the target and back, and the doppler shift of the reflected signals. The TrackMan 4, however, uses a combination of radar and dual-doppler radar technology, which provides more precise measurements of the golf ball's trajectory (18). The dual-doppler radar (TrackMan) measures the change in frequency of the radar signal reflected off the object in motion—in this case, the clubhead or ball, which allows for the calculation of velocity and direction. Therefore, the differences in measurement techniques between devices is likely to result in different sensitivities in how data are captured, consequently leading to disparities in results. Collectively though, the findings of this study show that the FlightScope Mevo+ has very large or near-perfect associations with the TrackMan 4 for CHS, ball speed, carry distance, and smash factor, when using both a driver and a 6-iron.

These findings are further supported when we consider levels of agreement from the Bland-Altman plots. Specifically, when a driver was used, the Mevo+ device exhibited mean bias estimates of 1.7 and 0.9 mph, for CHS and ball speed, respectively. Linked to this, with smash factor being a product of these 2 metrics, mean bias estimates for this metric were −0.01 (no units), showcasing the near-perfect levels of agreement

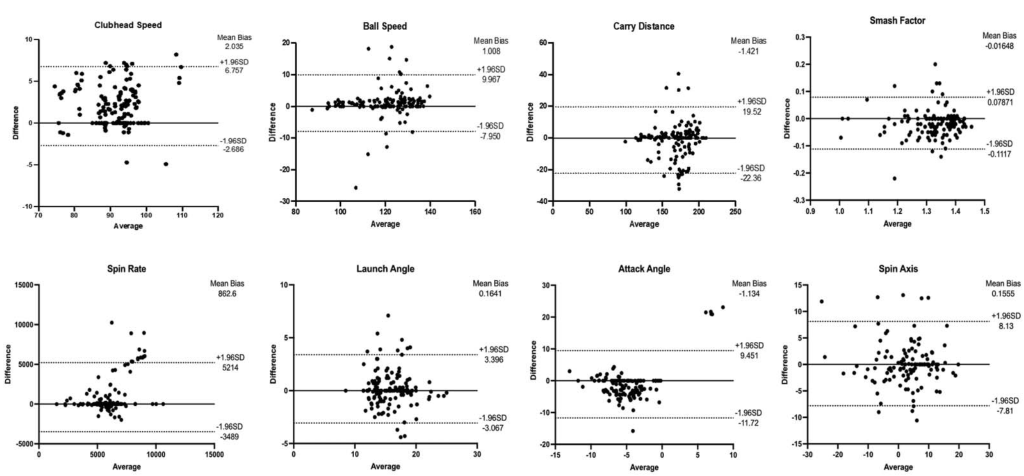

Figure 5. Bland-Altman plot depicting levels of agreement for Mevo+ and TrackMan for all 6-iron shot metrics, including bias estimate and both lower and upper limits of agreement.

with TrackMan and indicating that the FlightScope launch monitor is accurate for these metrics. Similar data were also shown when using a 6-iron, with mean bias estimates of 2.0 mph, 1.0 mph, and −0.02, for CHS, ball speed, and smash factor, respectively. In contrast, when viewing Figures 3 and 5, metrics such as spin rate and attack angle showed substantially poorer levels of agreement between devices. For example, the Mevo+ showed a mean bias estimate of 1,238 rpm for spin rate and −1.86° for attack angle, when using a driver (Figure 3). When using a 6-iron (Figure 5), the data for spin rate again highlights poor levels of agreement between launch monitors, with a mean bias estimate of 863 rpm. Consequently, the more "strategy-based" metrics (where the *r* values are typically lower between devices) also exhibit reduced levels of agreement, highlighting that practitioners should be mindful of the accuracy of metrics like spin rate and attack angle, if using the FlightScope Mevo+ launch monitor.

Unsurprisingly, the strongest reliability data for both launch monitors mirrors the largest relationships seen between devices. Specifically, CHS, ball speed, and smash factor all exhibited CV values <5%, with carry distance showing slightly greater, but acceptable variability from both launch monitors, using both clubs ≤7.72%. Despite the very low CV values for smash factor, ICC values were only "good" for both devices when using a driver (ICC = 0.78–0.88) and "moderate" when using a 6-iron (ICC = 0.60–0.68). Practitioners should be mindful that smash factor is a ratio metric, calculated as: ball speed ÷ CHS, and there is plenty of evidence outlining the limitations of ratio data (3,4). Although smash factor data, at any single moment in time, may not provide an issue when reliability data is acceptable, an issue may arise when tracking or monitoring change over time. Specifically, given this metric has 2 component parts (ball speed and CHS), any resultant change in smash factor can come about from increases or decreases in one or both components. Thus, to fully understand why smash factor values change, practitioners have to look at changes in both ball speed and CHS, independently. Furthermore, given both ball speed and CHS are of interest to practitioners, it becomes challenging to understand what additional value a ratio like smash factor really adds to the monitoring puzzle (3).

When we consider some of the strategy metrics, reliability data were considerably worse, and there were also some clear distinctions between launch monitors too. For example, CV values were poor for spin rate, spin axis, launch angle, and attack angle, when using a driver. However, it is worth acknowledging that the CV is a relative percentage value, which becomes inflated when we use smaller raw numbers. Spin axis and attack angle are a good example of this, which showed poor CV scores, but actually good to excellent ICC data, for both clubs and launch monitors. Thus, although the CV tells us that these data exhibit unacceptable reliability, it may not be the most appropriate measure of reliability for these metrics. Consequently, we also included *SEM* data to provide a more realistic understanding of the measurement error in some of these metrics, which is reported in the units of the metric itself. One key difference between launch monitors though, which cannot be ignored, was for spin rate. Intraclass correlation coefficient values were moderate to good when using the TrackMan but poor (and completely different) for the Mevo+ device (Tables 2 and 3). In addition, this was the one metric that showed a significant difference between launch monitors when using both a driver ($d = 1.27$) and a 6-iron ($d = 0.90$). Thus, it becomes challenging to suggest that spin rate is a usable metric when using the FlightScope Mevo+. Furthermore, both launch angle ($d = 0.54$) and attack angle ($d = -0.51$) also showed significant differences between devices, when using a driver, which also raises questions as to their accuracy and usability for practitioners.

Despite the usefulness of these findings, a few acknowledgments should be made. First, to maintain consistency during data collection, all golfers were instructed to try and achieve maximal distance from each shot. As maximal distance is strongly related to CHS and ball speed, some golfers (especially those that are highly-skilled) may take differing approaches from shot to shot to achieve a given outcome, which could result in inconsistent data related to metrics such as spin rate, spin axis, launch angle, and attack angle. Therefore, if golfers were instructed to perform shots with different instructions (e.g., accuracy over distance), it could be hypothesized that some of these strategy-based metrics may exhibit different levels of variability, a concept that requires further investigation. Second, and somewhat anecdotally, the usability of these metrics may be determined by the skill level of the golfer. For example, more skilled golfers may be able to possess consistent smash factor data if instructed to achieve maximal shot outcome, whereas low-levelled golfers may be able to produce consistent levels of CHS but not be able to translate this maximal ball speed if asked to achieve maximal distance. This theory is supported by empirical research from Betzler et al. (2) who showed that as handicap decreased (i.e., indicative of more skillful players), golfers exhibited increased CHS and improved their efficiency (i.e., ratio of ball speed to CHS), which is now commonly referred to as smash factor. However, this was not entirely consistent for lesser-skilled golfers with higher handicaps. Thus, with a mean handicap of 6.7 for golfers in the present study, future research should aim to determine whether reliability and variability are improved with professional or higher-standard amateur players, especially for metrics such as spin rate, spin axis, launch angle, and attack angle.

Practical Applications

From a practical standpoint, the findings of this current study help to do 2 things. First, our results support the usability of CHS, ball speed, carry distance, and smash factor, regardless of which launch monitor is being used. Second, and somewhat surprisingly, the results of the current study suggest that the Mevo+ presents strong agreements with a TrackMan 4, for these same 4 metrics. Given these launch monitors sit on differing ends of the price scale, these results may be of value to many golfers, coaches, and practitioners, who do not have access to launch monitors on the higher price scales, but who are looking to use some data to support the development of their golf game. Naturally though, the choice between different launch monitors is ultimately dependent on the specific needs, budget, and level of precision required by the coach or player using the system.

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