Effect of launch monitor technology on performance in golf

1. Executive summary

Launch monitors allow the instantaneous measurement of clubhead presentation, ball launch and ball flight variables. There are now many different models of launch monitors on the market. The measurements from launch monitors have been used to enhance coaching, provide entertainment, enable player development, conduct research and facilitate equipment fitting; their use is ubiquitous across golf.

Overall, the reliability of measurements has not been independently verified except for the reliability of two popular high-end launch monitors which has been established scientifically. Measurements were found to be of high enough quality for coaches and club-fitters but clubhead parameters were not found to be sufficiently reliable for scientific research. Care should be taken in interpreting the measurements from launch monitors in which the uncertainty is unknown.

The hypothetical benefit of launch monitors is clear, and it is easy to map out several ways in which they might be used to enhance performance and improve the golfing experience. There are many anecdotal examples of the benefits of launch monitors and their ubiquity is evidence of the way they have been embraced by the golf industry. There is, however, little objective evidence which can disentangle the real-world effect of the use of launch monitors on performance.

Equipment fitting is an area in which the objective feedback provided by launch monitors is likely to have made a profound difference to efficacy of practise but, again, there is little evidence as to the actual size of this effect. Furthermore, whilst there is an intuitive value to optimally fitting equipment, the robustness of golfers to poorly fitting equipment is unclear and potentially individual specific.

The potential effect of launch monitor use on performance can be partly understood through an analysis of overall changes in performance, but it should be noted that overall performance may be affected by many factors, not only launch monitor use. There was a clear increase in driving distance in the early 2000's, when the first commercial launch monitors were launched, but this period is also synonymous with other technological advancements; particularly the modern, solid-core golf ball. Since 2007 overall distance has been relatively stable, but data suggests that there may be a trend toward increased clubhead and ball speed, slightly increased launch angle and slightly decreased spin in professional golfers. The effect of launch monitors on these changes is unknown, there are several other potential factors, but launch monitor use may be both informing these changes and helping to achieve them.

In summary, the proliferation of launch monitors has likely benefited many players, but there does not appear to be clear evidence that their widespread use has had a large impact on overall playing performance or distance.

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2. Introduction

Over the last two decades, commercially available launch monitors have become widely available in the golf industry, enabling the recording of variables associated with the clubhead-ball impact to become widespread. Modern launch monitors can measure a host of variables associated with the clubhead-ball impact and resulting ball flight; including clubhead speed, face angle, impact position, ball speed, launch angle, and carry distance among others. Products range from affordable units targeted at club level golfers to more expensive solutions targeted at professionals and commercial applications. This report will discuss the use of launch monitor technology in golf and its theoretical benefits. The potential impact of increased launch monitor use on performance and evidence of this impact will be examined.

3. Short history of launch monitor development and adoption

Systems which monitor the launch of the ball and the clubhead presentation at impact have been used in the golf industry for many decades. Patents on this topic dating back to at least the 1950's (Simjian, 1959) and launch monitors which bear resemblance to those in modern use are evident in patents from the 1970's onward (for example: Sullivan et al., 1979). These early launch monitors were mainly in-house solutions or niche products designed for research and testing rather than wider use.

The early 2000's saw the introduction of the first commercially available launch monitors. Notable early launch monitors included the Vector in 2002 (Accusport, 2019) and Trackman in 2003 (Trackman, 2019). Initial interest in these technologies came primarily from equipment manufacturers (Trackman, 2019) but the professional tours were also early adopters of the technology. In-house solutions were costly and time-consuming to develop so a commercial solution was an improvement for many manufacturers. The introduction of commercially available launch monitors increased the availability of reliable data on the golf swing, which was not only of interest to large companies in the golf industry, but also to coaches, club fitters and players of all levels. The use of launch monitors has steadily increased to the point where their usage is now common throughout golf.

As well as their widespread use in research and broadcasting, launch monitors are now used for a wide range of applications in golf. Launch monitors are valued for coaching and game improvement. Driving ranges with each golfer accompanied by their own launch monitor are now a common sight on tour and their use in teaching and education is commonplace. The introduction of launch monitors into driving range facilities, like the Trackman range at the St Andrews Links (St Andrews Links, 2019), has opened the use of technology to every day golfers and allows a range to increase the perceived value of their services. Equipment fitting, where the effect of changes in equipment can now be readily measured, and entertainment, where launch monitors can provide data for indoor golf simulators, are also important markets for the technology. Whilst unit costs have decreased somewhat, a high-end launch monitor remains a significant investment and, as such, their widespread adoption is testament to their success.

Modern launch monitors are generally based on one of two technologies, cameras or Doppler radar, both of which were evident in the first commercial units seen in the early 2000's. Companies have iterated and improved their products in the years which have followed, but the underlying technology

remains similar. This iteration has resulted in obvious improvements in size and usability, but general improvements in accuracy and reliability would also be expected. One significant development has been the production of units that can accurately measure putting and short game performance, widening the application of initial units which focussed on quantifying the long game.

Detailed information on the accuracy or reliability of launch monitors is sparse, especially for the initial launch monitors introduced in the early 2000's, but the use of launch monitors in scientific research has prompted some independent validation of measurements. In investigations of two popular high-end launch monitors, measurements were found to be sufficiently reliable for coaches and club fitters. However, ball launch parameters were of higher quality than club parameters and the quality of club parameters deemed to be too low for robust scientific research (Jones, 2019; Leach et al., 2017). The units tested in these investigations cost in excess of $10,000 (USD) per unit, and likely represented some of the more accurate of products on the market at the time. The quality of measurements from cheaper units, with some modern launch monitors costing as little as $200 (USD), is unknown, but it is likely that there are products on the market which cannot provide quality, actionable data. In general, if the reliability of measurements is adequate, increased access to the information provided by launch monitors is surely a benefit to the golf industry.

4. Benefits of launch monitors

Launch monitors provide objective feedback which can be used to improve practise. With regard to swing improvements, there is no specific evidence of the effect of launch monitor feedback on performance in golf, but it is generally accepted that augmented feedback increases the effectiveness of motor learning (Wulf et al., 1998, for example). It would also be expected that objective feedback would benefit a practitioner, providing evidence for intervention. The wide range of uses within the golfing industry suggests that this data can be used in several ways to improve performance.

As well as facilitating improvements to a player's game through more effective motor learning, launch monitors may be used to augment the practise of golf professionals, improve the understanding and engagement of the client golfer, and provide motivation through measurement of progress. The inclusion of launch monitor measurements may reduce a practitioner's reliance on guesswork or intuition, improving the overall standard of decisions made during interactions. Overall, this may improve the efficiency of a lesson or fitting session, expedite performance gains and increase the perceived value of the session for the client golfer. Accurate performance information may also improve on-course performance, influencing the likelihood a player will attempt a shot or choose a club.

The use of launch monitors as the basis for indoor simulators allows golf to occur in locations where space or climate would be otherwise limiting, and can provide fun videogame-type experiences, increasing engagement.

The availability of launch monitors significantly lowers the bar for entry to scientific investigation of the swing. With a launch monitor, an individual or organisation can collect accurate and reliable data regarding the golf swing. Whilst such investigations might not meet the standards of rigorous control set

by the scientific community, they provide an opportunity for rapid hypothesis testing and performance tuning which would be otherwise impossible without the technology.

Another benefit of launch monitors may be an increased awareness and understanding of optimal ball flight and clubhead presentation parameters. An understanding of launch conditions can increase the effectiveness of changes to the golf swing, with better informed choices on equipment and biomechanics as a result. This may be tempered by differences in the definition of launch variables between different launch monitors, which could be a source of confusion, but the overall effect on the understanding of ball flight and impact mechanics is most likely positive; although there is no specific metric via which this can be tested. Anecdotally, launch monitor use has been a contributing factor to the demise of several myths around the club-ball impact and ball flight.

Despite a clear hypothetical benefit to launch monitor technology, the overall effect on performance is difficult to pin down. The benefit gained by the golfer likely depends on the knowledge and skill of the person operating the unit, as the feedback from the launch monitor augments existing methods of improvement, rather than being a new route for improvement. Whether the use of launch monitors can increase skill or facilitate equipment fitting to a level beyond what was previously possible or whether their use simply expedites this process is not known. It is also unclear whether golfers of all abilities would benefit similarly from using the technology. Benefits may be smaller in professional golfers, who have developed understanding through many years of practise. Conversely, golfers who utilise launch monitors heavily in their development may be able to develop greater distance compared to golfers who have already reached a high level without their use. There are many nuances which are not understood. As such, it is also not known whether future growth in performance associated with the use of launch monitors should be expected.

5. Use of launch monitors in equipment fitting

A case example of the use of launch monitors in golf may help to understand their impact more fully, and the use of launch monitors in equipment fitting is one topic in which this can be achieved.

Fitting refers to the selection or customization of golf equipment for an individual and can include selection from off-the-rack items, selection of component parts, or custom modifications to individual components. Almost every aspect of a golf club can be custom fit, including the clubhead, shaft, grip and general club set up. Furthermore, adjustable components allow the equipment to be further fine-tuned to the individual. As well as golf clubs, many manufacturers run programmes which offer to fit a golfer to an ideal golf ball, considering their preferences and the characteristics of their swing. The characteristics of equipment fitting are varied, but it generally seeks to find the optimum equipment for a given individual based on characteristics of the equipment and the individual.

Despite its widespread use in golf, there is surprisingly little scientific research on the efficacy of equipment fitting. Significant research has considered the effect of changes in equipment characteristics on performance, for example the swing weight (Schorah et al., 2012) or shaft stiffness (Betzler et al., 2012), but almost no research has considered the assignment of optimal equipment to an individual.

Bertram and Guadagnoli (2008) found club fitting to have a positive effect on clubhead velocity and face angle consistency, but was limited by unclear reporting of procedures and the small number of golfers studied; less than ten with custom fitted clubs.

The most similar area of scientific research is probably the fitting of running shoes to individuals, a topic which has received more attention. Results are generally mixed and there is no clear evidence that any method of fitting for running shoes is significantly better than subjective feel (Malisoux et al., 2016; Nielsen et al., 2014; Richards et al., 2009). In contrast to running, golf has a clear outcome on which fitting may be based. In particular, the use of launch monitors and the objective feedback they provide may allow modern golf fitting procedures to obtain a more accurate fit than procedures based on anthropometric measurements, subjective observations or feel. Further scientific research to understand equipment fitting in golf would surely be of benefit.

There is intuitive value to equipment which suits the characteristics of the individual golfer, but the range of optimal parameters and the difference in performance between optimal and non-optimal equipment is unclear and potentially individual specific. One player may find performance to be much worse with non-optimal equipment, whilst other players may be more robust to changes. Furthermore, psychology and marketing are also likely to influence the efficacy of fitting. These effects are difficult to separate from those relating to equipment properties or the fitting process and may be responsible for some of the increases in performance which are anecdotally reported.

There are many anecdotal accounts of improvements following a change of equipment, presumably relating, in part, to better fitting equipment, but it is not clear whether equipment can be individually fit in a robust, repeatable manner. Better fitting equipment may improve performance, but this is immaterial if fitting procedures cannot effectively match an individual to their optimum. An effective fitting procedure must be repeatable, unbiased and communicable for improvements to be significantly widespread and launch monitors may facilitate this better than previously possible.

Procedures which fit golfers to equipment based on anthropometric or other non-dynamic characteristics are somewhat like the procedures used in running shoe prescription, which have been extensively studied and are unlikely to be consistently precise. It is possible that fitting golf equipment based on anthropometric measurements could be more successful than fitting running shoes, but it is difficult to make a strong case for this in the absence of scientific evidence. Furthermore, research has shown that golfers cannot accurately determine between clubs with slightly different properties (Harper et al., 2005); which makes fitting based on a golfers perception unlikely to be an effective alternative.

Launch monitor technology allows fitting based on empirical measurements; increasing the repeatability and precision of observations. For example, if a launch monitor identified that a golfer hit the ball with greater spin than ideal, a lower spinning ball could be fit to the golfer; this is an evidence-based fitting. With the use of technology, it is possible to determine the equipment which results in the best performance for an individual and make fine adjustments to equipment based on data. The effect of incremental changes to equipment on performance can be evaluated in comparison to target launch

conditions and, on this basis, the use of launch monitors in fitting is a large improvement on more traditional methods; likely resulting in increased efficiency and reliability.

Day-to-day variability in performance may limit the effectiveness of equipment fitting, including fitting which is based on objective measurements. It is generally accepted that better golfers have lower variability in outcome variables, but even highly skilled golfers display variability both within and between a testing session (Corke, 2015; Jones, 2019). For example, data recorded by Trackman on the PGA tour found the standard deviation of Dustin Johnson's driver clubhead speed in the 2018 season to be 2.1 mph with a range of 10.6 mph. As well as variability of the individual, variability in the environment, within a session or between the fitting and on-course performance, may also affect the reliability of fitting. Human and environmental variability may limit the effectiveness of equipment fitting, but skilled practitioners may be able to account for this in the fitting process.

Fitting equipment to an individual golfer could increase performance if optimum equipment characteristics can be identified but it is important to stress that these improvements are likely to vary on an individual basis; based on the golfer, the equipment and the process by which the equipment is fitted. Thus, whilst individual players may see performance benefits from better fitting equipment, these improvements may not be large or widespread enough to have had a significant effect on overall distance; at least at a professional level.

6. Development in the launch conditions of professional golfers since the introduction of launch monitor technology

There are many theoretical benefits of launch monitors but empirical evidence regarding these benefits is scarce. This is because no single measure encapsulates only the effect of launch monitors on performance. Considering overall changes in performance since the introduction in launch monitors can provide some context in which the effect of launch monitors can be evaluated, with the caveat that changes in overall performance may have many contributing factors.

The overall performance metric of primary interest is driving distance, which is reported annually by The R&A and USGA (The R&A and USGA, 2019). Data from this report indicates that driving distance underwent a steady increase during the 1990's and the early 2000's, with smaller annual fluctuations since 2004. The first introduction of commercially available launch monitors overlaps with the latter part of this increase but the introduction of other technologies, particularly multi-layered solid-core golf balls, also occurred in this time period. Changes in distance have been more modest since 2004 despite the continued growth of launch monitor usage, suggesting either that most performance gains were achieved soon after the introduction of launch monitors in the early 2000's, or that performance gains are small, and the benefit of their increased use are masked by yearly fluctuations.

It may be more revealing to consider changes in launch conditions rather than overall distance, since there may be fewer contributing factors. The main source of information on launch conditions are from the PGA Tour, which has used Trackman launch monitors to collect data at tournament events since 2007. Since the period of interest predates the data from the PGA Tour, alternative sources of launch

condition data from before 2007 were sought. Launch condition data from the Great North Open at Slaley Hall in 2002, the Volvo PGA Championship at Wentworth in 2003 and the BMW Championship at Wentworth in 2006 were included for this purpose (Table 1). Data at these tournaments were collected using two different launch monitors, a camera-based model in 2002 and 2003 and a Trackman in 2006. Data in 2002 and 2003 was collected from shots hit on the range, whereas data in 2006 was collected during tournament play. Caution should be applied when comparing results from a single tournament to average results from a season, but the data gives an indication of the potential changes which might have occurred.

Table 1 Launch conditions measured at professional tournaments

	2002	2003	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Clubhead Speed (mph)	-	-	109	112.4	112.3	111.7	112.6	112.8	113.0	113.2	113.0	113.2	112.9	113.9	113.7
Ball Speed (mph)	158	159	163	165.4	165.2	165.2	166.2	166.8	167.2	167.4	167.2	167.7	167.7	168.8	169.2
Launch Angle (°)	10.9	9.7	10.6	10.8	11.3	11.3	10.7	10.8	10.9	10.9	11.0	10.8	10.5	11.1	11.1
Spin (RPM)	2725	2891	2733	2814	2670	2670	2714	2667	2686	2639	2619	2599	2544	2578	2641

Between 2007 and 2018, clubhead and ball speed increased by 1.3 and 3.8 mph respectively, launch angle increased by 0.3° and spin decreased by 173 rpm. Prior to 2007, data from isolated tournaments suggest that clubhead and ball speed increased from 2002 to 2007; which would be expected given the changes in driving distance reported during this period. Due to a lack of data, it is not possible to know if changes in clubhead and ball speed stabilised at the same time as changes in driving distance; around 2004. The clubhead and ball speeds observed at the BMW Championship in 2006 were slower than on the PGA Tour in 2007 but may not reflect the overall trend for the year. Differences between launch angle and spin rate were smaller than differences in clubhead and ball speed, especially when considering the data from before 2007.

To further understand changes in launch conditions, the data from each shot recorded by Trackman on the PGA Tour from 2007 to 2018 was used as input into a forced entry multiple linear regression, with year as the outcome variable and ball speed, launch angle and spin as predictors (Table 2). The coefficients of this model suggest a small increase in ball speed and launch angle over the time period and minimal change in spin rate. However, care should be taken when interpreting these results, as the model is only able to explain 37% of the variance in the dataset.

Table 2 Multiple linear regression of launch conditions against year.

	$R^2 = 0.37$	$F = 2050, P < 0.01$	
	b	SE B	p
(Intercept)	1999.2	0.207	< 0.01
Ball speed	0.08	0.001	< 0.01
Launch Angle	0.03	0.003	< 0.01
Spin	-0.00	0.00	< 0.01

To separate the effect of changes in ball speed and other launch conditions on distance, the 2007-2018 launch conditions were input into a ball flight simulator. This simulated the expected ball flight for a solid-core tour-standard golf ball in fixed environmental conditions; temperature of 75°F, pressure of 30 mmHg and humidity of 50%. After this initial simulation, two further sets of simulations were performed; the first with a constant ball speed equal to the average ball speed over the period and the second with constant launch conditions equal to the average launch angle and spin over the period (Figure 1). This approach allowed the effect of changes in ball speed to be investigated separately from other launch conditions.

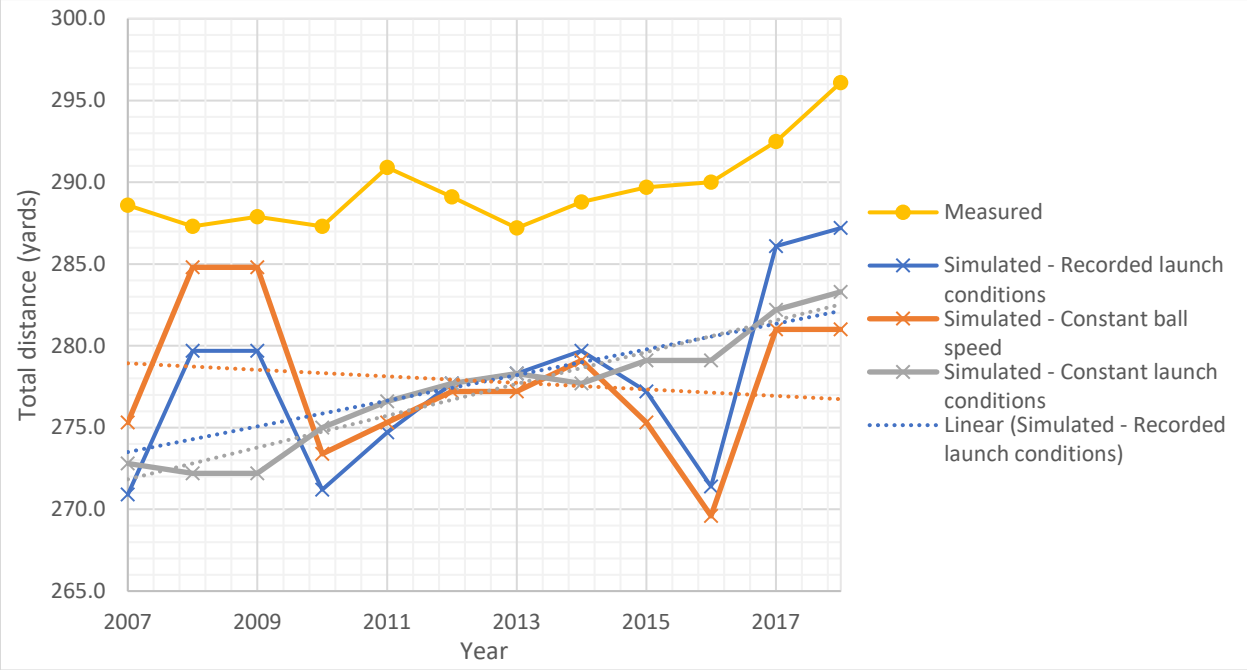

Figure 1 Results of ball flight simulations from measured and theoretical launch conditions.

The estimated total distance provided by the simulations were less than the observed distances in competition. There are several explanations for why the model might not accurately reflect the measured distance, including differences between the simulation and the real world in environment or bounce and roll. The simulation with constant launch conditions shows a pattern of gradual increase, whilst the simulation with constant ball speed shows larger fluctuations year to year with no trend toward increasing distance. The results could be interpreted as indicating that increases in distance over the period are more due to increases in ball speed than changes in launch condition. The year to year fluctuations in the simulated distance suggest that some care should be taken when interpreting the results of the simulation model, as these fluctuations are not observed in the measured data.

Overall, it is possible to suggest that launch conditions have changed prior to 2007, certainly toward increased clubhead and ball speed and potentially toward increased launch angle and decreased spin rate. However, the influencing factors behind these potential changes are not clear. Launch monitor technology might be a factor, but other factors, such as multi-layered solid-core golf balls, might have played more of a role. Since 2007, launch monitor use and sophistication has developed, but launch

conditions have remained relatively stable. There may be a small trend toward increasing ball speed or launch angle during this time period, but differences are much smaller than prior to 2007.

7. Summary

In summary, it is likely that the increased availability and use of sophisticated launch monitors has had a positive affect on performance due to the quality of feedback provided to the golfer or practitioner. The size of this effect is unclear but considering overall changes in performance since the introduction of launch monitors the size of this effect is likely to be small. Alternatively, the size of the effect may be smaller in professional golfers, who already have a high level of performance, but it is difficult to test or quantify these hypotheses without detailed information from all levels of the game. The almost universal use of launch monitors by modern professional golfers, coaches and club fitters typifies the way launch monitor technology has been embraced by the modern golf industry and may be interpreted as evidence of the value of the technology. However, despite a logical path of improvement and an anecdotal belief in their effect, there does not appear to be enough evidence to conclude that increased use of launch monitor technology has contributed significantly to a change in distance.

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Appendix A – List of Figures

Appendix B – List of Tables