TRACK MAN

COOLCLUBS

Shot details

CLUB
Club speed【mph】 クラブのヘッドスピード
Attack angle【deg】 ボールに対してクラブの入射角度・・・0を基準にマイナス数値はボールに対してダウンブローで入射、逆にプラスはボールに対してアッパーブローで入射してきている事を意味している。 例）DRIVER・・・0～＋3　6IRON・・・－2～－5
Club path【deg】 クラブの軌道・・・0をストレート軌道にマイナス数値は左（アウトサイトイン）、プラス数値は右（インサイドアウト）にクラブの軌道が動いている。
Swing plane (Vertical Swing plane)【deg】 インパクト時のクラブ角度・・・インパクトした時のクラブの角度（ライ角）
Swing direction (horizontal swing plane)【deg】 スイングの面・・・スイングを面で考えた時にどちらを向いているか。マイナス数値は面が左を、プラス数値は面が右を向いている状態。
Dynamic loft【deg】 クラブの角度・・・インパクト時のクラブ角度（ハンドファースト）
Face angle【deg】 フェースの向き・・・インパクト時のフェースの向き。マイナス数値は左に向き、プラス数値は右に向いていることを意味している。

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LAUNCH
Ball speed【mph】 ボールの初速　1mph 早くなると 2yards 距離が伸びる
Smash factor ボールの強さ・・・ball speed をclub speed で割った数値の値。
Launch angle (Vertical launch angle)【deg】 打出し角・・・ボールの上下、打出していく時の角度。
Launch direction (horizontal angle)【deg】 打出し方向・・・ボールの左右への打出し角度。マイナス数値は左に、プラス数値は右に打出している角度。
Spin rate【rpm】 スピン量・・・ボールの1分間あたりのスピン量。 例）DRIVER・・・2000～2500　6 IRON・・・5500～6000
Spin axis【deg】 回転軸・・・回転軸を平行に考え0の値としたときに、マイナス数値は回転軸が左に傾きスライス回転がかかり、プラス数値は回転軸が右に傾き フック回転がかかっている。
Face to path Face angle と club path の間に生じた差。

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Shot details

LANDING
Max height【yds】 最高到達点・・・ボールを打出してから最高到達点に達したときの、地面とボールとの距離。
Carry【yds】 距離・・・ボールが落下するまでの距離
Side【yds】 曲り幅・・・ボールが地面に落ちるまでの左右の曲り幅の値。Rは右に、Lは左に曲がっていることを示す。
Flight time【s】 滞空時間
Landing angle【deg】 落下角度・・・地面に落ちる際のボールの落下角度。

FOCUS: The Secret Of The Straight Shot

The correlation between *attack angle/swing plane* to *face angle/club path* and its impact on the trajectory of the ball leads to a paradigm shift in the world of golf. In this in-depth interview, Fredrik Tuxen – CTO at ISG and inventor of TrackMan™ – explains the secret behind the straight shot and reveals that all golfers should be instructed according to a new set of ball flight laws.

Fredrik, how would you define a straight shot?

A straight shot is a shot with a trajectory that starts directly on the target line, i.e., with a horizontal launch angle of 0 degrees, and where there is no draw or fade (assuming no cross wind). This happens when the spin axis is 0 degrees. So in short, a straight shot means: horizontal launch angle 0 degrees and spin axis 0 degrees.

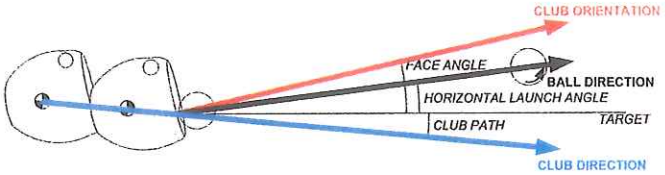
So what determines the initial direction of the ball (HLA)?

The horizontal launch angle is determined by only two parameters, the club path and the face angle. As a rule of thumb, the horizontal launch angle is 15% determined by the club path and 85% determined by the face angle. For example, assume a club path of +6.7 degrees (6.7 degrees inside-out for a right-handed player) and a face angle of -1 degree (1 degree closed for a right-handed player). This would result in a horizontal launch angle of 0 degrees (ball starting at the target line).

> "According to the "old" ball flight laws, the initial direction of the ball (HLA) is 100% dictated by the club path. All the scientific people in the golf industry know that this is very wrong"
>
> ***Fredrik Tuxen***

In other words, you are saying that the face angle is by far the most dominating factor for the initial direction of the ball. Is this not in direct contradiction with the "Ball Flight Laws"?

Yes it is. According to the "old" ball flight laws, the initial direction of the ball (HLA) is 100% dictated by the club path. All the scientific people in the golf industry know that this is wrong, yet still a lot of PGA professionals use the incorrect 'old' ball flight laws in teaching. And many PGA organizations around the world do not teach their apprentice and member professionals according to the 'true' ball flight laws. However, things are changing. Whenever I am doing presentations for PGA professionals I spend the necessary time to help them really understand the "true" ball flight laws. Hitting balls in front of TrackMan™, measuring club delivery, ball launch, and trajectory independently, is a real eye-opener in this process.



Top view of club and ball collision

How about the bending of the shot - isn't this also related to the club path and face angle relation?

Yes it is. According to the 'old' Ball Flight Laws, the shot will bend in direction according to the club face orientation relative to the path. In other words, if the face angle is more positive than the club path, this would create a fade (positive spin axis). Oppositely, with a face angle more negative than the club path, this would create a draw (negative spin axis).

However, there are some additions to this statement by the 'old' Ball Flight Laws that can affect the spin axis if the ball is impacted on the club face away from the center of gravity on the club head in the heel-toe direction: this is the so-called "horizontal gear effect". If the ball is impacted on the toe, the club head will rotate towards a more open club face. The counter reaction of the ball is to rotate the opposite way (like a gear). This will have the effect of tilting the spin axis towards the left (because of toe impact) – meaning a more negative spin axis compared to having no gear effect.

Then, in order to hit a straight shot with no draw or fade, what do you have to do?

Actually, there are three ways to hit a straight shot where horizontal launch angle and spin axis are 0 degrees (see Table 1).

Method 1 is by far the preferred way since this is the solution that will carry the furthest and is also independent of club and ball properties. In both methods 2 and 3, there are two things that the golfer needs to balance to create a straight shot. First, the club path and the face angle must be balanced to start the ball on the target line. Second, the ball must be hit on the toe or heel to compensate for the fade or draw that normally would be created by the difference between club path and face angle. The balancing is dependent on the club properties, the friction between the club, and ball and the club loft. So essentially, a lot of parameters need to be tuned precisely to offset one another.

Of course, it can be quite acceptable to have a trajectory which is a small draw or fade throughout the set, but you would then be giving up a little distance compared to the "Classic" swing off Method 1.

(continues)

FOCUS: The Secret Of The Straight Shot (continued)

	Method 1 "Classic"	Method 2 "Inside-Out"	Method 3 "Outside-In"
Club Path	0 deg	Positive (inside-out)	Negative (outside-in)
Face Angle	0 deg	Negative	Positive
Impact Location	Center Impact	Heel Impact	Toe Impact
Carry Distance	Longest *Highest ball speed*	Shortest *Heel club head speed lower than center club head speed*	Medium *Toe club head speed higher than center club head speed*

Table 1: Ways to hit a straight shot

How do you know when you're there – i.e., when the club path/face angle relation is perfect?

It is impossible to determine what the club path and face angle are without a measurement device. During the club and ball contact time of around 1/2000 of a second, the club path (and attack angle) change approximately 1 degree, which is about the accuracy required in order to be able to work with the numbers!

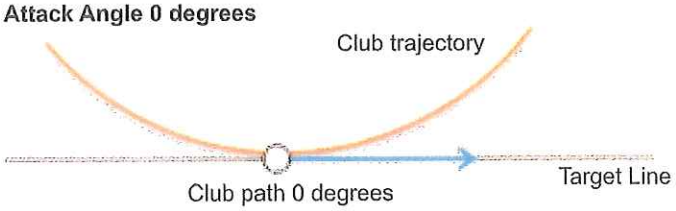
In traditional digital video analysis, the time between each picture is around 1/60 of a second, meaning there is no chance at all to determine the magnitudes of club path and attack angle. Currently available on the market, I am only aware of TrackMan™ having the ability to provide these important data with the sufficient high accuracy in a non-lab environment.

It is important to realize the difference between the *club path*, which is the horizontal direction of the club head at impact, and the *horizontal swing plane*, which is the direction of the club head at the bottom of the swing arc. Let me illustrate with an example: If the horizontal swing plane is 0 degrees and the attack angle is 0 degrees, then the club path will be 0 degrees. However, if the attack angle is -5 degrees (downward 5 degrees) with the same horizontal swing plane of 0 degrees, then the club path would be around +5 degrees (5 degrees inside-out) with the assumption of a 45 degree vertical swing plane.

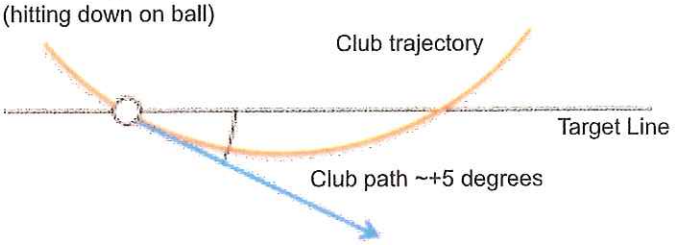
Note that a horizontal swing plane of 0 degrees from a video taken directly down the target line would show the club being on the perfect plane both before and after impact. But in the case of an 8-9 iron with an attack angle of -5 degrees (typical) and a horizontal swing plane of 0 degrees, then the club path would be positive (inside-out) around +3 degrees (only 3 degrees because of a vertical swing plane of 57 degrees for 8-9 irons).

Top view of right-handed swing
(0 degree horizontal swing plane, 45 degree vertical swing plane)

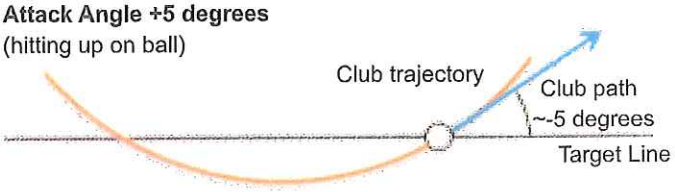
Attack Angle 0 degrees



Attack Angle -5 degrees
(hitting down on ball)



Attack Angle +5 degrees
(hitting up on ball)



Difference between *club path* and *horizontal swing plane* depending on attack angle

How good are the tour pros at getting these numbers right?

The tour pros are amazingly good at being consistent with their club path and face angle. Of all the tour pro data I have ever seen, Jim Furyk is the one with the most consistent club path and face angle (about 0.4 degrees in consistency with his driver), and in addition Furyk's average club path and face angle for the data I have seen are exactly 0 degrees. I am convinced that this is one of the reasons Furyk is always in the top rankings on fairways hit.

Many of the tour pros are far from Furyk's 0 degree club path/face angle standards. A big part of the pros either hit a small draw or small fade deliberately. Among tour pros, club path ranges from about -6 degrees to +6 degrees. Kenny Perry has an inside-out club path of +6 degrees with his driver and deliberately hits a big draw, while on the other side, Colin Montgomery has an outside-in club path of around -6 degrees on his drives and deliberately hits a big fade.

(continues)

FOCUS: The Secret Of The Straight Shot (continued)

Can amateur golfers – and also those with middle and high handicaps – achieve these ideal numbers?

Yes they can. The only requirement is that you are swinging the club fairly consistently. But through proper guidance, without actually changing the swing, but only adjusting ball position and setup alignment, it is possible for any decent golfer to get the "Classic" impact (club path and face angle at 0 degrees). Using a club head with a static open or closed face can also in some situations help the average golfer get close to the "Classic" impact much more quickly.

However, I will always recommend consulting your local teaching professional when trying to improve these swing variables. This will help ensure that you don't end up with an awkward swing that might be difficult to repeat and that might even harm your body.

> "The challenge is now to communicate and implement this message of the "true" ball flight laws in the golfing community at large"
>
> ***Fredrik Tuxen***

What other discoveries are left to make regarding club path/face angle and the straight shot?

There will always be new aspects to discover in this connection, but honestly, I think the current focus should be on this very important change of thinking, "what determines the direction and curvature of ball flight and how you change it". The correlation between attack angle/swing plane to face angle/club path and its impact on the trajectory of the ball is such a paradigm shift that the challenge is now to communicate and implement this message and the "true" ball flight laws in the golfing community at large so that pros and teachers all over the world can start implementing these facts in their instruction for the benefit of all golfers. Golfers today don't improve their golf nearly as fast as they could – now they get the tools to deal with this.

FOCUS: The Secret of the `Straight Shot´ II

In the January Newsletter #4, ISG CTO and TrackMan™ inventor Fredrik Tuxen talked about the straight shot and the new ball flight laws. For this in-depth interview, Tuxen expands upon the January article and reveals that horizontal swing planes must vary in order to accommodate the optimal Angles of Attack for different clubs (i.e. Driver vs. Irons).

Tuxen then continues by sharing newly discovered science about the implications of horizontal face impact position and how it relates to ball flight. These findings will shock any instructor who has built a teaching methodology around the mantra: "Ball Flight doesn't lie."

TrackMan™'s Club Delivery, launch, and ball flight data reveal many interesting things about the Ball Flight Laws.

First of all, the data reveal that a shot's Horizontal Launch Angle (HLA) is 85% determined by face angle and only 15% determined by club path. This means that starting a shot perfectly on line (0° HLA) not only can be accomplished if the club path is 0° and the face angle is 0°, but also if, for example, the club path is + 6.7° (inside-out) and the face angle is 1° closed (relative to the target line)! This is in direct contradiction to the 'old' Ball Flight Laws, which explained the starting direction of the ball (HLA) is determined by the club path.

This was the central focus of our in-depth interview with Fredrik Tuxen in the January Newsletter. But there are many other factors that combine to result in a straight shot.

What are the keys to achieving the optimal, straight shot?

In terms of club delivery, it is fairly simple since there are just three parameters in play. To hit a straight and effective shot at the target, you need:

1. Club Path ZERO
2. Face Angle ZERO
3. Impact in the center of the clubface.

Regardless if you are a weekend golfer or full status member on the PGA TOUR – this will work!

How close to 0 deg needs the club path and face angle be for achieving a 'straight shot'?

If your horizontal launch angle is within +/-1° and your spin axis is within +/-2°, you will consider it being a straight shot.

Taking this one step further, the requirement this puts on your club path and face angle depends on what club you are hitting.

> *"For years we have heard the mantra 'swing all clubs the same way'. But I would not agree to that"*
>
> ***Fredrik Tuxen***
> *CTO at ISG*

For a 6 iron, if the club path and face angle are both between +/- 1°, this would, more or less, guarantee a straight shot (assuming center hit). But for the Driver, it is required that the club path and face angle are both between +/- 0.5° to achieve the straight shot (assuming center hit).

Why is it more sensitive for the Driver than for the 6 iron?

As a rule of thumb, for a 6 iron the ball's spin axis will be tilted two times the difference between the face angle and the club path, whereas for the Driver, the ball's spin axis will be tilted 4 times the difference between the club path and the face angle. So if face angle is 5° and club path is 3°, then for a driver the spin axis will be around 8°, whereas for a 6 iron the spin axis would be around 4°. To understand why, we have to look at the so-called D-plane.

The D-plane is the wedge-shaped plane between two 3-dimensional directions: 1) clubhead direction at impact which is described by attack angle and club path and 2) clubface orientation at impact which is described by dynamic loft and face angle. In the figure below, the yellow shaded wedge-shaped plane is the D-plane. Note that the angle of the D-plane is actually the spin loft.

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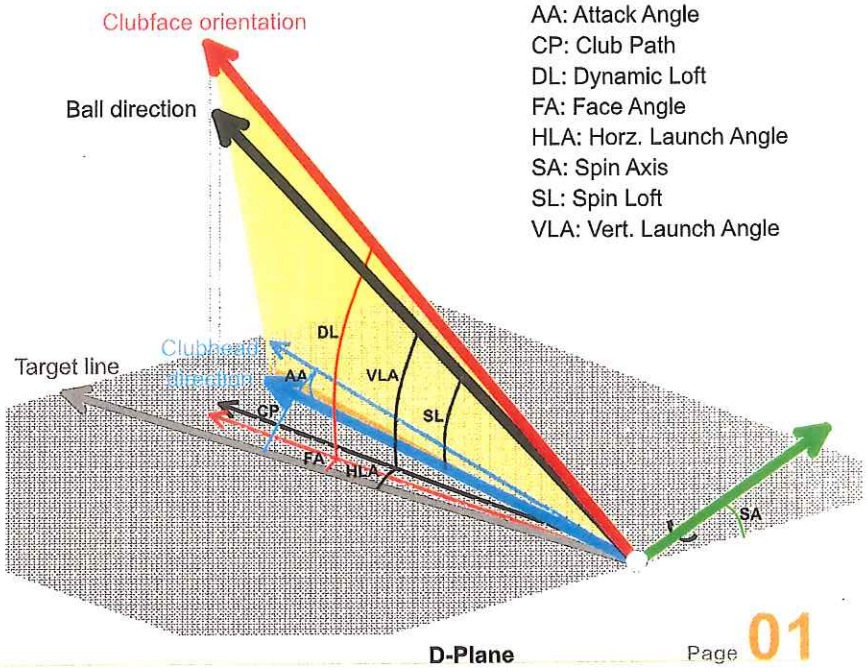


AA: Attack Angle
CP: Club Path
DL: Dynamic Loft
FA: Face Angle
HLA: Horz. Launch Angle
SA: Spin Axis
SL: Spin Loft
VLA: Vert. Launch Angle

D-Plane

FOCUS: The Secret of the `Straight Shot´ II

The laws of physics tell us:
- the initial direction of the ball will always happen in the D-plane
- assuming center impact on the clubface, the spin axis will be 90 degrees relative to the D-plane.

For a Driver, the D-plane is a much more narrow 'wedge' than for a 6 iron. This is because the club loft is much less with a driver. The consequence is that for a certain difference between face angle and club path, the D-plane will be tilted more the lower the loft of the club. Since the spin loft of a driver shot is around half the spin loft of a 6 iron shot, the result is the spin axis of a 6 iron shot will only be half that of a Driver shot having the same delta between club path and face angle.

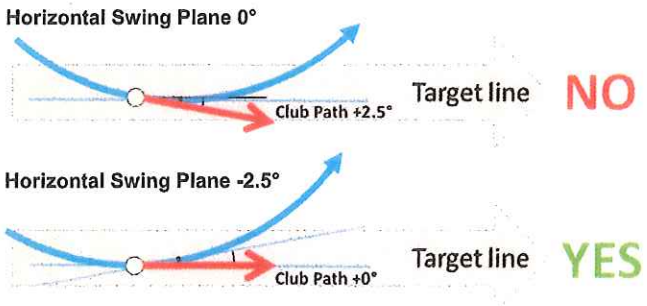
With club path being such an important factor, attack angle must be another key factor?

Yes it is. For years we have heard the mantra 'swing all clubs the same way'. But I would not agree to that. Golfers need different swings to be most effective with their shots. In order to take a divot after impacting the ball (irons), you need to hit down on the ball – negative Attack Angle. Conversely, hitting up on the ball – positive Attack Angle – with the driver enables you to maximize your distance for your club head speed.

So, let's assume that your vertical swing plane with a 6 iron is 60° and your attack angle is -5°. In order to create a straight shot, your goal is a club path of 0°. How can this be achieved? The answer is a Horizontal Swing Plane of -2.5°, which means aim 2.5° left of the target line with your swing plane.

In summary, for a swing having a 60° vertical swing plane, an attack angle of -5°, and a horizontal swing plane of -2.5°, the result will be a club path of 0°.

Clubhead Trajectory - TOP VIEW
(-5° Attack Angle, 60° Vertical Swing Plane)



The mark I indicates the bottom of the swing

With driver, the vertical swing plane is typically around 45°. Assuming a positive attack angle of 2° is desired, a horizontal swing plane of +2° is required to achieve the goal of club path 0°. With the driver, aim 2° right of the target with your swing plane.
In summary, you need two different swings – or at least two different set-ups – to be most effective with the Driver and irons.

Does that apply throughout the set?

If you are hitting down -5° with every iron, the shorter the iron you hit the steeper your vertical swing plane will be and the lesser you'll have to compensate your horizontal swing plane to achieve a club path of 0°.

The shorter the iron with the same attack angle, the more direct at the target you should aim. In other words, it is more important to compensate – aim left – with the 3 iron than with the 8 iron.

CORRELATION BETWEEN HORIZONTAL SWING PLANE AND CLUB PATH

	ATTACK ANGLE [deg]	VERT. SW. PLANE [deg]	HORZ. SW. PLANE [deg]		CLUB PATH [deg]	
DRIVER	+2	45	0	=>	-2	
DRIVER	+2	45	+2	=>	0	*
6 IRON	-5	60	0	=>	+2.5	
6 IRON	-5	60	-2.5	=>	0	*
	doesn't matter	90 **	0	=>	0	

* Optimal combination

** In the hypothetical scenario of vertical swing plane equals 90 degrees, club path would always equal horizontal swing plane.

These charts and figures can be rather academic. Can you explain it in a very down to earth way?

I can try: We can say that with the driver you need the same value for attack angle and horizontal swing plane in order to obtain a 0° club path – for example if your attack angle is +3°, the horizontal swing plane needs to be +3° to obtain a club path of 0°. And for irons it is half effect – for example if attack angle is -4°, the horizontal swing plane needs to be -2° to obtain zero club path. In short, aim left when hitting down on the ball and aim right when hitting up upon the ball. And remember when I say 'aim left' I mean the swing plane, the face angle should always be aligned towards the target line.

Ball position is an issue here as well?

Absolutely. If you move the ball back towards your right foot for the same horizontal swing plane, the effect will be a steeper attack angle (more negative) and a more inside-out club path (more positive). So, in order to maintain a zero club path while moving the ball further back in your stance, you simply have to rotate your horizontal swing plane towards the left (more open stance).

Before we discussed that the shorter the club and the steeper the vertical swing plane, the less you had to compensate your horizontal swing plane away from the target line.

(continues)

FOCUS: The Secret of the `Straight Shot´ II

However, if you add the effect of moving the ball backwards in your stance progressively with the shorter club, it is possible to counter balance this so you can end up with the same horizontal swing plane (aiming) for all your irons! Other than that, ball position is very much a teaching philosophy in which I will not take a strong position - but I can analyze the data! Some teachers want to keep the same ball position throughout the set while others speak for moving the ball progressively towards the right foot. Analyzing the data I would probably tend towards the idea of moving the ball backwards, since this could enable your setup to be the same for all irons and hybrids.

> "However, if you impact the ball just 1 dimple (0.14 inch) towards the heel of your driver with face angle being zero at point of impact on the club face, it creates a spin axis of +6° (fade spin) and the ball will end up 10 yards right of the target line on a 250 yards carry shot."
>
> ***Fredrik Tuxen***

We know that if club path is 0° and face angle is 0°, the ball will start on the target line. What makes the ball go offline?

wo things make the ball go offline. Launch conditions – i.e. horizontal launch angle, either a push or a pull, which is determined by face angle and club path, and secondly the spin axis which is responsible for the curving of the shot. Then, of course, other factors not related to the swing itself, such as wind.

There are two contributions to the tilting of the spin-axis.; The first is the tilting of the D-plane, which as discussed earlier, happens if club path does not equal face angle. The second contribution to the tilting of spin-axis is the result of horizontal gear effect. The horizontal gear effect occurs when the ball is impacted anywhere but the center of gravity of the club head in the heel-toe direction. If the ball is hit towards the toe, the club head will twist clockwise, and the gear effect causes the ball spin-axis to tilt anti clockwise i.e. a draw spin. If the ball is hit towards the heel, we'll get the opposite effect, or a fade spin-axis tilt.

How close to center impact do you need to be? How big is the effect of off-center hits?

.mpact location and gear effect have a surprisingly significant effect on the curvature of a golf shot. If we start with the ideal situation with a face angle of 0° and a club path of 0° and impacting the ball in the center of gravity of the club face, then the ball will go straight. However, if you impact the ball just 1 dimple (0.14 inch) towards the heel of your driver, it creates a spin axis of +6° (fade spin) and the ball will end up 10 yards right of the target line on a 250 yards carry shot.

You will probably be on the fairway, but in a major with very narrow landing areas and firm turf conditions, the shot may be in jeopardy of missing the fairway. If you impact as much as half an inch towards the Toe, the dispersion will be 35 yards left of the target on a 250 yards carry!

Luckily the club manufactures have added a curvature to the club face (the bulge) on woods and drivers. This means that when you impact the ball on the heel your face angle at the impact point will most likely be closed, hereby starting the ball more left and tilting the D-plane towards a draw spin. The net effect will be a much straighter shot compared to the zero face angle situation.

Does horizontal gear effect have the same influence on an iron-shot as on a drive?

The spin created by the gear effect is a spin around a vertical axis (sidespin) that is added to the spin from the D-plane. The vertical spin from the horizontal gear effect tilts the spin axis. The contribution to the vertical spin is roughly the same in rpm's throughout the set for the same off-center distance, but because you get much less spin with the driver the effect of the added vertical spin is much more pronounced than with a wedge, for example. If we have a spin rate of 2500 rpm with the Driver and 10000 rpm with a wedge, the effect of 500 rpm of sidespin on the spin axis will be 11° for the driver and only a quarter of that, or 2.8°, for a wedge.

If we take an example of hitting a 6 iron with zero club path and face angle, and impacting the ball 1 dimple towards the toe of the club face, this will cause a spin axis of -2°, resulting in a shot being almost 2½ yards offline at 170 yards carry. A spin-axis of -2° is not a serious problem and often is what we refer to as a 'baby draw'. For comparison, a 2° spin axis could be originated from a center-impact 6-iron shot where the club path is 0° and the face angle is +1°; so a 1 dimple off-center impact has the same effect as 1° difference between club path and face angle on the spin axis for a 6 iron shot! For a driver shot, 1 dimple off-center corresponds to 1½° difference between club path and face angle.

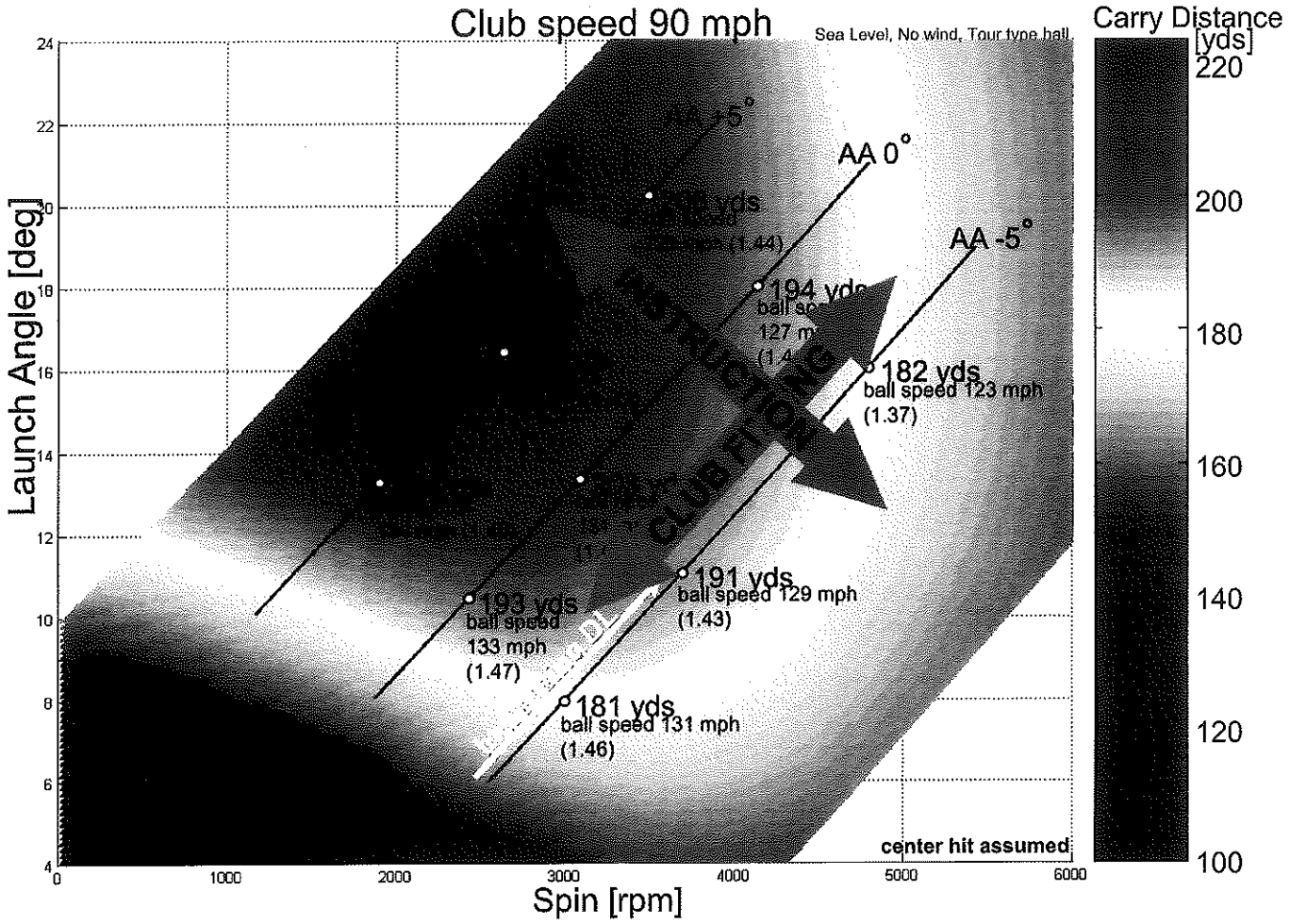
DRIVER: EFFECT OF OFF-CENTER HITS

CLUB PATH [deg]	FACE ANGLE [deg]	FACE IMPACT	HORZ. LAUNCH [deg]	SPIN AXIS [deg]	SIDE OFFLINE [deg]
0	0	Center	0	0	On Target
0	0	1 dimple (0.14") towards heel	0	+6	10 yds R at 250 yds
0	0	½" towards heel	0	+20	35 yds R at 250 yds

6 IRON: EFFECT OF OFF-CENTER HITS

CLUB PATH [deg]	FACE ANGLE [deg]	FACE IMPACT	HORZ. LAUNCH [deg]	SPIN AXIS [deg]	SIDE OFFLINE [deg]
0	0	Center	0	0	On Target
0	0	1 dimple (0.14") towards toe	0	-2	2½ yds L at 170 yds
0	0	½" towards toe	0	-7	8 yds L at 170 yds

*Typical MOI and COG assumed


Club speed 90 mph
Sea Level, No wind, Tour type ball
Carry Distance [yds]
220
200
180
160
140
120
100
Launch Angle [deg]
24
22
20
18
16
14
12
10
8
6
4
Spin [rpm]
0
1000
2000
3000
4000
5000
6000
AA +5°
AA 0°
AA -5°
194 yds
ball speed
127 m
(1.4
182 yds
ball speed 123 mph
(1.37)
191 yds
ball speed 129 mph
(1.43)
193 yds
ball speed
133 mph
(1.47)
181 yds
ball speed 131 mph
(1.46)
center hit assumed

TRACKMAN

PROGRESS REPORT: TRACKMAN COMBINE

Since its birth in May, hundreds of golfers, ranging from the world's top tour professionals all the way to high handicappers, have tested their shot-making abilities with the TrackMan Combine.

We've received tremendous positive feedback not just on the benchmarking merit of Combine, but on the game improvement and practice value of the process itself. Before we go into details let´s quickly remind you what the TrackMan combine is.

What is the TrackMan Combine?

1. Player hits shots at 10 targets/zones (60, 70, 80, 90, 100, 120, 140, 160, and 180 yds plus drives)

2. Player receives the following feedback:
- Average Distance from Pin at each target yardage
- Average Drive Distance
- Average Offline for Drives
- Score (0-100) for every shot category
- Percentile Rankings for every shot category
- Aggregate TrackMan Combine Score

This article highlights the top results so far and provides additional insight on TrackMan Combine scoring benchmarks by using PGA TOUR ShotLink data and more.

Top scores to date

While the maximum possible TrackMan Combine score is 100, such a score may prove impossible for any one player to achieve in a single session. To date, our best score is an 87 accomplished by LPGA Tour Professional and Rolex World Ranked #26 Sun Young Yoo.

Ms. Yoo's combine was completed during a training session with ...ier coaches at David Leadbetter Golf Academy in ChampionsGate, FL, just prior to her winning the Sybase Match Play Championship in Gladstone, NJ. In reviewing Ms. Yoo's TrackMan Combine results below, you can see she is a model of consistency with no glaring weaknesses:

TrackMan Combine: Sun Young Yoo

Target	Points	Avg. Dist from pin (yds)
60 yds	81	3.0
70 yds	90	2.4
80 yds	90	3.0
90 yds	85	4.3
100 yds	88	3.9
120 yds	95	2.8
140 yds	90	4.4
160 yds	91	5.5
180 yds	90	5.9
Drives	74	Carry 231.7 Side 7.2
Total score: 87		

Luke Donald and James Morrison currently share the lead for best men's Combine score with 86. Days after making his Combine score of 86, Luke Donald finished in 2nd place at the European PGA Tour's BMW PGA Championship at Wentworth Club and was tournament champion the following week at the Madrid Masters. Earlier in the season, James Morrison was the European PGA Tour's champion at Madeira Islands Open BPI event. You can review Donald's and Morrison's TrackMan Combine results below:

TrackMan Combine: Luke Donald

Target	Points	Avg. Dist from pin (yds)
60 yds	83	3.4
70 yds	85	3.2
80 yds	88	3.3
90 yds	86	3.6
100 yds	89	3.5
120 yds	96	2.8
140 yds	83	7.4
160 yds	84	7.7
180 yds	86	6.5
Drives	79	Carry 255.8 Side 9.1
Total score: 86		

TrackMan Combine: James Morrison

Target	Points	Avg. Dist from pin (yds)
60 yds	86	2.6
70 yds	75	4.7
80 yds	90	3.0
90 yds	80	5.0
100 yds	89	3.8
120 yds	88	4.8
140 yds	85	6.1
160 yds	86	7.0
180 yds	89	6.6
Drives	79	Carry 252.1 Side 6.4
Total score: 86		

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PROGRESS REPORT: TRACKMAN COMBINE

Our best Combine score turned in by an amateur is from Casey Baker, co-owner of Miles of Golf in Ann Arbor, MI. Baker, a top Michigan amateur, scored 84 on his Combine and later in the golf season captured the championship at one of Michigan's most prestigious amateur events, the GAM Championship. Baker commented, "The TrackMan Combine is an awesome test and process. It helped me realize my best layup yardage was 80 yards and not 100 yards as I had been playing to, not to mention it gave me a clear understanding of my strengths and weaknesses. It allowed me under pressure to have total confidence in my yardages. Following the combine, I've played some of the best tournament golf of my life, including a final round 65 at Flint Golf Club which helped me win the GAM Championship."

TrackMan Combine: Casey Baker

Target	Points	Avg. Dist from pin (yds)
60 yds	76	4.0
70 yds	85	3.3
80 yds	94	2.2
90 yds	83	4.8
100 yds	84	4.6
120 yds	85	5.2
140 yds	85	6.2
160 yds	83	8.3
180 yds	90	6.7
Drives	75	Carry 246.8 Side 9.6
Total score: 84		

Average Golfer

When describing the "average golfer", most industry professionals refer to the 18-handicapper. Using the TrackMan Combine database, we took all the 18-handicap results and averaged them for each scoring zone and drives, as well assigned the corresponding Combine score. In Table 1, you can see the shot-making ability for the "average 18-handicapper" produced a TrackMan Combine score of 42, with 90 yards being the strongest scoring zone.

Table 1: TrackMan Combine: 18 HCP average

Target	Points	Avg. Dist from pin (yds)
60 yds	34	13.7
70 yds	47	10.6
80 yds	50	12.5
90 yds	51	14.1
100 yds	50	15.8
120 yds	49	19.2
140 yds	49	24.0
160 yds	36	31.7
180 yds	24	50.6
Drives	30	Carry 160 Side 16.6
Total score: 42		

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PROGRESS REPORT: TRACKMAN COMBINE

Combine versus Shotlink

Knowing that no golfing reference is complete without comparisons to PGA TOUR data, we took 2010 PGA TOUR ShotLink statistics and contrasted them to TrackMan Combine scoring using Combine's scoring system. We looked at the average distance from the pin on shots hit at various target yardages, as well as drive carry and side during PGA TOUR events, which had been gathered by ShotLink. We then calculated each "implied scoring result" using TrackMan Combine's scoring system. The two tables below are the results. Table 2 represents best performance at each target. To clarify, this is not the same person hitting through all scoring zones, but rather a composite of PGA player statistics and our choosing the #1 stat/result for each target. Table 3 shows PGA TOUR averages.

Table 2: Best PGA TOUR implied score

Best for each target

Target	Points*	Avg. Dist** from pin (yds)
60 yds	89	2.9
70 yds	90	3.2
80 yds	91	3.5
90 yds	91	3.9
100 yds	92	4.2
120 yds	91	5.1
140 yds	91	6.2
160 yds	90	7.4
180 yds	89	8.8
Drives	96	Carry 285 Side 7.4
Total score: 91		

* ShotLink data converted to Combine scoring
** ShotLink Data

Table 3: Average PGA TOUR implied score

Target	Points*	Avg. Dist** from pin (yds)
60 yds	72	5.3
70 yds	76	5.5
80 yds	79	5.8
90 yds	81	6.1
100 yds	83	6.4
120 yds	85	7.1
140 yds	85	8.0
160 yds	85	9.1
180 yds	85	10.6
Drives	83	Carry 268 Side 8.5
Total score: 82		

* ShotLink data converted to Combine scoring
** ShotLink Data

As you can see from the above, taking the #1 result at each target from all players on the PGA TOUR results in an implied TrackMan Combine Total Score of 91, while the PGA TOUR average implied TrackMan Combine Total Score is 82. A technical note: standard TrackMan Combine results are based on landing (carry), but the two tables above that use ShotLink data are based on the final resting result for each scoring zone (including roll) and driver side result. As with Combine, the PGA TOUR computes its driving distance based on carry. It should further be noted that TrackMan Combine scores may be slightly better relative to the above PGA TOUR scores, because in the TrackMan Combine, golfers take 4 consecutive shots at the same target (so the participant effectively gets to make adjustments based on feedback very quickly), while naturally the PGA TOUR scores are based on course performance, where players just get one shot at a time.

Importance of hitting it close

How do we know these TrackMan Combine Scores map to improved scoring performance on the course, besides the testimonials we have received? One thing we looked at is the relationship between distance from the pin on approach shots and percentage of one putts made. Take a look at Table 4 below, where we took the PGA TOUR ShotLink results from each TrackMan Combine Scoring Zone and compared those under the assumption of being an Average PGA TOUR putter trying to one putt from the shot result distance.

Unbelievably, From 60 to 100 yards, assuming an average putter on the PGA TOUR (based on percentage of one putts from each distance), the #1 player on the PGA TOUR at TrackMan Combine yardages (60, 70, 80, 90, and 100 yards) is twice as likely to get up and down as the average PGA TOUR player. In other words, improving and benchmarking your accuracy with target practice using Combine or the TrackMan Range directly translates into superior results on the golf course.

Table 4: One putt made

	PGA TOUR Best for each target		PGA TOUR Average	
Target	Avg. Dist from pin (yds)	One Putt made	Avg. Dist from pin (yds)	One Putt made
60 yds	2.9	44.3%	5.3	20.7%
70 yds	3.2	40.1%	5.5	19.6%
80 yds	3.5	35.9%	5.8	18.6%
90 yds	3.9	31.8%	6.1	17.3%
100 yds	4.2	28.0%	6.4	16.1%
120 yds	5.1	21.6%	7.1	13.7%
140 yds	6.2	16.8%	8.0	11.0%
160 yds	7.4	12.7%	9.1	8.6%
180 yds	8.8	9.2%	10.6	6.2%

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Data From The Tours (continued)

Ball Speed

Continued Cabrera supremacy
Angel Cabrera recorded the highest ball speed and demonstrated Driver efficiency.

- Cabrera delivered the top 3 ball speeds.
- Cabrera delivered 5 of the 8 highest ball speeds.
- Three players (Angel Cabrera, Henrik Stenson and Nick Watney) delivered the top 18 ball speeds.
- Charles Howell III delivered the 19, 20, 21, 22, 26, 29 and 32 fastest ball speeds, hence no. 4 in the field when it comes to ball speed. However, Charles Howell III was not able to convert this speed efficiently into carry distance.
- On the other hand, Charles Howell III achieved a good total distance on his drives as his drives roll a lot. This is because Charles Howell III had 3 of the 6 lowest landing angles (17.3, 22.2, 23.3).
- Charles Howell III had the 5 lowest launch angles (3.9, 4.9, 5.1, 5.5, and 5.6 degrees).

RNK	PLAYER	HOLE	RND	BALL SPEED [mph]
1	Angel Cabrera	12	4	183.6
2	Angel Cabrera	18	4	183.0
3	Angel Cabrera	18	2	182.7
4	Nick Watney	18	4	182.6
5	Henrik Stenson	18	3	181.8
6	Nick Watney	12	3	181.5
7	Angel Cabrera	12	3	181.2
8	Angel Cabrera	18	3	181.2
9	Henrik Stenson	18	4	181.1
10	Nick Watney	12	4	180.7
11	Nick Watney	18	2	180.2
12	Nick Watney	18	3	180.1
13	Angel Cabrera	12	1	179.8
14	Nick Watney	12	2	179.7
15	Henrik Stenson	18	2	179.6
16	Nick Watney	18	1	179.5
17	Henrik Stenson	18	1	179.4
18	Angel Cabrera	18	1	177.5
19	Charles Howell III	18	2	177.1
20	Charles Howell III	12	3	177.0

Carry Distance

Angel Cabrera is not surprisingly the longest hitter
Angel Cabrera hit the drives with the two longest carries.

- Of all the shots captured by TrackMan™, Angel Cabrera hit the drive with the longest carry – 331 yards, recorded on the 12th hole during the last round.
- Cabrera's longest drive had his lowest recorded spin rate, 2014 rpm, and his highest launch angle of 13.3 degrees.
- Cabrera had 3 drives in the top 4 carry distance.
- Charley Hoffman had the 3rd longest drive – 319 yards on the 12th hole during the 3 round.
- Charles Howell III had no drives in the top 48 carry distances, even though all his club speeds rank in the top 32!
- Vijay Singh had only the 45th highest club head speed recorded (118 mph), but still had 4 shots among the 18 longest carries (8,13,14,18). He was extremely effective in converting club head speed to carry distance!

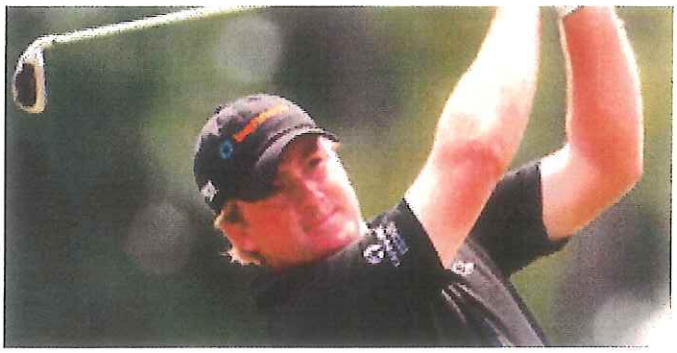
RNK	PLAYER	HOLE	RND	BALL CARRY [yds]
1	Angel Cabrera	12	4	331.1
2	Angel Cabrera	12	1	322.4
3	Charley Hoffman	12	3	319.7
4	Angel Cabrera	12	3	315.9
5	Brian Bateman	12	4	312.4
6	Boo Weekley	12	2	312.1
7	Nick Watney	12	2	310.7
8	Vijay Singh	12	3	308.9
9	Nick Watney	12	4	307.8
10	Daniel Chopra	12	4	306.9
11	Woody Austin	12	3	306.8
12	Angel Cabrera	18	3	305.9
13	Vijay Singh	12	2	305.9
14	Vijay Singh	12	4	304.4
15	Charley Hoffman	12	4	304.3
16	Woody Austin	12	1	304.1
17	Boo Weekley	12	2	302.5
18	Vijay Singh	18	2	300.9
19	Henrik Stenson	18	3	300.8
20	Charley Hoffman	18	4	299.7

Miscellaneous

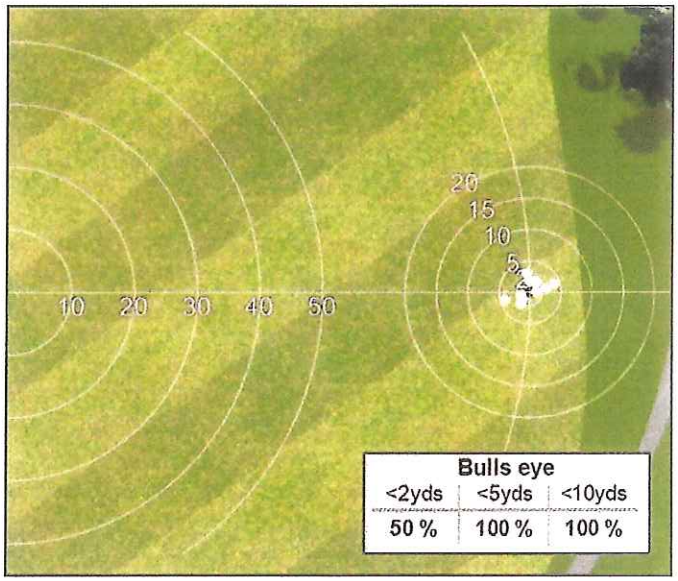
McDowell excels in approach shot test

Carrying out TrackMan™'s 83-yard Approach Test at Lake Nona in December 2007, top tour pro, Graeme McDowell, achieved an excellent score of 91 points.

With an average distance to the pin of 2.4 yards, McDowell was sharp with his 60 degrees wedge and displayed one of the weapons behind his ability to go on birdie streaks.



		LANDING			
Shot#	Club	Carry [yds]	Side [yds]	From Pin [yds]	Points
1	60°	82.6	3.0L	3.0	9
2	60°	83.0	1.9L	1.9	9
3	60°	78.9	1.2R	4.2	8
4	60°	81.6	0.5R	1.5	10
5	60°	86.9	1.4L	4.1	8
6	60°	84.0	1.6L	1.9	9
7	60°	85.6	0.6L	2.6	9
8	60°	81.8	1.0R	1.5	10
9	60°	81.6	1.8R	2.3	9
10	60°	84.1	0.1L	1.1	10
	AVERAGE	83.0	-0.4	2.4	



New instruction videos on the TrackMan™ website

5 brand new TrackMan™ Introduction videos have been added to the video section on the TrackMan™ website that also includes several videos with tour pros using TrackMan™ (such as Miguel Angel Jimenez and Graeme McDowell).

Go to the following link:
http://www.trackmangolf.com/index.php?introducingTrackMan
and watch the introduction videos that are entitled

* Introducing TrackMan™
* TrackMan™ Setup & Ease of Use
* Approach Practice and Approach Test*
* Driver Fitting
* Find your Distances

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FOCUS: Smash Factor (continued)

But do note that if you are hitting the very common high durability range balls the effective COR can easily be as low as 0.73 which will limit the smash factor realistically to about 1.41!

How much does the smash factor vary from club to club?

By using the equation above and assuming standard loft as being the SPIN LOFT and average male club head weights, the theoretical optimal smash factor throughout the set is shown in Table 1. For illustration, the corresponding club head speed and ball speed is shown where the club head speed has been scaled to match the average for the PGA TOUR.

CLUB	CLUB SPEED [mph]	SPIN LOFT [deg]	BALL SPEED [mph]	SMASH FACTOR []
Driver	112.6	10.0	167.9	1.49
3 wood	107.0	15.0	158.4	1.48
5 wood	103.0	21.0	149.6	1.45
3 iron	97.8	21.0	142.1	1.45
4 iron	95.8	23.5	137.2	1.43
5 iron	94.3	26.0	132.4	1.40
6 iron	92.3	29.0	126.7	1.37
7 iron	90.0	33.0	119.2	1.33
8 iron	86.8	37.0	111.0	1.28
9 iron	85.3	41.0	103.3	1.21
PW	83.2	46.0	93.7	1.13
SW	80.7	56.0	75.1	0.93

Table 1: Optimal smash factor from spin loft. Assuming premium ball being used.

The results in Table 1 agree very well with our observations of male and female tour pros for longer irons and woods. Some examples are presented in Table 2.

CLUB	OPTIMAL from SPIN LOFT	PGA #1	PGA #2	PGA #3	LPGA #1	LPGA #2
Driver	1.49	1.50	1.48	1.48	1.49	1.49
3 wood	1.48	1.47		1.47	1.48	1.48
5 wood	1.45				1.48	1.48
3 iron	1.45	1.40	1.40		1.48	
4 iron	1.43	1.40	1.40	1.46	1.48	1.46
5 iron	1.40	1.38	1.39	1.45	1.44	1.42
6 iron	1.37	1.36	1.38	1.41	1.44	1.40
7 iron	1.33	1.32	1.34	1.40	1.39	1.35
8 iron	1.28	1.28	1.31	1.37	1.35	1.34
9 iron	1.21	1.22	1.26	1.34	1.30	1.27
PW	1.13	1.19	1.21	1.28	1.27	1.21
SW	0.93			1.14		
Club Speed 5 iron		*98.4*	*94.9*	*93.9*	*82.1*	*78.0*
Club Speed Driver		*109.8*	*107.6*	*114.8*	*94.6*	*91.2*

Table 2: Smash factor of PGA and LPGA players.

In general, both the PGA and LPGA players seem to be right at the optimal smash factor - and sometimes actually slightly above. In particular on the shorter irons, the pros are achieving a higher smash factor than what is reasonably expected from the club loft. The likely explanation for these high smash factors is that the spin loft is actually lower than the club loft which will be the case if the ball is impacted with the hands leading the club head.

Another interesting observation in Table 2 is that LPGA players seem to generate higher smash factors for the longer irons in particular. A possible explanation for this is that there is a small increase in club/ball COR at lower club head speeds. Also the ladies tend to use more cavity back type of clubs which has slightly higher COR and slightly lower loft than corresponding blade type which is preferred by most PGA Tour players.

Have you come across any smash factors on the pro scene that stand out, positive or negative?

One thing I have found very remarkable is how consistently the tour pros are able to produce smash factors of 1.48 and above with their drivers.

One of the biggest concrete surprises I have had was when we had the Danish European Tour player Mads Vibe-Hastrup in front of TrackMan™ with his driver.

Mads initially had a smash factor of 1.42 (110 mph club head speed, 156 mph ball speed)! Interestingly enough, he was launching the ball at 14 degrees with a spin rate of 2500 rpm, so if you only looked at the ball speed, launch angle and spin rate, the data would look very close to optimal. But by measuring club head speed and ball speed independently, thus having a fully measured smash factor result, we could immediately see that something was very far from optimal.

It turned out that Mads was hitting significantly down on the ball and impacted the ball high on the club face, slightly towards the heel. As you can read elsewhere in this newsletter, Mads achieved the 1.48-1.49 smash factor with a significant distance increase in return for his hard work on TrackMan™.

Another surprise was LPGA player Natalie Gulbis during Wendy's 3-Tour Challenge in 2007 (see also newsletter #2). She was consistently getting smash factors around 1.42. So despite her very nice positive attack angle, she was at this event losing about 12 yards carry compared to her potential.

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FOCUS: Smash Factor (continued)

How does TrackMan™ actually measure smash factor?

While the calculation of smash factor is simply the ratio between ball speed and club head speed, there are some details that are worth noticing. The ball speed is very well defined, and TrackMan™ measures the ball speed directly within 0.1 mph.

However, with the club head speed things are not quite as simple. It might be a surprise to many golfers, but the club head speed actually varies significantly depending on where on the club face you are looking. On average there is a 14% difference between heel and toe speed. This means that if you have 100 mph club head speed in the center of the club face, the speed of the heel will be around 93 mph and the toe 107 mph. This is primarily due to two things: 1) the further distance from grip to the toe of the club compared to the grip to heel 2) the rotation of the club head during the downswing. Likewise, the club head speed low on the club face is higher than high on the club face.

TrackMan™ always refers to the club head speed at the center of the club face, but because of around a 3/8 inch uncertainty of the location of the radar reflection point on the back of the club face, this leads to an accuracy of the club head speed measurement of the TrackMan™ of ±1 mph with reference to the center of the club face.

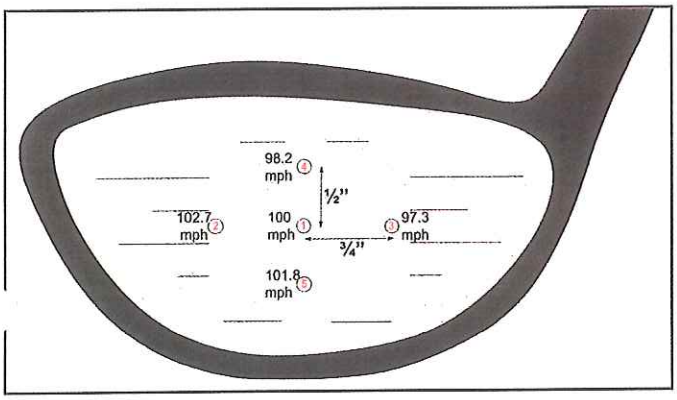


Figure 1: Typical club head speed variation across the club face.

Let me give you an example of how this affects your smash factor measurement: Let us assume a club head speed of 100 mph (in the center of the club face) with a dead center ball impact producing 148 mph ball speed. This should theoretically give a smash factor of 1.48. However, due to the uncertainty of the exact location of the club head speed reading of the TrackMan™, the smash factor might be measured somewhere between 148/101 and 148/99 (1.465 to 1.495).

Let us then take the other case where the ball is impacted at the 5 different locations indicated on the club face above but having the club delivered with the same speed and spin loft to the ball (Figure 1).The club head measured by the TrackMan™ is independent on where on the club face the ball is impacted, so this will be 100 mph for all the 5 different impact locations. In the table below, an example of a realistic variation of the COR variation across the club face has been used. Maximum ball speed is obtained with impact ¾ of an inch towards the toe despite the lower COR of 0.81 at this point on the club face.

IMPACT	CLUB SPEED [mph]	COR [-]	BALL SPEED [mph]	TrackMan SMASH FACTOR [-]	Theoretical SMASH FACTOR [-]
1 CENTER	100.0	0.83	148.0	1.480	1.480
2 ¾" TOE	102.7	0.81	150.3	1.463	1.463
3 ¾" HEEL	97.3	0.81	142.4	1.464	1.464
4 ½" HIGH	98.2	0.82	144.5	1.472	1.472
5 ½" LOW	101.8	0.82	149.8	1.472	1.472

Table 3: Smash factor variation across club face. Assuming no club head rotation due to off-center hits.

If the smash factor was calculated from straight theory (last column in table 3): ball speed divided with the club head speed at point of impact, the smash factor producing the highest 150.3 mph ball speed would come out as 1.463.

Since ball speed (together with launch angle and spin rate) is what matters for the ball flight, by using the center of the club face as reference for the club head speed measurement, maximizing your TrackMan™ smash factor means also maximizing your ball speed for a given physical strength.

This means that in the case the ball is impacted towards the toe (higher club head speed) but still with a high COR and no loss of energy due to twisting of the club head during impact, the theoretical maximum smash factor might be 1.48, but the TrackMan™ smash factor could come out higher.

Are there more smash factor discoveries left to make?

We have so far spent most of our time looking at smash factors for drivers. We have now started looking at smash factors for irons. The tour pros seem to generate a slightly higher smash factor with their irons, especially the shorter ones, than what you would expect from the loft of the club. So we are currently analyzing the tour pros' club delivery – in particular attack angle and dynamic loft to understand more precisely what the world's best ball strikers are doing. The results of this will be very valuable for both fitting and instruction.

Focus: Attack Angle (continued)

Are you saying that hitting down on the ball has no impact on the spin rate? That sounds very surprising...

Yes, actually you do not change the spin rate by hitting more down or up on the ball with the same club, assuming that the ball is impacted on the same spot on the face. Simplified slightly, the correlations are: Attack angle changes the launch angle, with club loft, including shaft flex, changing the spin rate.

When you hit more up on the ball, the launch angle will be higher but the spin rate will be virtually the same. The spin rate is dictated primarily by the spin loft and impact position on the club face. The spin loft is the difference between the dynamic loft and the attack angle. The spin loft is virtually constant for a given club. Of course, also the ball and club characteristics play an important role in the generation of spin.

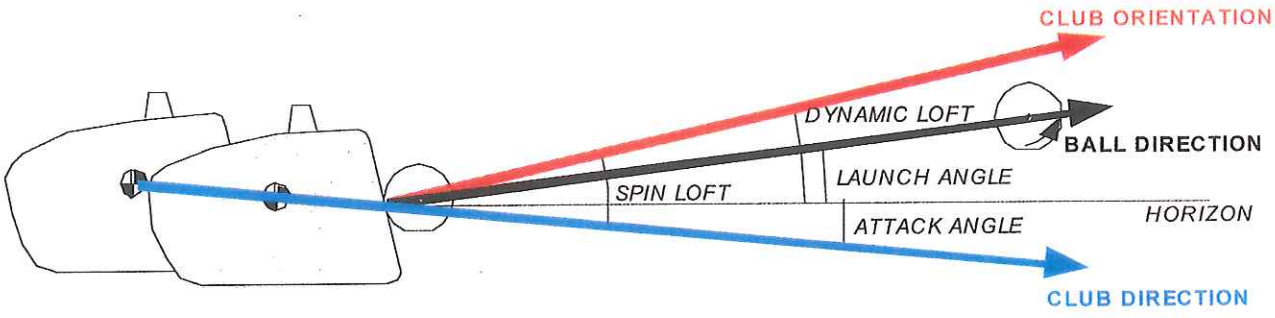
Having said all this, it is still a good idea to hit down on the ball with irons and wedges. A negative attack angle makes it easier to get proper contact to the ball which insures a predictable spin rate for your approach shots.

What other club delivery data discoveries are left to make?

We have pinned out almost every single detail on the driver shots. We have now switched to analyze attack angles for the tour pros on hybrids and irons to understand why the world's best players hit these shots like they do. Of special interest is also the horizontal club head movement and orientation at impact, meaning parameters like club path and face angle.

> "Attack angle is the primary parameter telling you why you obtain certain combinations of launch angle and spin rate - it is even more important than the club head speed!"

Fredrik Tuxen
The Inventor of TrackMan™



TrackMan™ Plays Witness To LPGA Triumph At Wendy's 3-Tour Challenge

A key to the victory might have been the ladies' competitive edge in spin rate and attack angle...

Apart from being used on the various tours' practice tees and during live competition at PGA TOUR events, TrackMan™ also assists at selected invitational events, such as The Skins Game and the 2007 edition of The Wendy's 3-Tour Challenge.

Benefiting child adoption, The Wendy's 3-Tour Challenge is a charity golf tournament putting three top players from the PGA, LPGA and Champions Tours up against one other in a team stroke play format.

The 2007 event was played on November 13, 2007, at the Reflection Bay Golf Club in Las Vegas (and televised nationally December 22 and 23). Nine stars of the professional golf world were present as the LPGA team (Kerr, Gulbis and Pressel) won the event, sealed by Cristie Kerr's 5-foot birdie putt on a sudden death playoff hole. The LPGA and Champions teams went to the extra hole after tying for first place at then end of regulation play at 7-under 209. The PGA team was one shot behind.

TrackMan™ assisted the event, measuring tee shots on six holes. All shots were hit with a driver. The significant amount of tee shots per player provided some very interesting data of which the highlights are presented here.

Tour positioning – adaptation to different needs

When making cross-tour comparisons on the basis of the club and ball data TrackMan™ collected during Wendy's, the analysis of 54 driver shots from the 9 top players leads to interesting differences. It is not very surprising that the LPGA stars trail their male colleagues in club speed, ball speed and carry distance in absolute terms. However, the interesting discovery is that the LPGA trio launches the ball significantly higher with a much more ideal attack angle and less spin. The female edge in these stats seems to show that top women tour pros focus on maximizing distance as they need it on par 5 and par 4 holes while their male colleagues "sacrifice" some yards, prioritizing accuracy as they are less dependent on driving distance on the same holes.

With a symbolic average attack angle of +5.1 degrees, Cristie Kerr had the most impressive TrackMan™ stats in the 2007 edition of Wendy's 3-Tour Challenge.

Tour Positioning - Data collected during Wendy's

TrackMan™ Data (average numbers)		USPGA	CHAMPIONS	LPGA
Club Speed	[mph]	115	106	93
Ball Speed	[mph]	170	155	136
Carry Distance	[yds]	276	253	215

TrackMan™ Data (average numbers)		USPGA	CHAMPIONS	LPGA
Spin Rate	[rpm]	2452	2672	2419
Launch Angle	[degrees]	9.5	11.6	13.5
Attack Angle	[degrees]	-1.2	-0.5	4.0
Smash Factor		1.48	1.47	1.46

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FOCUS: Smash Factor

In the analysis of a golf shot, "smash factor" is referred to increasingly in the golfing community. This in-depth interview with Fredrik Tuxen – CTO at ISG and the inventor of TrackMan™ – touches upon the relevance, measurement, and maximization of smash factor.

What is the smash factor?

The smash factor is the ratio between ball speed and club head speed.

$$\text{SMASH FACTOR} = \frac{\text{BALL SPEED}}{\text{CLUB HEAD SPEED}}$$

What does smash factor tell a golfer about a shot?

As a parameter, it is an expression of the player's ability to generate ball speed based on a given club speed. Technically, the smash factor says a lot about the centeredness of impact and the solidity of the shot - there is a strong correlation between the degree of centeredness at impact and the obtained smash factor.

How important is smash factor as a launch parameter?

It is very important – and to be honest, it is much more important than many think. Especially for those amateurs that try to swing too hard at the ball. By trying to achieve a high club speed, they lose control and don't obtain a solid, centered impact, resulting in a relatively low smash factor, far from what is optimal. When working with TrackMan™, the amateur and the pro should focus a lot more on ball speed and the smash factor in order to improve their ball striking. This is the reason why we have deliberately taken club speed away from the first page on the TrackMan™ screen and moved it down to page 3. We want players to focus on what is really significant to improve in their swing.

Let me give you an example. With a club speed of 100 mph and a smash factor of 1.40, the ball speed is 140 mph. But if the golfer could obtain a smash factor of 1.48 with a more controlled swing having a lower club speed of 98 mph, the ball speed would be increased to 145 mph – i.e. an additional 5 mph ball speed by swinging slower. Since 1 more mph ball speed (all other things equal) will generate 2 more yards carry, an extra 10 yards is added to the drive in this case by swinging with more control! Further, the more controlled swing will most likely have a very positive effect on dispersion.

What is the highest smash factor you can obtain?

The laws of physics do put some limitations on what is possible. Even though you may impact the ball dead-center on the club face, so the ball departs on a line that goes directly through the Center of Gravity (CoG) of the club head, there are 3 more factors that determine the maximum obtainable smash factor:

1) coefficient of restitution between club and ball (COR),
2) the SPIN LOFT – the angle between club face orientation and club head direction (see TrackMan™ newsletter #1 and #2), and
3) the mass ratio between ball weight and club head weight.

The equation below shows the maximum obtainable smash factor assuming a dead-center hit:

$$\text{SMASH FACTOR} \approx (1+\text{COR})\,\frac{\cos(\text{SPIN LOFT})}{1+\frac{\text{BALL MASS}}{\text{CLUB HEAD MASS}}}$$

For the coefficient of restitution, USGA and The R&A have limited golf clubs and balls to a maximum COR of 0.83.

While the spin loft could theoretically be 0 deg, it is impractical since this would mean something like a 0 deg lofted driver with a zero flex shaft producing 0 rpm of spin! The lowest realistic spin loft for a driver is around 8 deg.

As for the ball, the maximum allowed mass is 45.93 g, with no lower limit. However, it turns out that almost all golf balls have a mass above 45 g since the heavier weight makes the ball slow down less during flight (due to air resistance). For the club head mass, there are small variations among drivers. They typically range from 197 to 201 g, with tour pros using 202-207 g. The heaviest driver head I have heard about is 212 g.

By inserting realistic numbers in the equation above for maximizing the smash factor (COR 0.83, SPIN LOFT 8 deg, mass ratio 45/212), the highest realistic smash factor is 1.494.

A word of caution, before you start putting lead tape on your driver to make it heavier, that the heavier the club head the harder it is to generate club head speed. Maximum ball speed for a 45 inch driver is obtained for most people with a club head weight around 200 g. See "*Search for The Perfect Swing*" by Cochran and Stobbs for a study on how the club head speed varies with club head weight.

What is a good smash factor?

This depends highly on what club you are looking at and what ball type you are playing. For a driver with a premium ball, as an amateur, your smash factor should be above 1.42 and if you have elite ambitions, you should not be below 1.47. Tour pros should aim for nothing less than 1.48 as a minimum.

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TrackMan™ Plays Witness To LPGA Triumph At Wendy's 3-Tour Challenge

Bubba Watson – a master of variation

Bubba Watson has ranked #1 in driving distance on the PGA TOUR since he joined 2 years ago. In 2007, Bubba averaged 296 yards in carry distance on the holes where the PGA TOUR has recorded TrackMan™ measurements.

Looking at the more detailed driving stats from 2007, Bubba shows to have a lot of variation in how he hits his drives, having launch angles ranging from around 5 to 14 degrees, with corresponding carry distances from 240 to 330 yards. He obtains this by changing his attack angle while keeping the club head speed virtually constant. When Bubba wants to hit it really far, the launch angle is 13-14 degrees with 2250 rpm in spin rate. He achieves this through a +5 attack angle!

During Wendy's, Bubba deliberately used different driving shots from his arsenal having attack angles from -7.5 degrees to +0.3 degrees producing carry distances of 256 yards and 309 yards respectively. However, during a special segment where three drives of Bubba were compared to Fred Funk ("Longest Hitter on Tour vs. Straightest Hitter on Tour"), Bubba launched a 330 yards carry drive using a +5 attack angle.

Haas had the attack angle edge over Funk

These two Champions tour players had virtually the same club and ball speed averages, but Jay Haas' carry distance was an average of 8 yards longer (Haas 256 yards versus Fred Funk 248 yards). The main reason is that Haas had a positive average attack angle of 1.1 degrees, whereas Funk's average attack angle is 2.3 degrees negative. Through Haas' more positive attack angle his average launch angle was 1 degree higher (12.2 degrees vs Funk's 11.1 degrees) and 500 rpm less spin rate (2400 rpm vs Funk's 2950 rpm).

Natalie Gulbis off center

Natalie Gulbis was striking her driver with a relatively low smash factor (1.42), indicating she was not hitting the ball on the sweet spot of the club. Her TrackMan™ numbers indicate that she was striking the ball with an impact towards the upper part of the club head reducing the spin (vertical gear effect). Even though she was hitting her drives with a good high launch angle and low spin, she had a low driver shot efficiency, as the full club head force was not transferred to the ball.

Player shot performance

USPGA TOUR - Data collected during Wendy's

TrackMan™ Data		USPGA AVERAGE	BUBBA WATSON	CAMILO VILLEGAS	CHRIS DIMARCO
Club Speed	[mph]	115	123	114	107
Ball Speed	[mph]	170	181	169	159
Carry Distance	[yds]	276	292	280	258

CHAMPIONS TOUR - Data collected during Wendy's

TrackMan™ Data		CHAMPIONS AVERAGE	FRED FUNK	JAY HASS	NICK PRICE
Club Speed	[mph]	106	104	105	107
Ball Speed	[mph]	155	154	156	157
Carry Distance	[yds]	253	248	256	258

LPGA TOUR - Data collected during Wendy's

TrackMan™ Data		LPGA AVERAGE	CRISTIE KERR	MORGAN PRESSEL	NATALIE GULBIS
Club Speed	[mph]	93	95	89	94
Ball Speed	[mph]	136	141	132	133
Carry Distance	[yds]	215	229	207	210

Data From The Tours

Angel Cabrera dominated TrackMan™ stats at the Mercedes-Benz Championship.

As in the two previous seasons, TrackMan™ will in 2008 capture and deliver club and ball data from virtually every event on the PGA TOUR. Moreover, TrackMan™ data will become much more available to viewers all over the world as the networks increasingly integrate the data into their broadcasting.

The Golf Channel used TrackMan™ data from the Mercedes-Benz Championship in Hawaii extensively in their broadcasting. From live commentary to shot analysis from competitors, to in studio discussions, to "clinic clips" with Nick Faldo on the range with TrackMan™, golf fans were able to benefit from TrackMan™ data in many ways.

More than 250 tee shots were recorded by TrackMan™ at the limited field Mercedes-Benz Championship on Holes 12 and 18 during the championship rounds (1-4). Generally, each player recorded eight (8) tee shots. Key findings are presented below.

RNK	PLAYER	HOLE	RND	CLUB SPEED [mph]
1	Angel Cabrera	18	2	124.3
2	Angel Cabrera	12	4	124.2
3	Angel Cabrera	18	4	124.0
4	Angel Cabrera	18	3	123.9
5	Angel Cabrera	12	3	123.7
6	Henrik Stenson	18	3	123.6
7	Angel Cabrera	12	1	123.2
8	Nick Watney	18	4	123.2
9	Henrik Stenson	18	4	123.0
10	Nick Watney	12	3	122.7
11	Nick Watney	18	2	122.2
12	Nick Watney	18	3	122.1
13	Charles Howell III	18	2	121.8
14	Nick Watney	12	4	121.7
15	Nick Watney	18	1	121.6
16	Henrik Stenson	18	2	121.4
17	Nick Watney	12	2	121.4
18	Henrik Stenson	18	1	121.0
19	Daniel Chopra	18	4	120.9
20	Daniel Chopra	18	3	120.6

Best in class Cabrera.

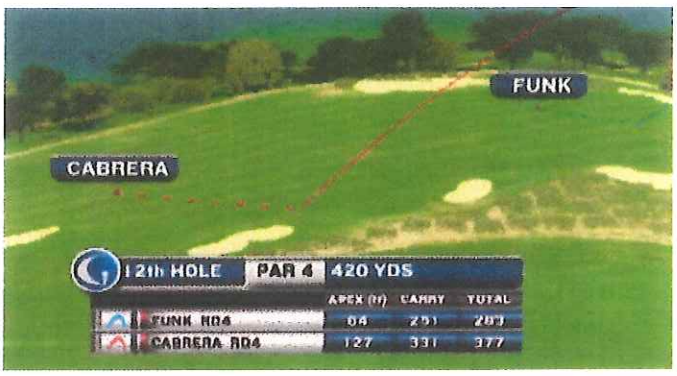
Smash Factor

All players had a relatively high smash factor (Ball speed/Club speed), indicating good centeredness of impact.

Club Speed

Angel Cabrera Supremacy
Angel Cabrera was the fastest swinger in The Mercedes-Benz Championship field.

- Cabrera delivered the top 5 club speeds.
- Cabrera delivered 6 of the 7 highest club speeds.
- Three players (Angel Cabrera, Henrik Stenson and Nick Watney) delivered 17 of the top 18 club speeds.
- Charles Howell III had 8 club speeds in the top 32 (13, 22, 23, 26, 27,29, 31,32).
- Mercedes-Benz Champion Daniel Chopra recorded 7 club speeds in the top 37 (19, 20, 25, 28, 30,34, 37)



Driving stats as captured by The Golf Channel and TrackMan™.

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