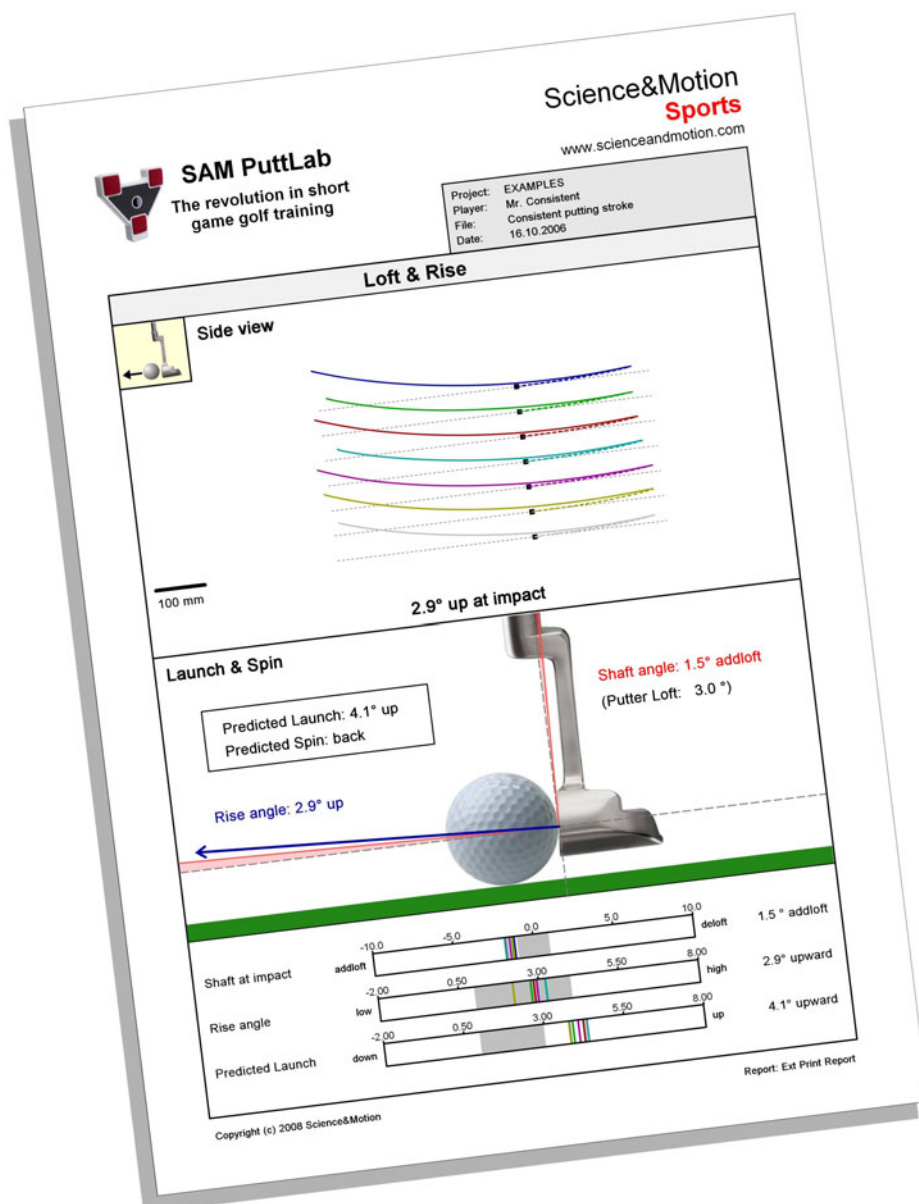# SAM PuttLab

Reports Manual

Version 2008

Reference

The information contained in this document is subject to change without notice. The software described in this document is furnished under a license agreement. The software may be used or copied only in accordance with the terms of the agreement. It is against the law to copy the software on any medium except as specially allowed in the license. No part of this document may be reproduced or transmitted in any form or by any means, electronical or mechanical, for any purpose, without the express written permission of the authors.

SAM PuttLab Reports Manual, **Version 2008** [05/2008]

Web: www.scienceandmotion.com
Email: info@scienceandmotion.com

Trademark Notices

- All trademarks and registered trademarks appearing in this document are the property of their respective owners.
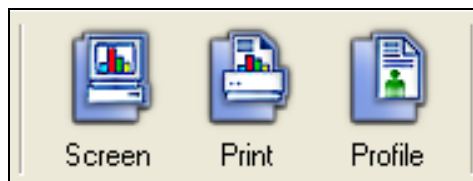
Table of Contents

1 SAM PuttLab Reports overview

1.1 What is a "Report"

Reports consist of an arrangement of different views in which the results are presented in easy to read graphics. There are different types of Reports available in SAM PuttLab:

"Screen" reports are optimized to be displayed on your computer display or to be projected with a beamer. Several single screen displays are summarized in a screen report. The reports used for training are very similar to the screen reports.

"Print" reports are optimized to be printed out and can be exported or send to your client via email as a PDF file (multi page document) or as image files in jpg format. Print reports contain several pages which are scrolled through using the arrow keys.

"Profile" reports are competence profiles, which give you an overview on the most important aspects of your performance, both in technical tendencies and in consistencies. Multi-competence profiles allow directly comparing different measurements, i.e. yourself to other players (PGA Tour players) or different putters.

You can also create a report by selecting a specific measurement via the "Data Selection" dialog bar in the left main screen of the SAM PuttLab software and then choose a report from the "main menu" or the toolbar.

After you selected a report and clicked the "OK" button, the report opens.

1.2 Print Report Screen
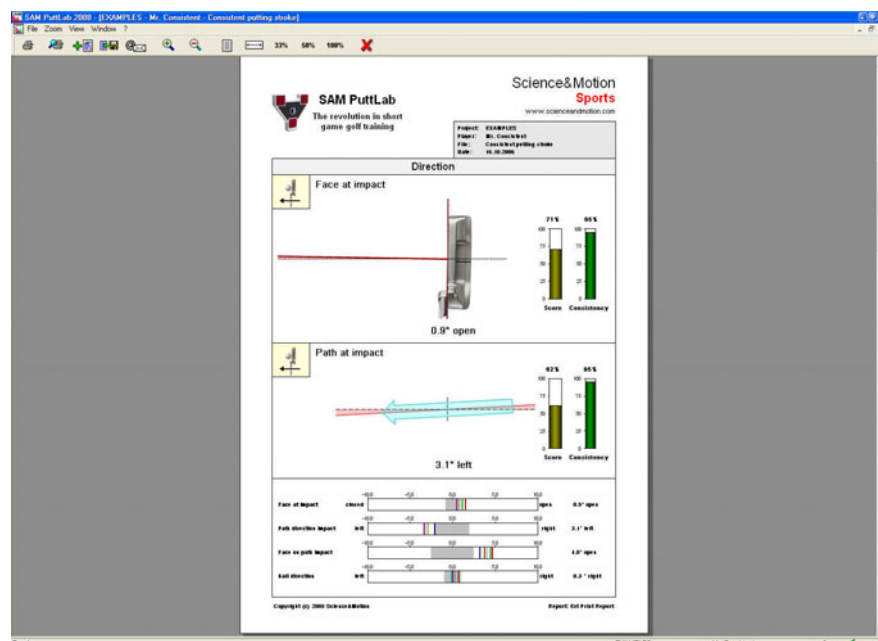
Print reports display the results for the currently selected measurement in a multi page document. You can scroll up and down via the cursor keys or by using the scrollbar at the right side of the screen to examine the different results for your stroke. The page up / page down keys browse through the pages.

All other possible functions like printing, zooming, etc. can be executed via the toolbar buttons and are described in the following section:

Print the report

Show a print preview

Open an additional report – The actual report can be directly compared with another report. Simply select the other report and it will be also displayed in the same screen. By holding the [CTRL]-key you can scroll in both reports at the same time using the cursor keys.

Save a report as PDF-file

Send report as PDF via your email account

Zoom-in, Zoom-out

Different zoom sizes – full page, full side width, 33%, 50% and 100% of the report

Close all open reports

2 Report view description

2.1 General

A Report consists of different views that display the SAM PuttLab result data. The reports may contain a combination of three display categories:

See the following example Report:

1. Graphical and numerical display of the results for the current parameter

2. Detailed output of the single result values in bar graphs with a benchmark range

3. Score and Consistency rating for the current parameter
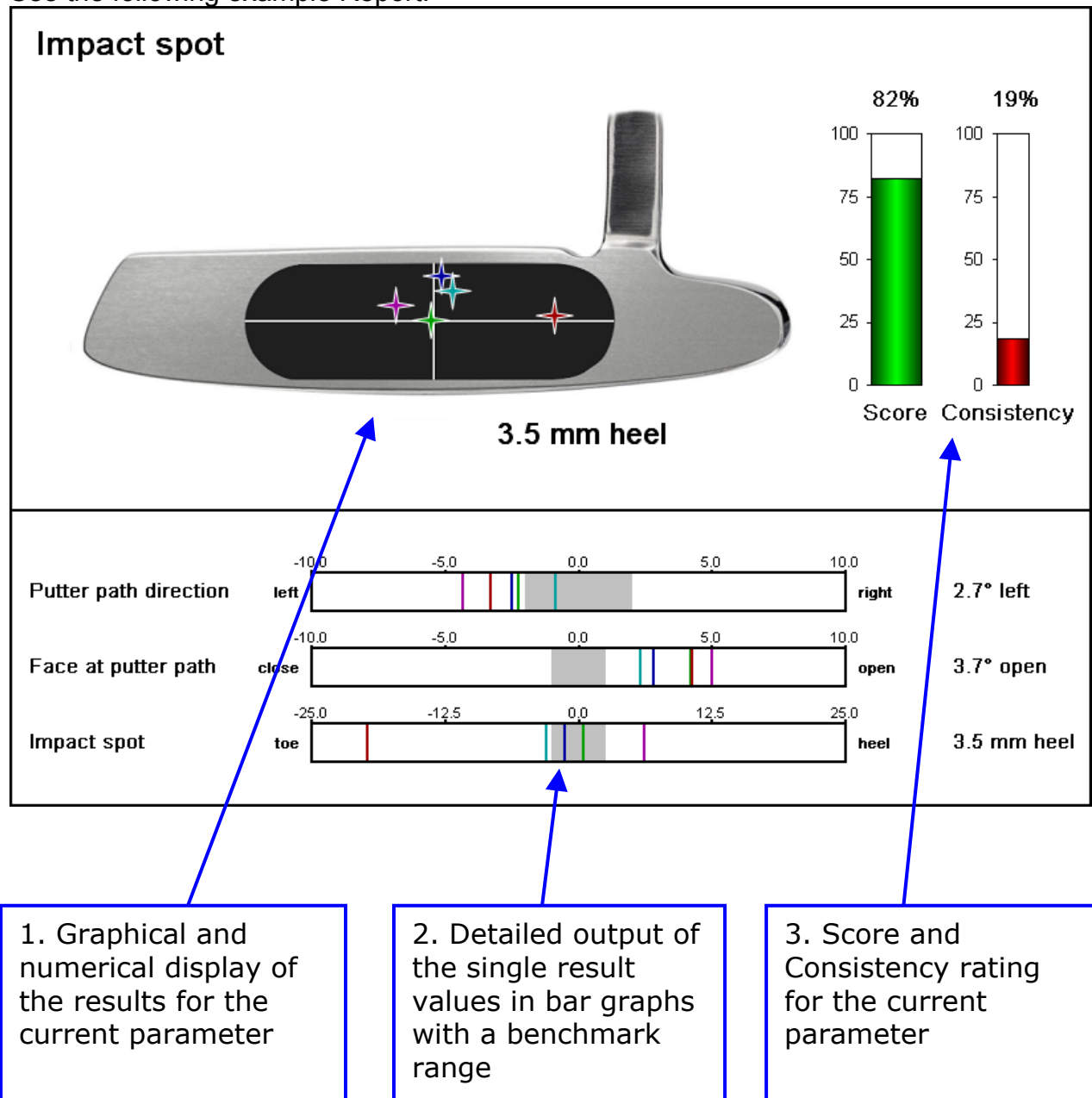
These three categories are described in the following:

1. Graphical display of the results for the current parameter

This section of the Report shows a graphical display of the results. This can be an image with additional numerical result display (e.g. Impact Spot) or data curves (e.g. Putter Path). Results for multiple putts are displayed in different colors. The color for a single putt will be the same for all views in this report. This allows comparing different parameters for the same putt.
Some graphics show the average value of multiple putts (Alignment, Rotation). However the consistency is also very important because it shows the variability of your putting. Good performance in the currently shown parameter is indicated by high ratings in both Score **and** Consistency.

2. Detailed output of the single result values in bar graphs with a benchmark range

The bar charts provide detailed information on each single putt. The numbers on top of the bars correspond to the data scale. The colored vertical stripes within the bars represent the different putts. The grey areas indicate the optimum data ranges as derived from the PGA Tour data sample.

The number printed on the right side of the bar represents the average value for this parameter, and the vertical lines in the bar show the value for each stroke. So you can inspect in detail both the average performance and the variability of your putts. The average is the basis of calculating the corresponding *Score* rating. The score is high if the deviation from a theoretical optimum or from Tour player's performance is small.

The spread of the single data values indicates the distribution for the single putts. The distribution of the data is the basis of calculating the corresponding *Consistency* rating. For high consistency of movement execution the stripes should be grouped very close together.

The grey area inside of the bar graphs represents the benchmark range and represents about 68 % of the Tour player's performance. For a high performance your results should be inside of this range but should also be grouped close together. The benchmark range data has been collected from about 100 European PGA Tour Players and shows their average performance and variability.

3. Score and consistency rating

The *Score* rating shows the deviation from the optimum data value on a uniform scale. The raw data value is compared with a Tour data sample and then the score rating is calculated. This allows to directly compare the performance in all parameters directly with each other. A Score of 100 % means that the performance is optimal. A Score rating of 75 % means that the performance is as good as for about 32% of the Tour player's performance. The bars are green for ratings above 75%, yellow between 50 and 75%, and are red for ratings below 50%.

The *Consistency* rating shows the distribution of the data values of the single putts on a uniform scale. The raw data values are compared with the distribution of the tour data sample and then the consistency rating is calculated. This allows to directly compare the consistencies in all parameters directly with each other. A Consistency rating of 75 % means that the performance is as good as for about 50% of the Tour player's consistency.

The rating and consistency bars have 3 ranges, indicated by different colors:

a) Green: 75% to 100%. This indicates a very good performance inside the Tour Pros benchmark range. High consistency shows that you execute the movement all the time the same and that your technique is well established.

b) Yellow: 50% to 75%. This indicates a performance slightly below the Tour Pros benchmark range, which is still good performance for an amateur player.

c) Red: 0% to 50%. This indicates a performance below the Tour Pros benchmark range. Low Score ratings indicate that this aspect of your technique is very much different from a Tour player's technique. Low Consistency ratings indicate that this aspect of your putting stroke varies all the time. High consistency shows the skill level and is the most important factor for skilled players.

Comparison of rating and Tour Professional performance

Sore and Consistency rating correspond to a PGA Tour player's reference data. This table shows some Rating benchmarks and corresponding virtual Tour player's ranking:

PuttLab Rating	Virtual Tour player ranking
100 %	1
97 %	10
83 %	50
75 %	68
50 %	95
25 %	100

➔ Statistically a rating of 75 % corresponds to exactly 1 standard deviation (SD) from the average of the reference. 1 SD always represents 68% of a normally distributed sample which corresponds to a Score rating of 75%.

2.2 Report Header

The report header displays comprehensive information on the data set.

- Project – The name of the project and the description. The project name corresponds to a data directory which is found in the data directory of the PuttLab installation. The project directory contains all corresponding players and their data sets.

- Player – The name of the player and the biometric data. The player name corresponds to a data directory which is found in the data project directory.

- Session – The name of the session, the description and the date when the session has been created. A session contains one or more data sets which belong together (i.e. in a putter selection process). Sometimes all data sets contained in a session are displayed in one report.

- File – The name of the file, the description, the date of the recording and the number of putts stored in this file. A file is a set of putts recorded during a measurement or a training session.

- Score rating – The scores for technical aspects and timing aspects of the data, the consistency of the putts and an overall score summarizing all three aspects. Please refer the operating manual for more details on the score ratings.
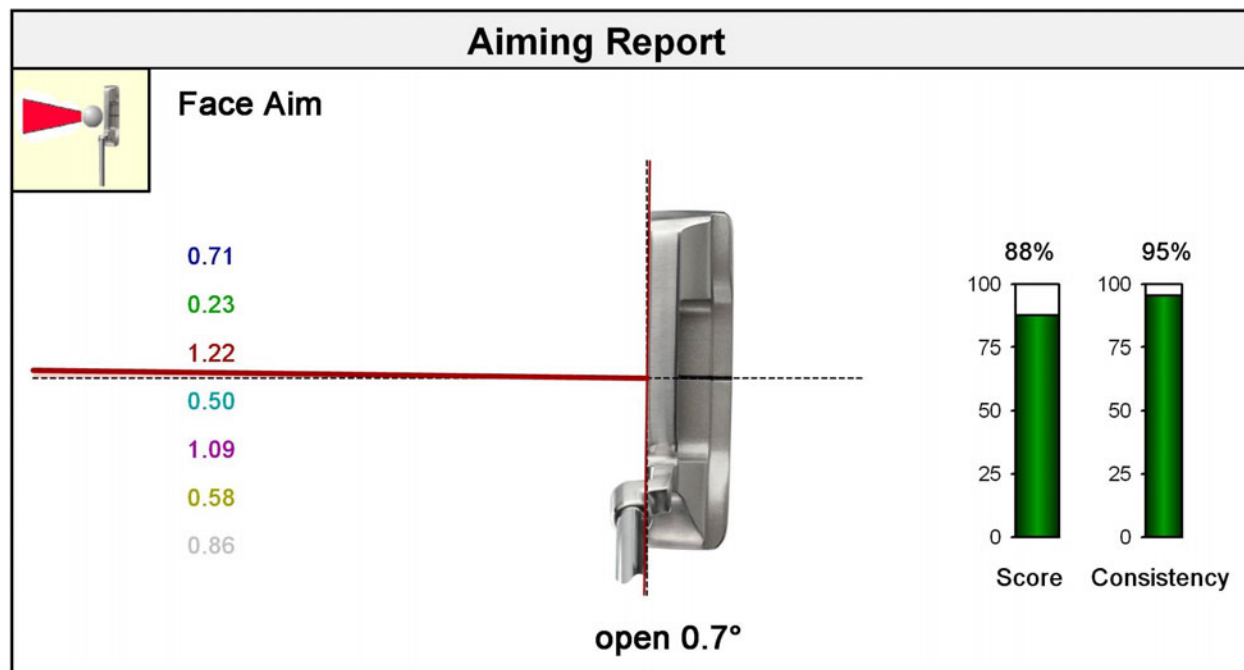

The following pages will describe the Report views for all parameters in detail.

i Not all of the result categories are used in every Report view. In the Training mode there will be no Consistency rating, because only one stroke will be displayed at a time.

3 Aiming Report

3.1 Face angle at aim

The first graph shows the alignment of the **putter face at address**. The dotted line exactly represents the calibrated target direction. A putter face 100% square to the target exactly results in 0 degrees. The average direction of the putter face alignment is represented by the thick red line. The area between the average alignment and the optimum target direction is filled in red colour to indicate the amount of deviation.

The average numerical value for the putter face angle at address is shown beneath the putter head in degrees. In this example, the putter head is 0.7 degrees open at address which means the face is slightly pointing to the right. The numbers for each single putt are displayed on the left side. The numbers display can be switched on and of with the F7 key.

The two bars on the right side of the graph show the Score rating for average alignment as well as the Consistency rating over the different putts. The bars are green for ratings above 75%, yellow for ratings between 50% and 75% and red for ratings below 50%. In this case, the Score for 0.7 degrees open results in 88 % performance. The Consistency rating is 95 % which is very high performance. This means the putter is aligned almost exactly to the same direction for the different putts.

3.2 Aiming bar charts
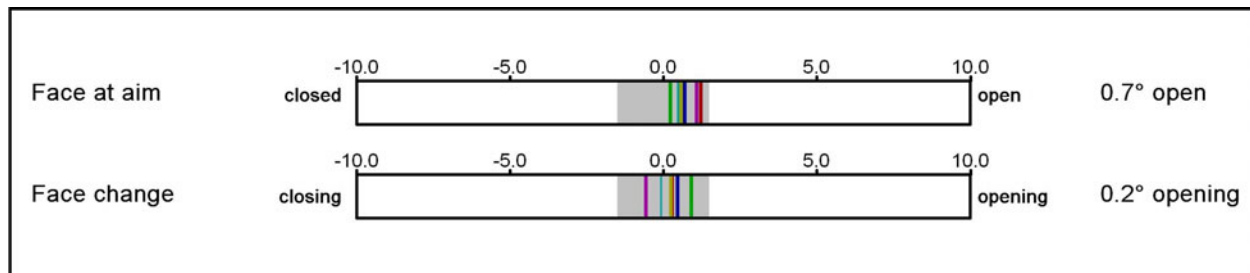
The aiming bar charts provide information on each single putt. The coloured stripes within the bars represent the different putts. These graphs do show both the average performance and the distribution of the single data values. For high consistency of movement execution the stripes should be grouped very closely together or should even overlap.

The numbers above the bars correspond to the data scale. In this case the numbers represent degrees for the alignment. At the left side of the bar the name of the displayed parameter is shown. The number on the right side of the bar represents the average data value for this parameter.

The upper bar shows the data for face at address. For this player the data are grouped very closely together which indicates the very high consistency of the aiming directions.

The parameter "face change" shows the change of putter face angle between address position and impact. This parameter provides additional information on the compensation of the putter face between aiming and impact and can explain sources of inconsistencies at impact. If the face change is inconsistent you should work on a more smooth and regular movement inside of the backswing. On the other hand, if face change is consistent but face at impact is inconsistent, then the inconsistencies do more result from inconsistent aiming. Consequently, you should then work on a more consistent setup and aim.

4 Direction Report

4.1 Face at impact
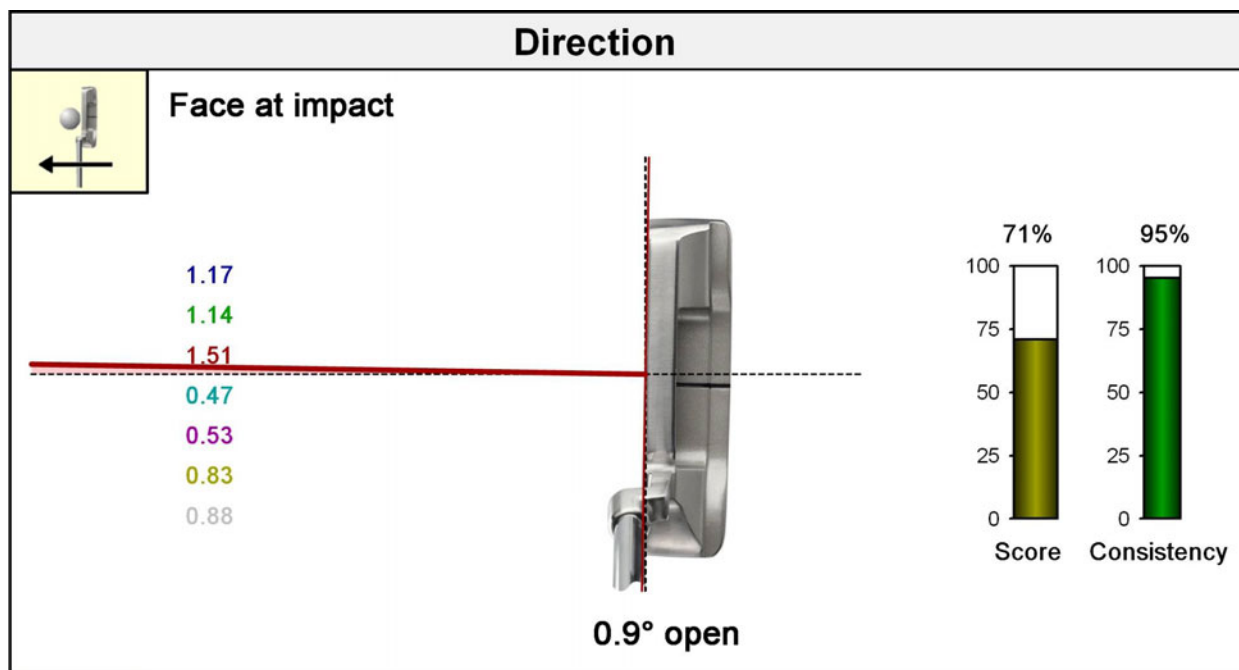
This graph shows the alignment of the **putter face at impact**. The structure of the graph is similar to the "face at address" graph as described in chapter 3.1.

The average numerical value for the putter face angle at impact is shown beneath the putter head in degrees. A putter head 0.9 degrees open at impact means that the face is pointing to the right. The face at impact determines ball direction to about 83%. The numbers for each single putt are displayed on the left side.
Due to the high consistency this might still be good performance, if the open face is then compensated by a path pointing to the left. Please note that a putter face which is more open / closed than 1 degree at impact results in missing a 4 meters putt to the right / left if the path is straight.

The two bars on the right side of the graph show the Score rating for average alignment as well as the Consistency rating over the different putts. In this case, the Score for 0.9 degrees open results in 71% performance. However the Consistency rating is 95 percent which is a very high performance. This means the putter face angle at impact is very much the same for the different putts.

4.2 Path direction at impact
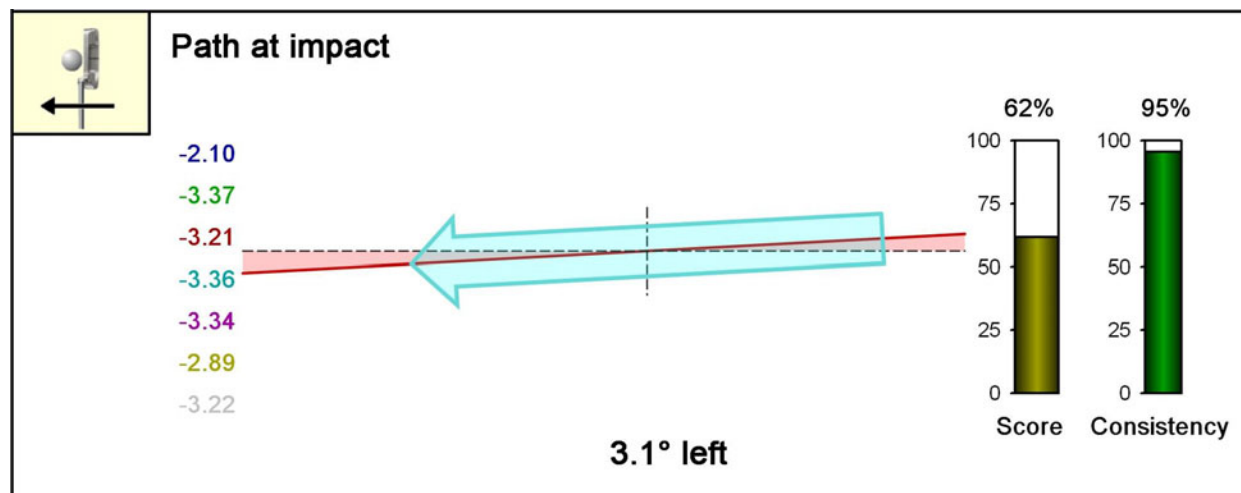
The blue arrow in this graph shows the **putter path direction at impact**. The dotted line represents exactly the calibrated target direction. A putter path pointing 100% to the target results in 0 degrees. The average direction of the putter path is also represented by the thick red line.

The average numerical value for the putter path direction at impact is shown beneath the arrow in degrees. In this example, the putter path is pointing 3.1 degrees to the left. The path at impact determines ball direction to about 17%. A path which is not pointing exactly to the target can be compensated with a face pointing into the opposite direction to make the ball still go straight. For this player in fact the face is pointing to the left which is compensated by the path pointing to the left. The numbers for each single path direction are displayed on the left side.
Although the path deviates from the target line, the path direction is very consistent. A path cutting 3.1° left could be compensated by a face being open to about 0.7 degrees to the right. Please note that a putter path which is more open / closed than 5 degree at impact results in missing a 4 meters putt to the right / left if the face is exactly square to the target.

The two bars on the right side of the graph show the Score rating for average alignment as well as the Consistency rating over the different putts. In this case, the Score for 3.1 degrees left results in 62% performance. However, the Consistency rating is 95 percent which is a very high performance. This means the putter path direction at impact is very much the same for the different putts.
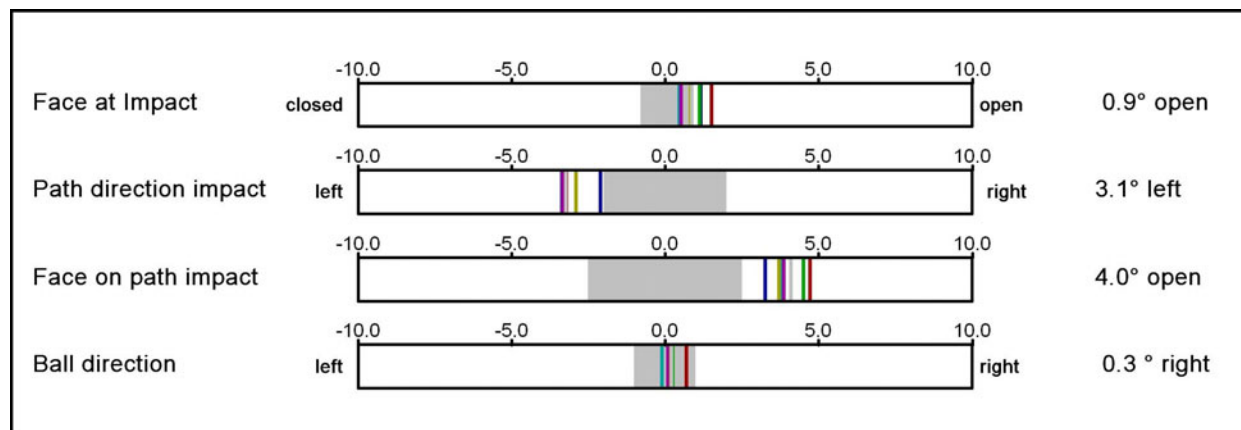
4.3 Direction bar charts

The bar charts for direction provide information on each single putt. The coloured stripes within the bars represent the different putts. The numbers above the bars correspond to the data scale. The number on the right side of the bar represents the average data value for this parameter.

For this player some data values are outside of the preferred range as indicated by the grey areas. The grey areas correspond to the Tour player's performance. The upper two bars show the data for face at impact and Path Direction at impact. For this player the data are grouped very closely together which indicates high consistency of movement execution.

The parameter "**Face on path impact**" shows the relative angle of the putter face compared with the putter path at impact. For this player the face is open 4.0 degrees in average on the path which is a significant compensation. For a neutral setup and a neutral stroke the face will be exactly square at the path. The most common compensation found in PGA Tour players is a putter path pointing to the left and a putter face slightly open at impact. Many Tour players tend to aim the face to the right edge of the hole because they know that they tend to pull the putt under pressure.

The ball direction is a calculation based on face and path direction at impact. Face angle is considered to contribute 83% and path direction contributes 17%. Please note that the effect of errors in putter path direction on ball direction is about 5 times less than errors in putter face alignment at impact. This means that a 1 degree open putter face at impact has the same effect on ball direction as a putter path pointing 5 degrees to the right.
For this player ball direction will be slightly right because the effect of a face 0.9 degrees open is having more effect than a path pointing 3.1 degrees left. An absolute deviation in ball direction of more than 0.7 degrees will result in missing a 4 meters putt.

5 Putter Path & Spot Report

5.1 Putter Path – Top View
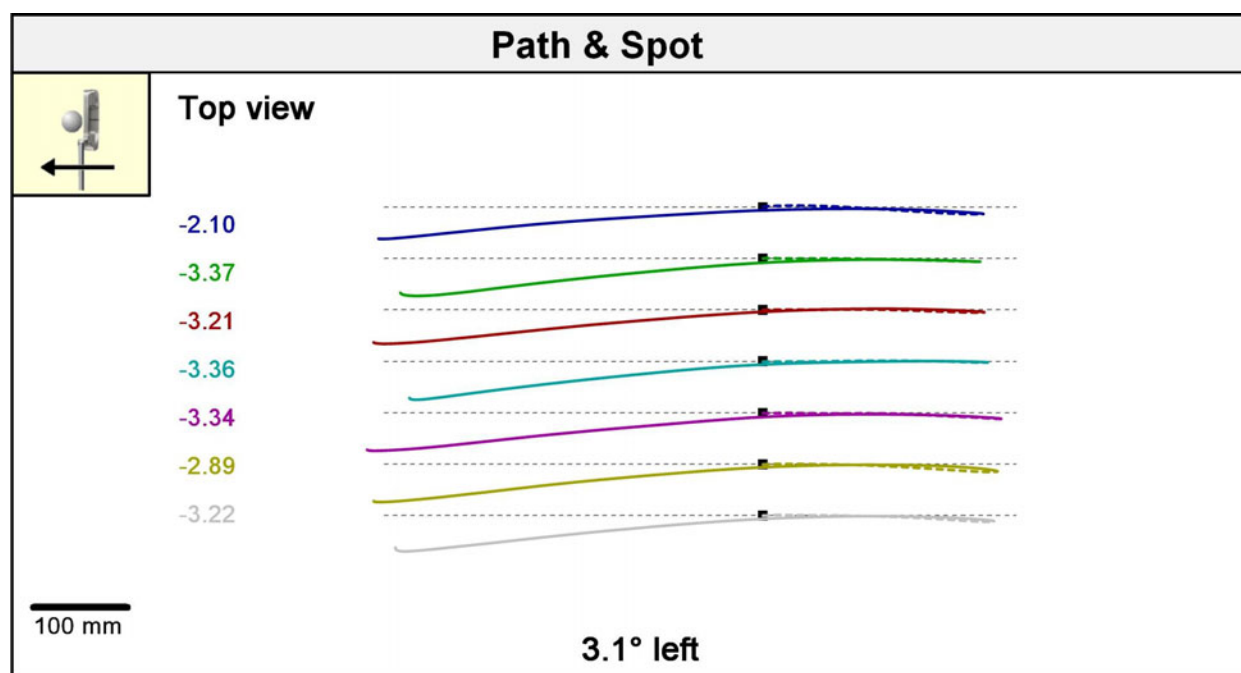
This graph displays the **path of the putter** viewed from above during back swing (dotted lines) and forward swing (solid lines). The different putts are indicated by different colours, with the first blue putt at the top.
The graph shows the bird's-eye view. The small black spot represents the starting point of the movement. The backswing is going to the right. The forward swing starts at the end of the backswing, crosses ball position and then ends up at the left side where the putter stops moving. The target direction is indicated by horizontal grey dashed lines.

For this player you find a very consistent backswing almost parallel to the target line. The consistency of the length of the backswing is very high, indicating that the length of the putts will be also consistent. The consistency of the forward swing is also high. The putter path is slightly arced to the left, and putter path direction at impact points 3.1 degrees to the left of the target line. Deviations in putter path very often correlate to a misaimed body line.

An irregular putter path is often a consequence of a putter length which does not fit to the player. The length of the backswing is considerable smaller as the follow through in Tour players. Backswing length is in average about only 35% of the forward swing. Short backswing is guaranteeing smooth acceleration through impact (see also 8.)

5.2 Impact Spot
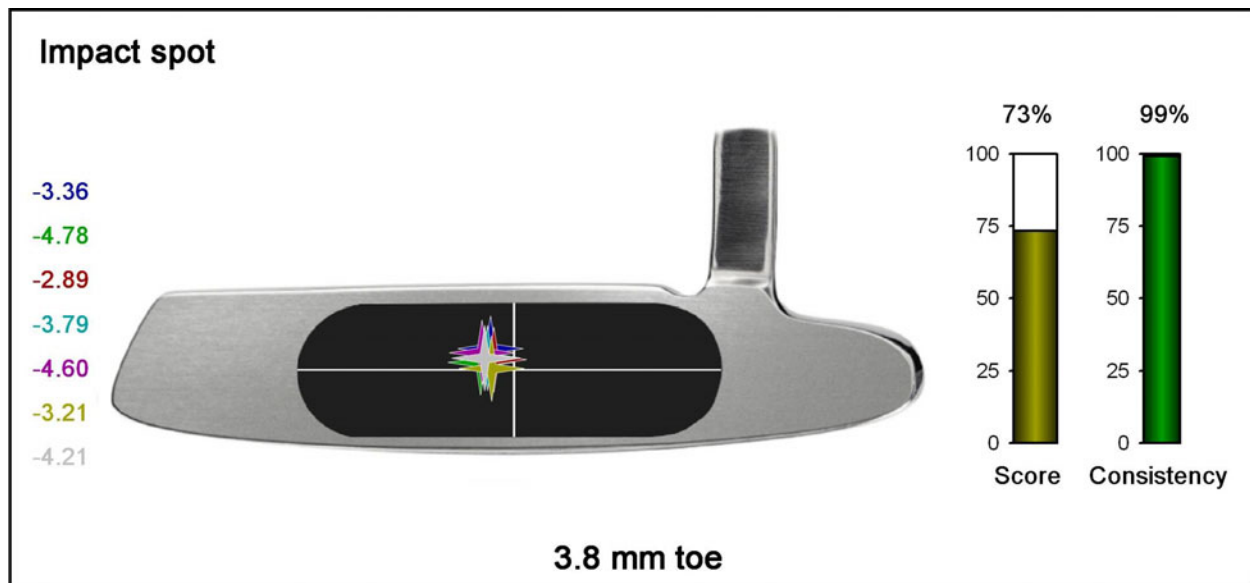
This graph shows where you exactly hit the balls on your putter face. The different impact spots are indicated by crosses in different colours. The horizontal and vertical lines in the middle of the putter face represent the geometrical centre of the putter which normally represents the sweet spot.

This player shows a very consistent impact spot slightly left on the putter face with 3.8 mm at the toe. The corresponding score is 73 % of the optimum. Consistency level is very high with 99%. Consequences of off-center hits are reduced putt length and face angle errors. However for consistent off-center hits near to the sweet spot effects will be very small.

Please note that the horizontal hit distance as measured on the putter face directly refers to the calibration. In this case the horizontal distance of about 3.8 mm indicates that the ball is hit in average 3.8 mm to the toe *as compared with the calibration position* (which should be exactly at the centre of the putter).

ℹ️ It is assumed that the ball lies exactly on the same spot for all putts (i.e. by using a position marker or a small ring). If you use different spots while putting you will get results for the hit spot which will deviate from the true hit spots (this is default setting).

ℹ️ If you use relative position calibration ("Ignore position when calibrating"), then the point where you aim each putt is assumed to represent the sweet spot of the putter. In this case you will get erroneous results for hit spot if you do not aim exactly at the sweet spot.

5.3 Path & Spot bar charts
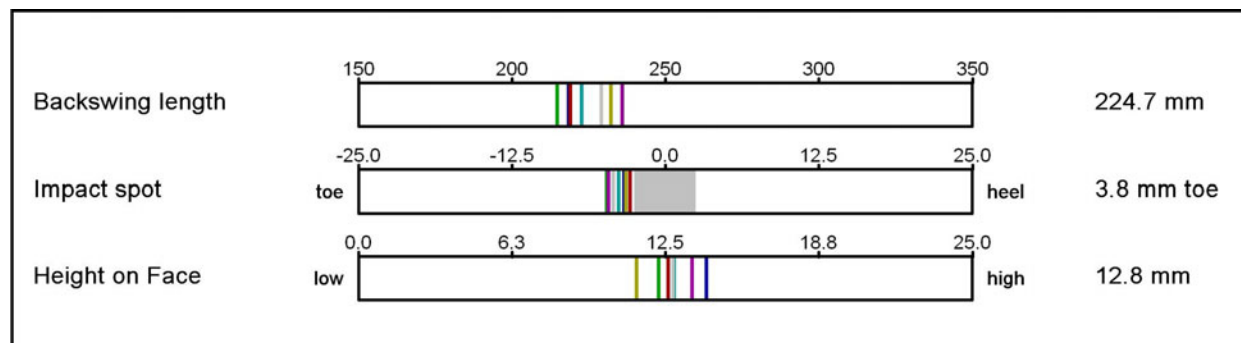
The top view bar charts provide information on each single putt. The coloured stripes within the bars represent the different putts. For high consistency of movement execution the stripes should be grouped closely together. The structure of the graph is identical to the "Alignment bar chart" in chapter 4.3.

The "**Backswing length**" parameter shows the length of the backswing in mm. The length of the backswing should always be exactly the same for perfect distance control.

The "**Impact spot**" parameter shows the horizontal deviation of impact position from the geometrical center of the putter. Especially on heel mounted putters off-centre hits at the toe are more vulnerable to a loss of energy which is transferred to the ball.

The "**Height on Face**" parameter represents the vertical height of the ball on the putter face. As we do not know the true vertical height of the putter face, this measure is given relatively to the sole of the putter.
This player hits the ball with a height of 12.8 mm above the sole of the putter, which will be slightly above the geometrical center of a standard putter. For hitting the ball in the vertical center a height of about 12.5 mm is needed. The impact position on the putter face is shown in the Impact spot graph in chapter 5.2. In this graph a standard height of 2.5 cm is assumed for the height of the putter.

6 Launch Report

6.1 Putter Path - Side View
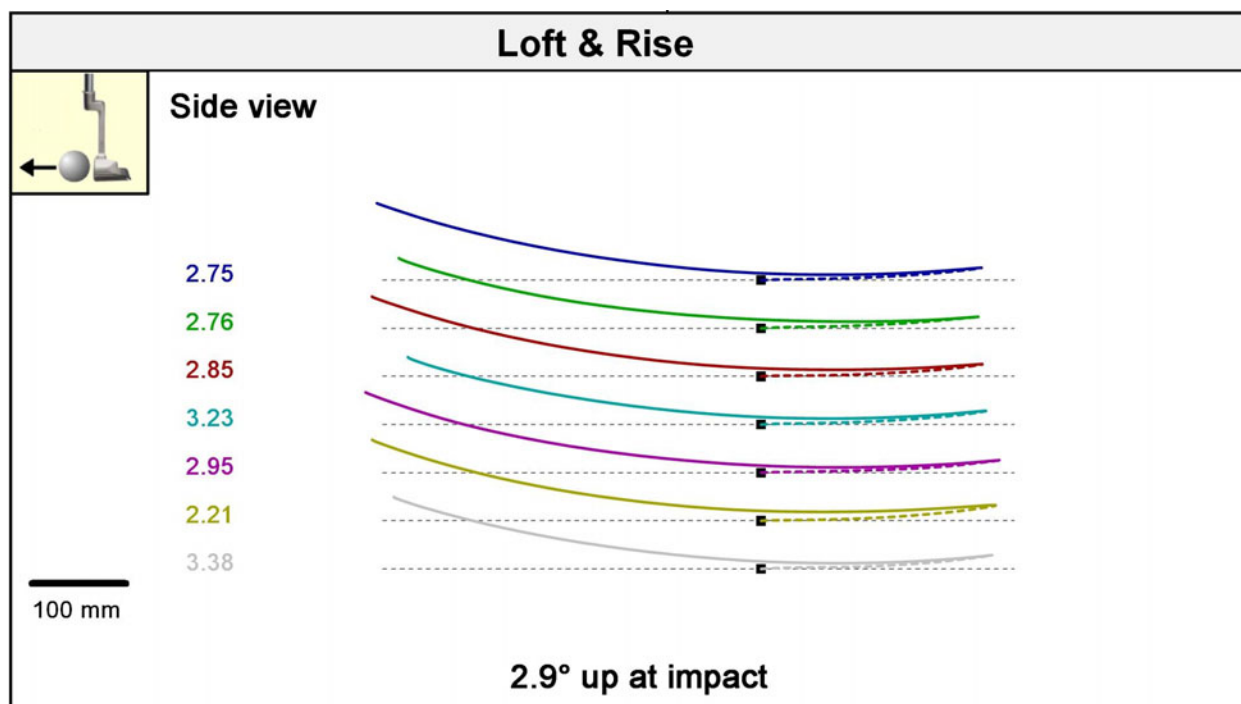
This graph shows a **horizontal side view** of the putter path during back swing (dotted lines) and forward swing (solid lines). The different putts are indicated by different colours, with the first putt at the top. The physical horizontal ground is indicated by horizontal grey dashed lines.

The small black dot represents the starting point of the movement. The putter is smoothly lifted at the beginning of the backswing while moving to the right. Backswing in Tour players is generally flat which allows the forward swing to then come up through impact.

The average numerical value for angle of attack (Rise) at impact is shown beneath the curves in degrees. For this player the forward swing path is leading 2.9 degrees upwards through the ball. The numbers for each single Rise angle are displayed on the left side.

The putter path curves run very parallel. The backswing lengths are considerable consistent. More explanations on consistency of the putter path length are found in chapter 5.15.1.

6.2 Loft & Rise angle at impact

Launch & Spin

Predicted Launch: 4.1° up
Predicted Spin: back

Rise angle: 2.9° up

Shaft angle: 1.5° addloft
(Putter Loft: 3.0 °)
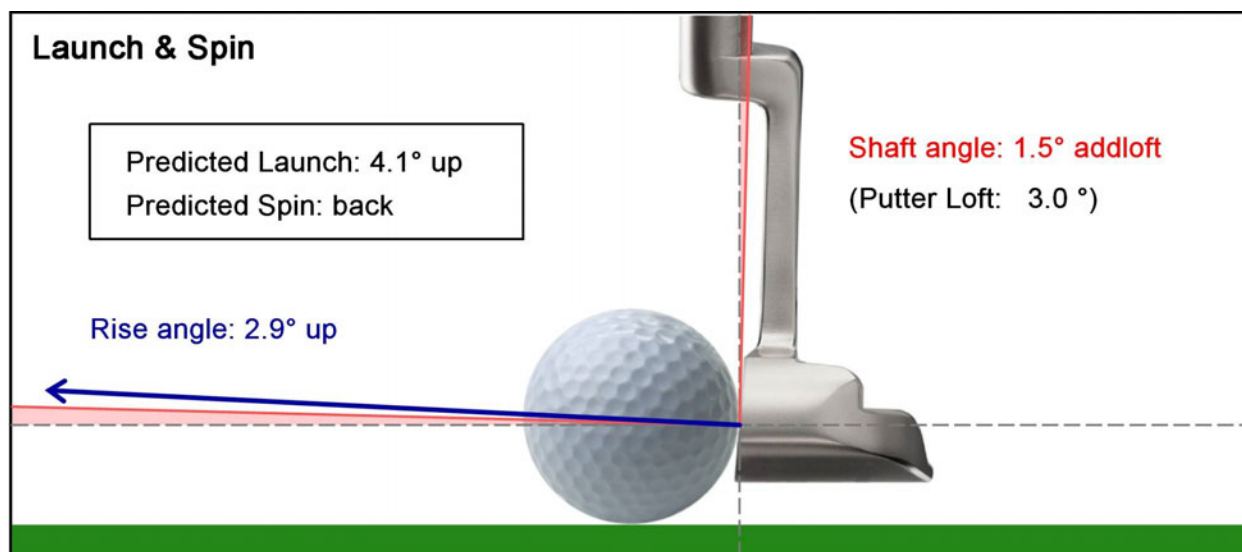
This graph shows the putter face at impact in a side view and provides information on the **shaft angle at impact**. The average shaft angle is represented by thick red lines. When the shaft is pressed forward or leaning back, the loft of the putter face is changed accordingly. In this case the hands are slightly behind the ball. The dynamic loft applied to the ball will then be the static loft (which is individually entered before each measurement) normally 3-4 degrees) and added loft of 1.5 degrees. The graph also shows the true average **putter height** at impact above ground.

The "**Rise angle**" shows the angle of attack of the putter to the ball in relation to the ground (see 6.1). For this player the rise angle is 2.9 degrees upward, which is in the perfect range of 3 to 4 degrees. A positive rise angle will give the ball some forward spin, better roll and reduced skidding.

The predicted Launch angle and Spin rate are estimations of ball behaviour after impact. Launch angle is mostly determined by dynamic loft with 83% and rise angle with 17% of influence (same as for putter face). The predicted spin correlates to the difference between Rise and dynamic loft angle. If Rise is higher than loft then top spin is predicted, is loft is higher than rise then backspin is predicted. If Rise – Loft is in a range of -1.5° to 0.5° then no spin is predicted (considering some friction with the surface).

ℹ️ The loft and rise measurement is very much depending on exact horizontal alignment of the measurement unit due to the spirit level at the backside of the unit. If the putting green has a slope then the measurement unit should be placed parallel to the surface.

ℹ️ The slope can be measured by placing the suitcase on the ground and then positioning the measurement unit upside down on the suitcase and inspecting the spirit level.

6.3 Loft & Rise bar charts
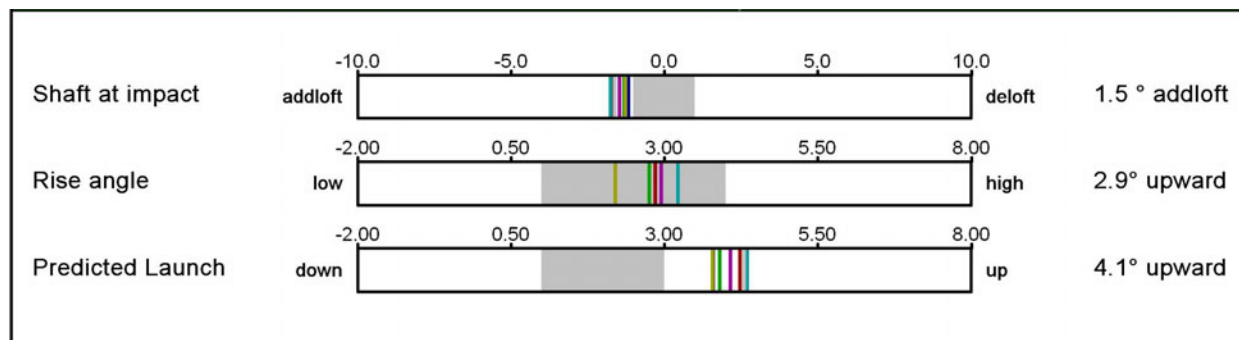
The side view bar charts provide information on each single putt. The coloured stripes within the bars represent the different putts. The more closely grouped the stripes are, the more consistent the performance is. The structure of the graph is identical to the "Alignment bar chart" in chapter 4.3.

The parameter "**Shaft at impact**" provides information on the shaft angle at impact. This parameter directly corresponds to adding loft or delofting the putter face at impact. For this player the shaft is almost neutral at impact. As consequence the net loft if the putter to the ball is the static loft plus 1.5 degrees.

The **"Rise angle"** parameter shows the angle of the putter path against the horizontal ground at impact. For this player the rise angle is 2.9 degrees upwards, which is little less than the perfect range of 3 to 4 degrees. A positive rise angle will give the ball some forward spin and a better roll. The skidding phase will also be reduced.

The **"Predicted launch"** parameter is estimating the launch angle which is mostly determined by the dynamic loft at impact. We consider dynamic loft with 83% and rise angle with 17% of influence (same as for putter face).

There is an inter-dependence between rise angle and loft at impact. The more rise angle at impact is found the less loft at impact is needed to properly lift the ball from the ground. High speed video suggests that you should avoid backspin and skidding of the ball for proper roll. On fast greens (10-11) we recommend only 2 degree dynamic loft but a rise angle of 3-4 degrees upwards, which will properly launch the ball and will impart some immediate topspin to the ball.

7 Rotation Report

7.1 Putter head rotation
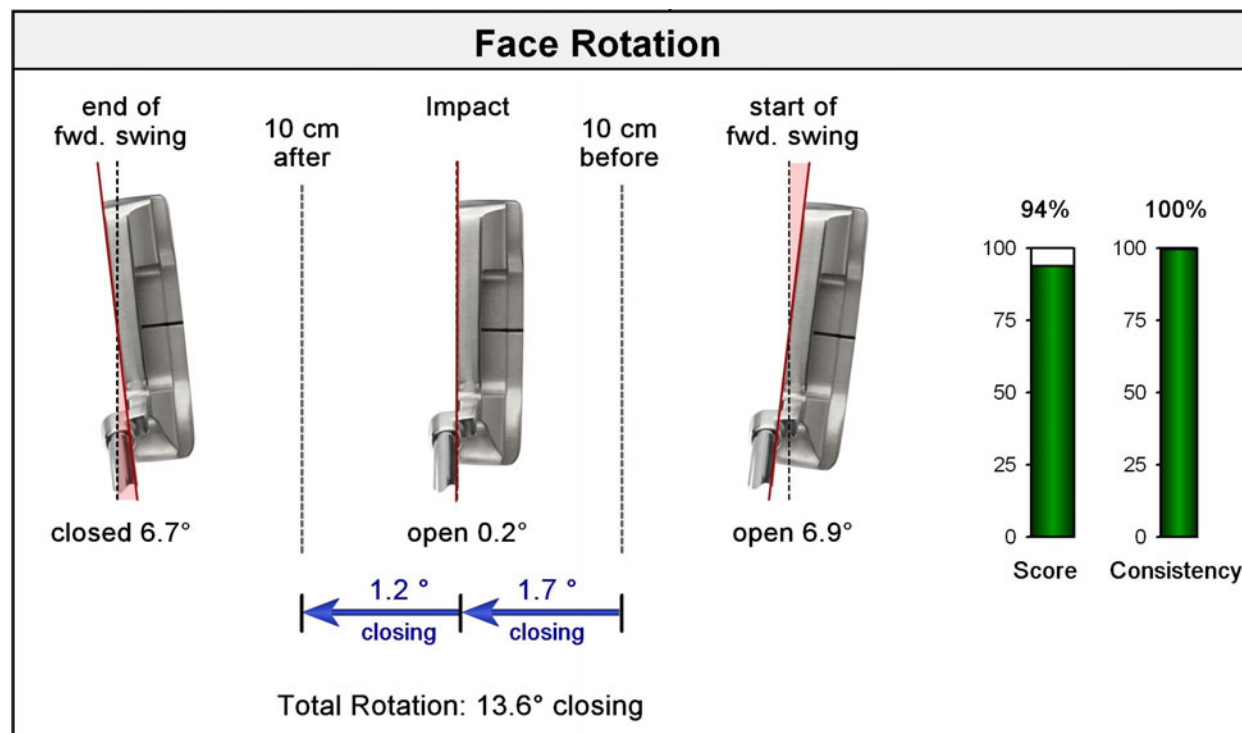
This graph shows the putter face angle at different positions in the forward swing: At the start of the forward swing (right), at impact (middle) and at the end (left) of forward swing. The red lines indicate the deviation of the putter angles from the square alignment.

The face angles are shown beneath the putter face pictures. The putter face is open 6.9 degrees at start of forward swing. At impact the putter face is still slightly open 0.2 degrees and then 6.7 degrees closed at end of forward swing. Overall rotation in the forward swing is 13.6 degrees.

In the middle of the graph the face rotation for a fixed area of +- 10 cm before and after impact is shown. The rotation inside of this fixed area is independent of the length of the putter path and allows directly comparing the rotation of putts with different path lengths. In this case the rotation inside of 10 cm before impact amounts to 1.7 degrees and the rotation inside of 10 cm after impact amounts to 1.2 degrees.

This player shows a rotation of 2.9 degrees inside of an area of +- 10 cm around impact. The preferred amount of rotation as measured on the Tour inside of this range is about 1 to 3 degrees. The score level of 94% is very high and corresponds to a rate of rotation at impact of 25.0 °/s (see 7.3). The consistency of rotation around impact is extremely high with 100% rating (see also next paragraph).

7.2 Rotation Graphs
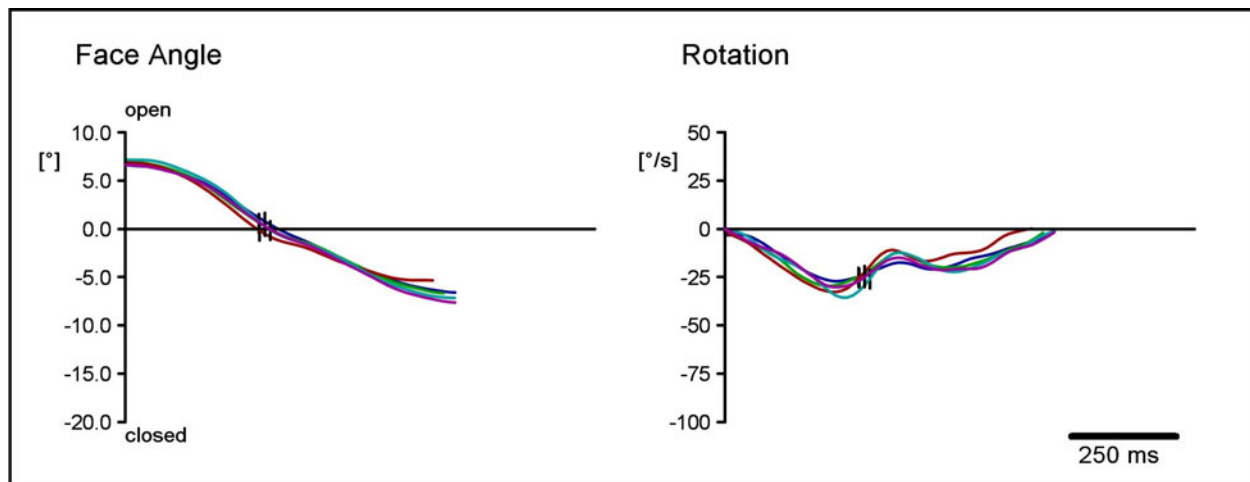
Face Angle graph: The graph on the left shows the face angle over time in the forward swing. The curves correspond to the putter face angles shown in 7.1.

➤ At the beginning of the forward swing (beginning of the curve at the left side) the putter face is about 6.9 degrees open.
➤ The impact is indicated by the small vertical stripes. The horizontal axis corresponds exactly to the putting line. The graph shows that the ball is hit with a slightly open putter face.
➤ At the end of the forward swing the putter face is about 6.7 degrees closed (right end of graphs).

For this player the course of rotation is smoothly running from open face at impact to a closed face at end of forward swing. For a natural and smooth movement the rotation will always be symmetric to impact (stripes).

Rotation graph: On the right side the corresponding rate of rotation (velocity of rotation) over time is displayed. The rate of rotation graph displays the change of putter face angle over time.

Irregularities in putter face change are magnified in the rotation data and correspond to peaks in the rotation curves. For this player you can identify some re-opening of the face directly after impact through a positive peak in the rotation curve. This "re-opening" can either be a consequence of hitting the ball off-center at the toe or can show the tendency of the player to interrupt the natural rotation of the face and to push the face more square through impact.

A natural and continuous putter face rotation always shows a smooth and flat rotation curve and corresponds to high consistency ratings.

7.3 Rotation bar charts
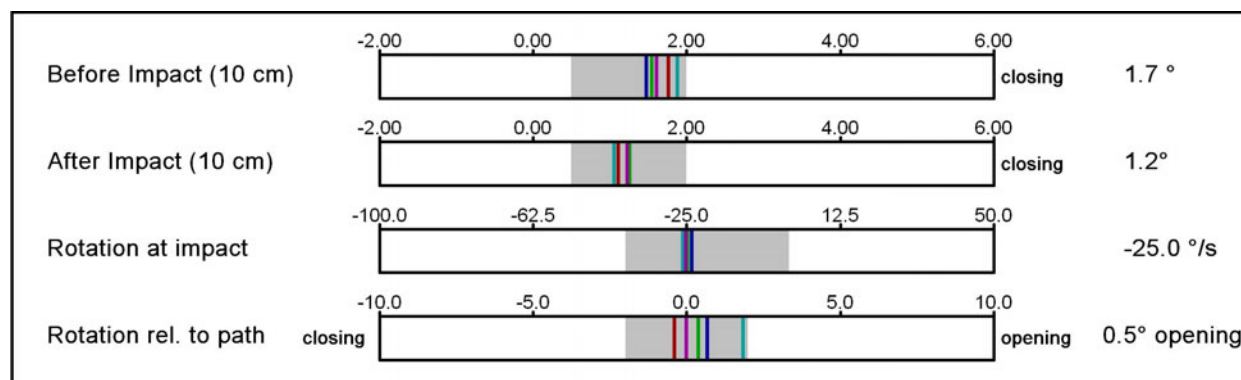
The rotation bar charts provide information on each single putt.

The "**Before impact**" bar shows the change of the putter face angle from 10 cm before impact until impact. 1.7 degrees rotation before impact is slightly more than the average of the European PGA Tour player's sample. The consistency of rotation is high.

The "**After impact**" bar shows the change of putter face angle from impact to 10 cm after impact. 1.2 degrees after impact match to the average value European PGA Tour players. The consistency of rotation after impact is high.

If rotation before impact and after impact are in the same range then rotation is changing smoothly through impact. If rotation after impact and rotation before impact differ, then the rotation is not naturally continued through impact, i.e. due to breaking wrists (closing more) or due to pushing the face open (closing less).

The "**Rotation at impact**" bar shows the dynamic putter face change at impact. 25.0 degrees per second is in the normal range of European PGA Tour players. If the rate of rotation at impact is high then the timing of the putting stroke becomes more important. If 50 degrees face change per second are assumed, then a timing error of 20 ms would result in putter face error of 1 degree (20 x 50 / 1000). This would mean you would miss a 4-meter putt. This illustrates that high amount of rotation requires high consistency of rotation and timing.

The "**Rotation rel to Path**" bar shows relative rotation on the arcing path. If the putter face is always square on the path, then the relative rotation is always zero irrespective of the amount of rotation. For more path arc there will be more rotation. This parameter is also relevant for putter fitting. If relative rotation is closing, then a toe hang putter might be selected to support smooth rotation. If relative rotation is opening, then a face balanced putter (mallet) is adequate. If relative rotation is neutral, an intermediate type of putter (Anser) or a face balanced putter is the choice.

8 Rhythm & Dynamics Report

8.1 Movement dynamics
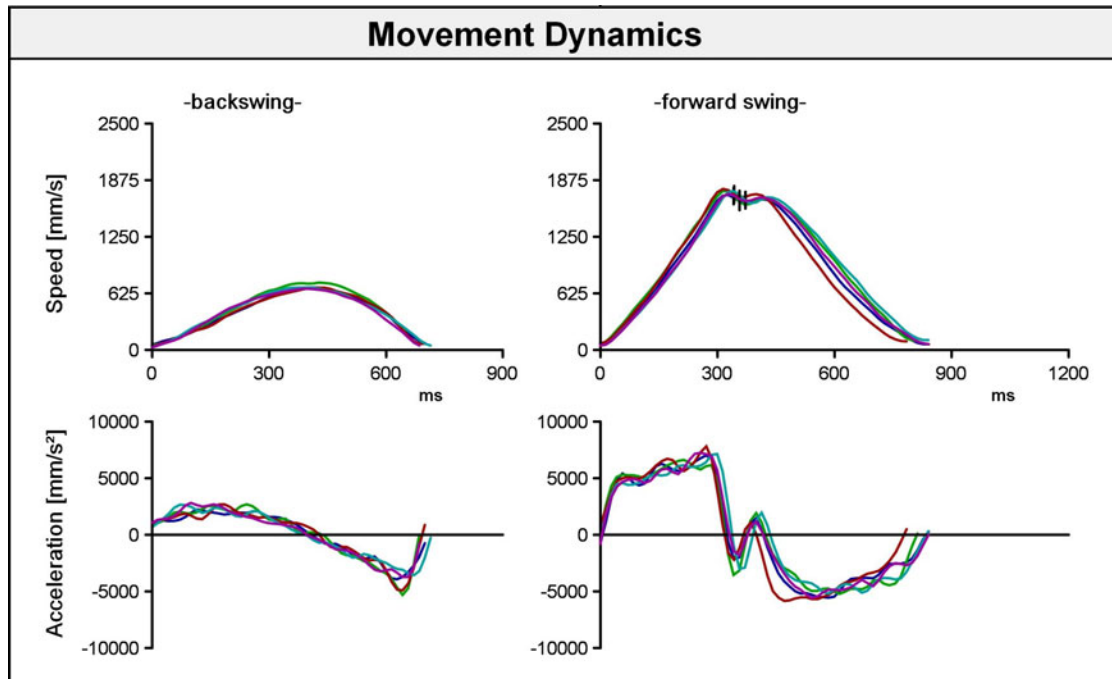
The description of movement dynamics includes velocity/speed and acceleration within backswing and forward swing. Movement dynamics are not directly related to putting technique. Movement dynamics rather show the motor skill level and the movement strategies underlying movement planning and execution. Backswing and forward swing curves are separated and displayed in two graphs only for educational purposes.

Velocity (upper graphs)
Movement velocity is always zero at the beginning and the end of a swing. The maximum velocity lies approximately in the middle of the movement (bell shaped profiles). The velocity curves should be smooth and regular for automated movement execution.

Acceleration (lower graphs)
The acceleration signal directly corresponds to the velocity signal: Acceleration is the change of velocity over time. High acceleration means fast increase of velocity. Zero acceleration means constant velocity. Negative acceleration means decreasing velocity.

Impact
The moment of impact is indicated with a vertical stripe in the velocity data. In the acceleration curve the impact with the ball can be identified by a steep cusp because the impact decelerates the putter face for a short moment. As the data is filtered, the cusp is wider than in reality. The exact impact is at the bottom of the cusp.

The characteristic of velocity and acceleration signals provide important information on the movement strategy of the player.

Backswing
Backswing duration is generally shorter than forward swing duration. The backswing starts smoothly. At the end of the backswing there is a sharp edge at the change from back to forward swing in the acceleration signal. Backswing and forward swing should not be two separate movements. This graphs show the typical characteristics of a committed putting technique. The backswing duration of 600-700 ms is in the optimal range.

Transition
The transition from backswing to forward swing is fluent without any pause. This is indicated a steep change from backswing into forward swing. This can be supported by a slight release of the putter at the top of the backswing. Hands and arms should be stable and firm but not stiff. Stiff limbs hinder smooth movement and do not provide proper feedback.

Forward swing
Forward swing starts approximately at the level where the backswing ended. So a committed begin of forward swing is preceded by a committed end of backswing and a steep transition.
The acceleration profile allows identifying the putting technique of the player. For a **swing** putting technique acceleration starts at a high level and is then kept **constant** until impact. For a **hit** putting technique acceleration starts at a lower level, **increases** steeply just before impact (to more than double), and decreases steeply after impact. For the player shown in this graph, acceleration increases slightly, but indicates still a swing type stroke. Forward swing duration of 800-900 ms is in the optimal range.

Consistency
Automated movements should be executed each time in exactly the same way. In particular the acceleration signal is extremely sensitive to muscle action and shows all details of movement execution. This refers to the shape of the curves, to height and position of the peaks, and to duration of the movements. For this player the repeatability of the curves, the duration of the movements and the position and height of the peaks is very similar. This indicates a high degree of movement automation and a high skill level.

8.2 Rhythm and Timing
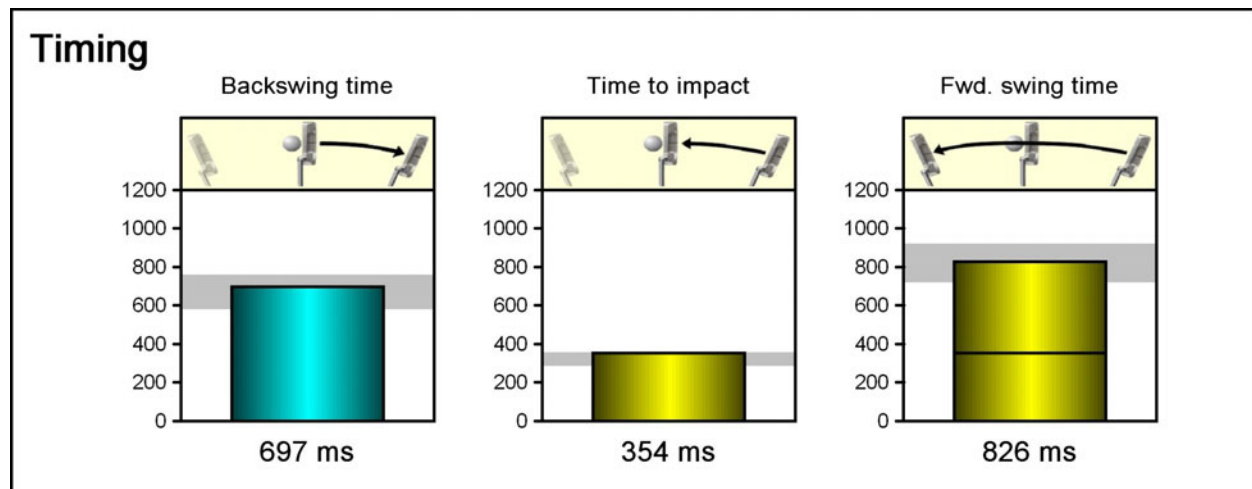
Rhythm and timing are generally guiding human movements. Consistent rhythm and timing are crucial for high consistency of the complete stroke. Proper rhythm and timing are the basic principles in skilled movement performance.

The graph shows the time of backswing, the time from beginning of forward swing to impact, and the time of the complete forward swing in bar charts. Time to impact is also marked with a horizontal line inside of the forward swing bar. The grey areas indicate the preferred range of the timings of the PGA Tour sample. The average time values are shown below the bars.

Backswing time
Backswing time should be generally about 100-200 ms shorter than forward swing time. Backswing duration of 600-700 ms is in the preferred range of PGA Tour Pros.

Time to impact
Time from beginning of forward swing to impact is approximately half time of backswing time (see 8.3) which would mean 300-350 ms.

Forward swing time
Forward swing time should be generally about 100-200 ms longer than backswing time. The putter swinging on its own has a cycle time of about 950 ms. Forward swing time is approximately in this range. Forward swing duration of 800-900 ms is in the preferred range of PGA Tour Pros.

The absolute times can differ between different stroke types, more aggressive (committed) players generally show shorter times and more cautious (anxious) players show longer times. However, rhythm and timing (the relation of the components) should then still be in a preferred range (see 8.3). In other words, the complete stroke can be somewhat slower or faster, but rhythm and timing are always the same range.

8.3 Dynamics bar charts
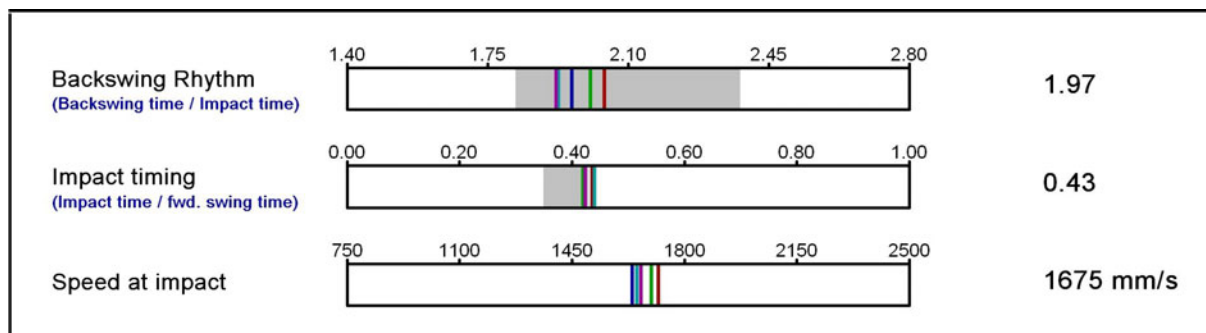
The dynamics bar charts provide information on each single putt.

Backswing Rhythm
The Backswing rhythm describes the ratio of backswing time to impact time. Backswing time should be approximately double as compared with impact time. The Tour average is 2.1.

- Fast rhythm: Players with a fast rhythm (< 2) are normally faster and more aggressive in the backswing. They tend to go for the ball and do not monitor details of their putting stroke, especially in the backswing. Another reason can be a long backswing with deceleration to impact.
- Slow Rhythm: High numbers for backswing rhythm (>2.2) identify players with a cautious backswing who tend to control the technique during the stroke. Processing of information during the backswing needs time which will slow down the backswing time. Another reason can be a short backswing resulting in steep acceleration to impact.

For a smooth rhythm counting the backswing and time to impact with "1001" can help. For backswing you count "1000" and for time to impact "1".

Impact timing
The "Impact timing" parameter indicates when you hit the ball during the forward swing. Impact timing describes the ratio of impact time to forward swing time. For beginners impact timing can be 0.5 or even higher because the ball is in the center of their stroke. For professional players the timing comes down to about 0.35-0.4. Hitting the ball early in the stroke ensures impact before maximum velocity, and hitting before maximum velocity per definition means accelerating through impact. Average impact timing of the Tour Pros is about 0.39 which means the hit the ball after 39% of forward swing time.

Speed at impact
The "Speed at impact" parameter shows the velocity of the putter face exactly at impact. High consistency of impact velocity is most important for distance control of the putt. Inconsistent impact velocity can be consequence of poor timing and / or inconsistent backswing length.

9 Face On Path

9.1 Face on path graph
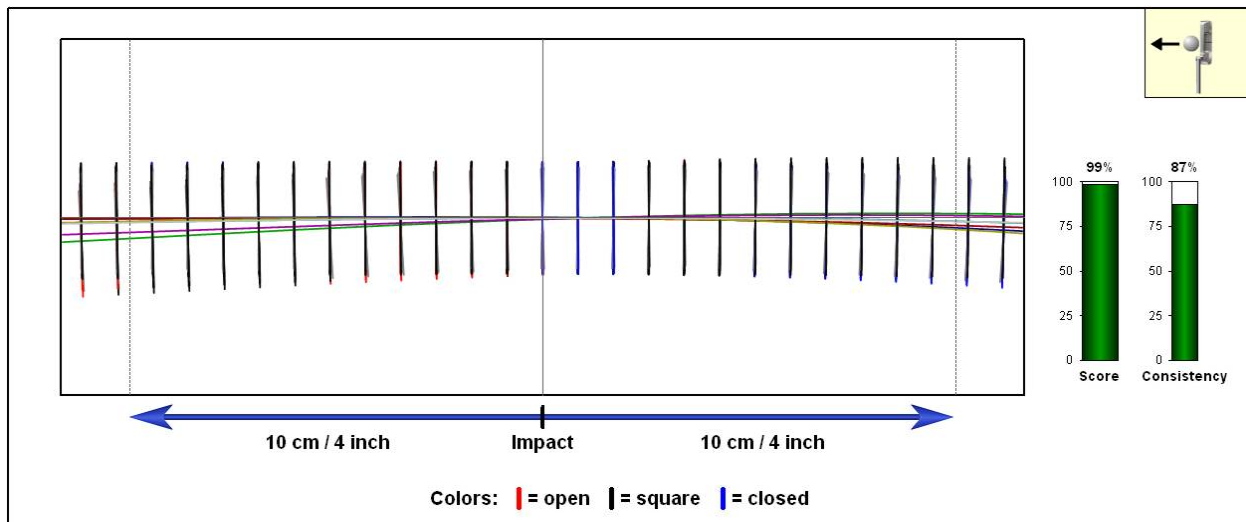
This report exactly indicates how the putter face is aligned relatively to the putter path around impact. For a natural stroke the path can be more or less arced, but the putter face will be always square on the path, which means there will also be more or less rotation on the arced path. Arc and rotation are then only a consequence of the tilted swing plane.

The graph shows the putter path in top view in a range of 20 cm or 8 inches around impact. The vertical lines represent the relative putter face angle along the path in the displayed area. The different colours of the lines show how the putter face is aligned relatively to the direction of the path (NOT TO THE TARGET!).

- Red line: The Putter face is open more than 1 degree on the path
- Black line: The putter face is aligned in between +/- 1 degrees on the path (this means it is nearly perfectly square)
- Blue line: The putter face is closed more than 1 degree on the path

For this player almost all lines are black indicating that the face is always pretty square on path. The Score rating on the right side relates to the Face on Path at impact parameter. The face is almost square to path at impact with only 0.1 degrees closed, which results in 99% Score. The consistency is also high with 87%.

> **i** The FaceOnPath angle is measured against the path direction for every displayed line, NOT against the target alignment. If the face is square on path at impact, then the ball is going exactly into the direction where face and path are pointing to. If the putt still misses the target, then probably the body is mis-aligned as compared with the calibrated target line.

10 Fitting Report

At the first page of the Print fitting report you find a data header which is described in Chapter 2.2 in detail.

The data table beneath the header presents relevant data for the single putts as well as average data values and standard deviations. Additionally the corresponding Score values are displayed. Depending on the Score level a small coloured triangle in the data cell indicates the performance level according to the colour coding of the Score bars in the graphical reports.
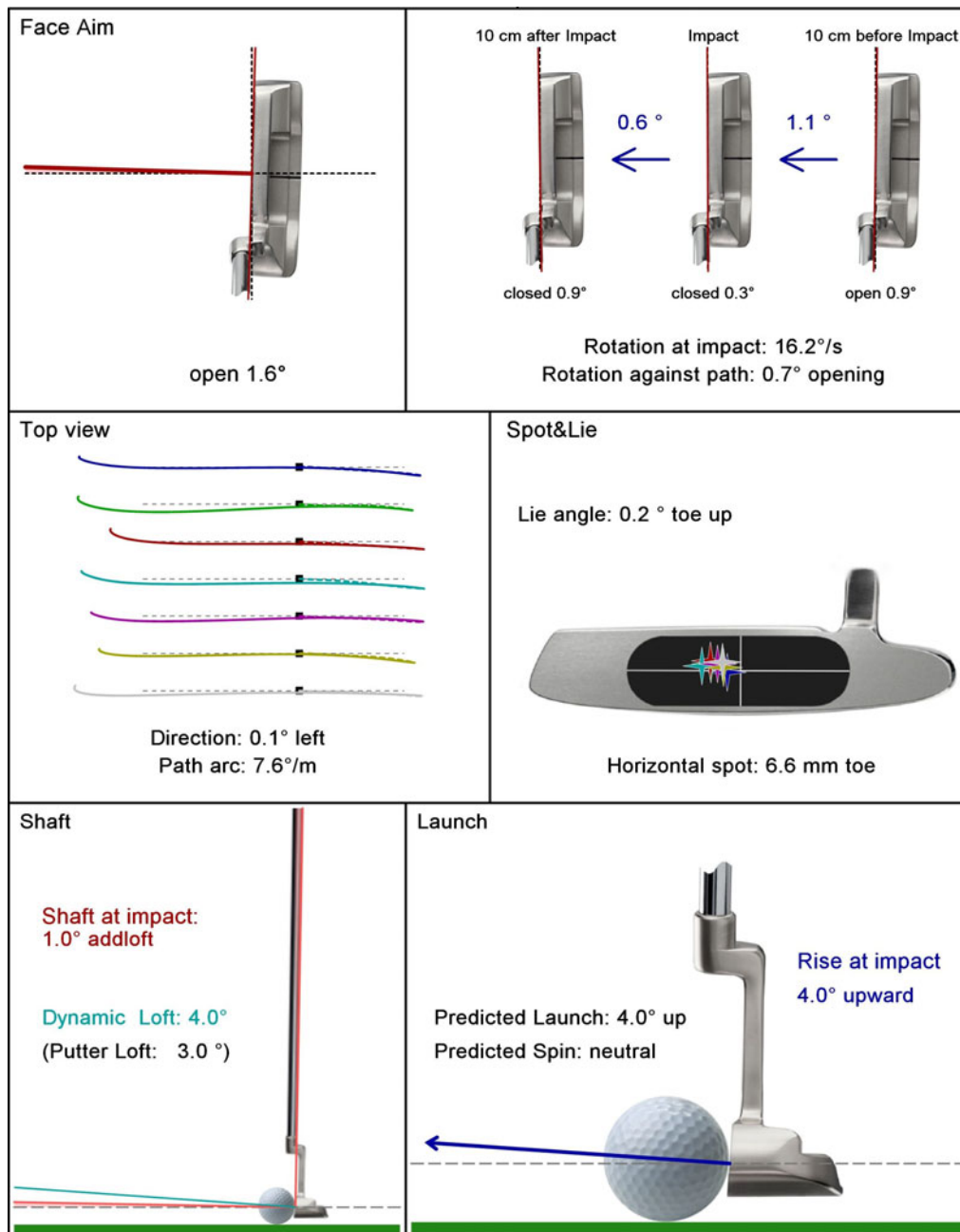
#	Face Angle		Direction	Rotation	Horizontal Spot		Height	Rise	Shaft Angle		Lie Angle	
	Address	Impact	Impact	Rotation	Address	Impact	Impact	Impact	Address	Impact	Address	Impact
	[°]	[°]	[°]	[°/s]	[mm]	[mm]	[mm]	[°]	[°]	[°]	[°]	[°]
1	1.7 op.	0.1 op.	0.6 right	-13.9	3 toe	4 toe	11	4.1 up	1.8 add	1.1 add	2.1 down	0.1 up
2	0.6 op.	0.7 cl.	1.6 left	-21.7	2 toe	8 toe	8	4.1 up	2.4 add	2.0 add	2.0 down	0.2 down
3	2.3 op.	0.0 op.	0.5 right	-15.5	3 toe	8 toe	7	3.9 up	1.6 add	0.5 add	1.6 down	0.1 down
4	2.5 op.	0.0 op.	0.0 left	-17.3	1 toe	11 toe	9	3.7 up	1.4 add	0.7 add	1.8 down	0.2 up
5	1.4 op.	0.5 cl.	1.0 left	-13.0	2 toe	6 toe	8	3.8 up	1.7 add	1.0 add	1.7 down	0.1 down
6	2.2 op.	0.2 cl.	0.6 right	-17.8	3 toe	5 toe	9	4.3 up	1.4 add	1.0 add	1.6 down	0.5 up
7	0.7 op.	0.5 cl.	0.0 right	-13.9	0 toe	5 toe	8	3.9 up	2.4 add	1.0 add	1.0 down	0.9 up
AV	1.6 op.	0.3 cl.	0.1 left	-16.2	2.0 toe	6.6 toe	8.6	4.0 up	1.8 add	1.0 add	1.7 down	0.2 up
SC	72.8%	91.9%	98.4%	95.2%	49.8%	54.0%	92.1%	84.1%	77.2%	87.0%	78.8%	97.6%
SD	0.8	0.3	0.9	3.0	1.0	2.4	1.0	0.2	0.4	0.5	0.4	0.4
CO	78.6%	96.6%	85.5%	93.8%	84.6%	79.3%	90.4%	98.4%	73.2%	76.5%	53.1%	91.3%

i Please note that negative values for **Rotation** mean a face that is closing through impact. The **Height** value corresponds to the height of the putter above ground at impact. The **Shaft angle** refers to the physical vertical of the receiver unit. For tilted surfaces the receiver units needs to be set up parallel to the surface. The **Lie angle** is given *relative* to calibration position. The putter must be set flat to the ground during calibration to measure the correct lie value.

The second page shows relevant data in graphical views. The data reveals information to determine correct putter length (amount of rotation, arc, irregular path), loft (dynamic loft, launch and spin), lie, grip size (breaking wrists, over-rotation), MOI (off-center hits), head configuration (over- or under-rotation, or shaft configuration (mis-aiming), all depending on the fitting protocol used. The corresponding Consistency Scores can be inspected in the data table.
For more sophisticated aspects of fitting such as head weighting or swing weight the Dynamics and Rhythm report need to be considered.

Face Aim — open 1.6°

10 cm after Impact — closed 0.9° — 0.6°
Impact — closed 0.3°
10 cm before Impact — open 0.9° — 1.1°

Rotation at impact: 16.2°/s
Rotation against path: 0.7° opening

Top view
Direction: 0.1° left
Path arc: 7.6°/m

Spot&Lie
Lie angle: 0.2 ° toe up
Horizontal spot: 6.6 mm toe

Shaft
Shaft at impact: 1.0° addloft
Dynamic Loft: 4.0°
(Putter Loft: 3.0 °)

Launch
Rise at impact 4.0° upward
Predicted Launch: 4.0° up
Predicted Spin: neutral

- Rotation against path: This parameter describes the rotation of the putter face relative to the arc of the putter path inside of the impact zone of +- 10cm around impact. For a natural movement the relative rotation on the arcing path is always zero irrespective of the absolute amount of rotation as compared with the target line. Relative opening action is associated with Mallets or face balanced putters, closing action is associated with Blade putters or toe weighted putters.

- Path arc: This parameter describes the curvature of the path at impact. For a neutral stroke with an adequately fitted putter path arc amounts to about 15 °/s. Path arc < 10 °/s are more straight paths, arcs > 20 °/s are more curved paths.

11 Competence Profiles

Competence Profiles present an overview on the putting performance in bar graphs. The *PersonalCompetenceProfile* shows only data for the currently selected data set. The *MultiCompetenceProfile* allows to compare profiles of different measurements or different players. The data for each measurement is shown in a specific color. The Score Rating for each aspect is shown numerically as well as in a bar chart.

The bars at the left side correspond to the *Tendencies* of a player and represent the deviation from an optimal *technical* value. The Score rating bar can point to the left or the right. To the left, the average data value is smaller (i.e. for swing time) or is more left (i.e. swing path) than the optimal data value. To the right the average data value is higher or more right. The longer the bar the more the performance deviates from a Tour player's average performance. The shorter the bar the better. The longest bar in the profile shows the aspect with the largest deviation from Tour player's performance. 100% is optimal performance. The green range (75-100%) represents +- one standard deviation of Tour player's data.

The bars on the right side correspond to the *Consistency* of a player and represent the repeatability of a putting stroke. The Consistency rating has no sign. The more the data values for each putt are close together the higher is the consistency. The longer the Consistency bar the better. The highest consistency is 100%. The shortest Consistency bar in the profile shows the aspect with the lowest consistency which needs to be considered during training.

For more details on Score and Consistency rating please consider Chapter 2.
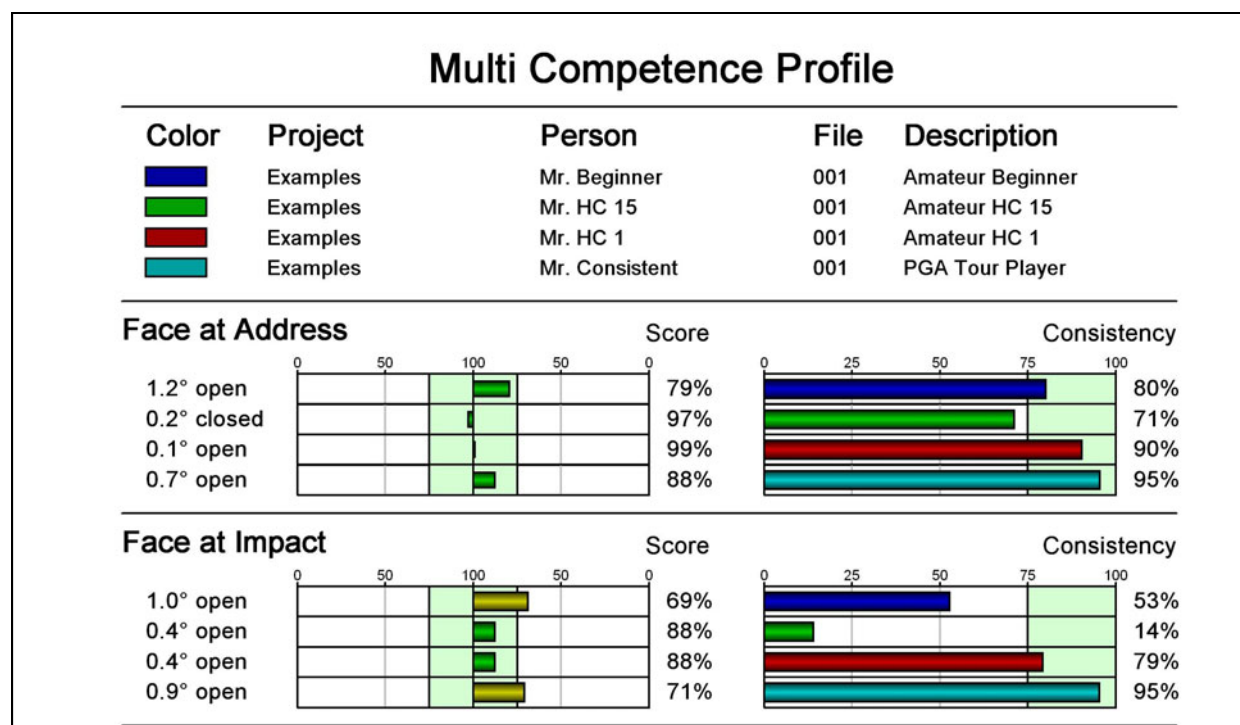
A deviation from a technical optimum might be acceptable as long as the deviation is consistent and as long as the profile as a whole makes sense (i.e. path pointing left and face slightly open). High consistencies are more important for the skilled players. Amateurs might show somehow neutral technique but will tend to show low consistency. The performance is then result of a random process.

Summary Scores

The overall scores summarize the performance for the different aspects:

- **Technique** – includes face at address, face at impact, path direction, face on path, impact spot and rotation at impact

- **Timing** – includes time to impact, backswing timing, impact timing, path symmetry

- **Consistency** – includes consistencies of face at address, face at impact, path direction, path length, face on path, impact spot, rotation at impact, backswing time, impact time, impact velocity

- **Overall rating** - summarizes technique (25%), timing (25%) and consistency (50%).
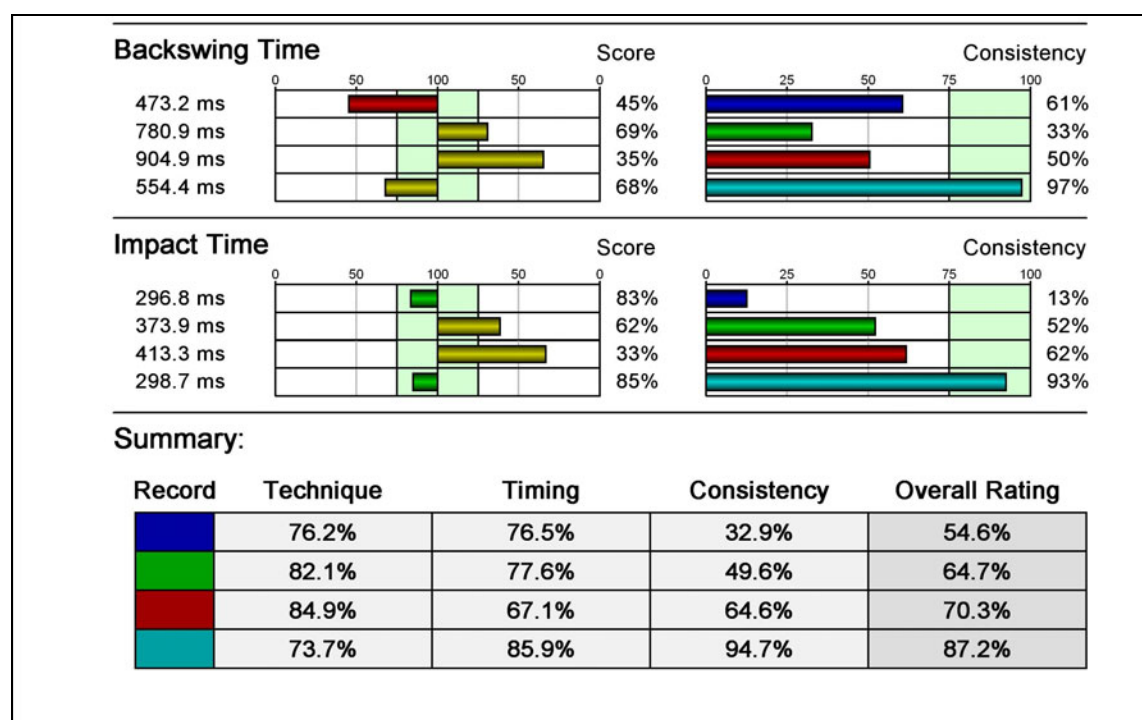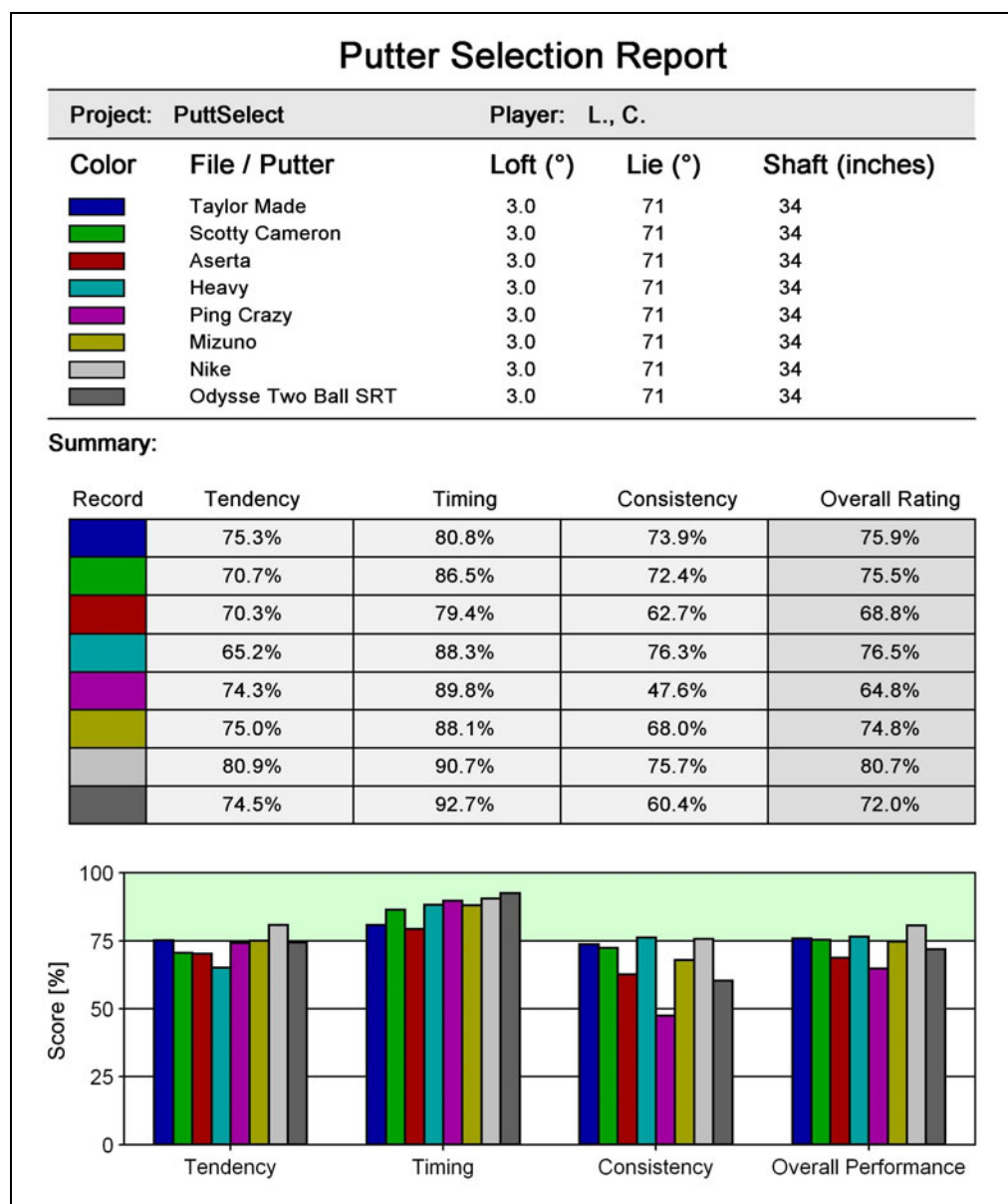

This Competence Profile shows the comparison of a Beginner, a HC15, a HC1 and a Tour player. Please note that the amateurs even show higher technique Scores than the Tour player. However the Tour player shows higher values for Timing and especially for Consistency. The Consistency Rating is dramatically increasing from the Beginner (blue, 33%) to the Tour player (cyan, 95%).

12 Putter Selection

The Putter Selection Report directly compares the performance of different putters for one person. Up to eight putters can be selected. The overall score directly shows the putter with the highest performance for a player. One of the specific Scores may be considered, if i.e. consistency needs to be improved in particular.

If you run the Putter Selection from the Sessions menu in the PuttLab main screen, then a dialog wizard is completely guiding you through the process. The measurements will be grouped together in one session. The putter names, loft, lie and length information is entered before each measurement. The Score rating for Tendency, Technique, Consistency and Overall Rating corresponds to the Rating in the competence profiles (see 11.). The table shows the scores in numbers, the same score is shown graphically in the bar graphs beneath.

Putter Selection Report

Project:	PuttSelect		Player:	L., C.	

Color	File / Putter	Loft (°)	Lie (°)	Shaft (inches)
	Taylor Made	3.0	71	34
	Scotty Cameron	3.0	71	34
	Aserta	3.0	71	34
	Heavy	3.0	71	34
	Ping Crazy	3.0	71	34
	Mizuno	3.0	71	34
	Nike	3.0	71	34
	Odysse Two Ball SRT	3.0	71	34

Summary:

| Record	Tendency	Timing	Consistency	Overall Rating
	75.3%	80.8%	73.9%	75.9%
	70.7%	86.5%	72.4%	75.5%
	70.3%	79.4%	62.7%	68.8%
	65.2%	88.3%	76.3%	76.5%
	74.3%	89.8%	47.6%	64.8%
	75.0%	88.1%	68.0%	74.8%
	80.9%	90.7%	75.7%	80.7%
	74.5%	92.7%	60.4%	72.0%

13 Head Movement Report (Pro Edition only)

The PuttLab PRO edition includes an additional sensor for head or wrist measurement. The use of the sensor is described in the Head_Wrist Manual. The data of the head sensor can be viewed at in a top view and in a side view. The head position graphs can also be displayed in the trainings mode. The reference point at zero exactly corresponds to the position of the head sensor during calibration. The ball is displayed in real size. The movement trace of the head sensor is shown corresponding to the movement paths of the putter. The dotted line represents backswing and the solid line forward swing. The black spot is the address position.

In this example, the head position at address is relatively stable slightly left and front over the ball. The head is stable in the front / back direction, but the head is turned to the left after impact. Additional information is provided in the middle of the reports for the movement (velocity) of the head. At impact, the head is moving with 57 mm/s to the left. In contrast, the small graph at the right shows a stable head position during the stroke.
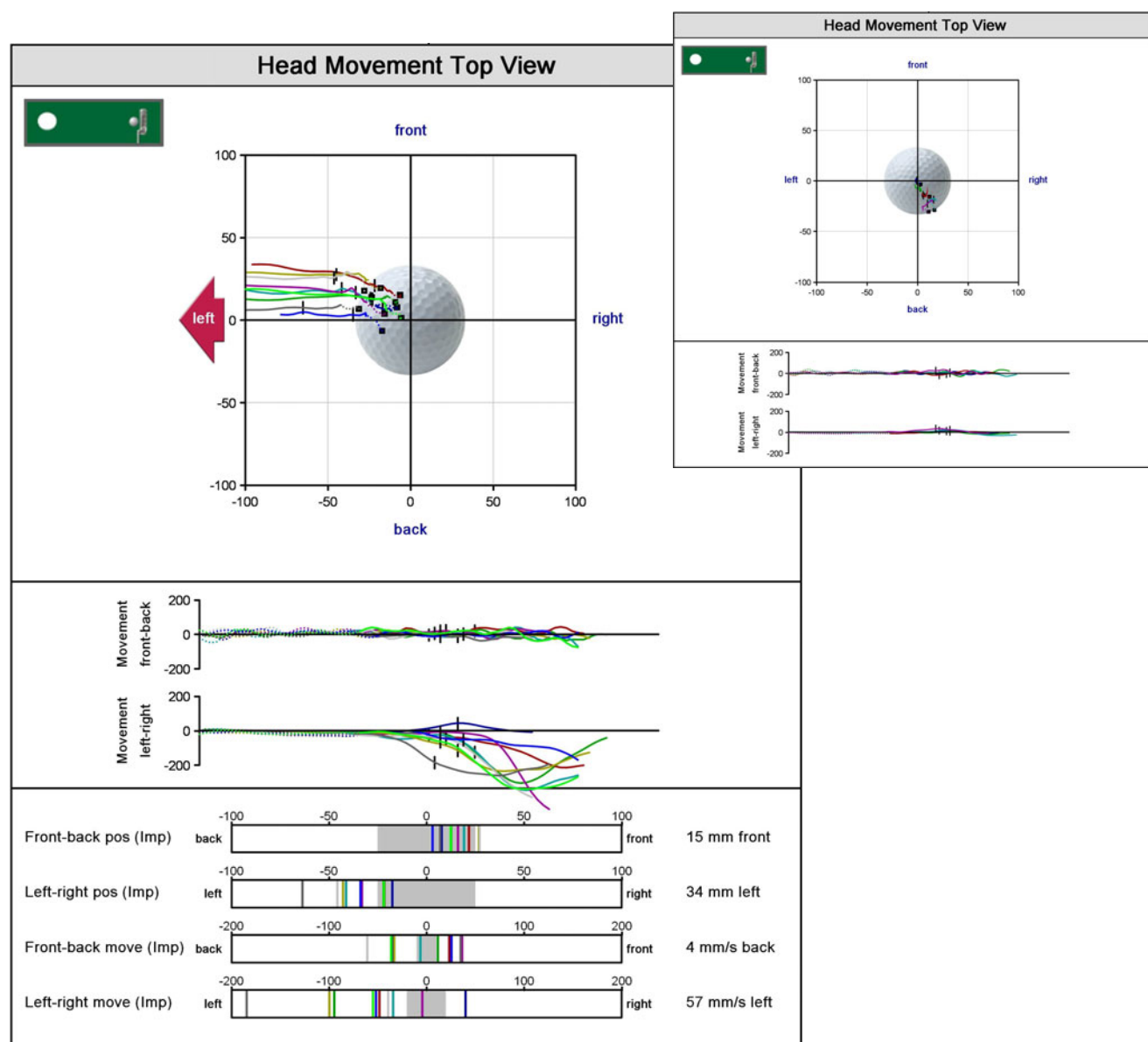
This graph shows the data of the head sensor in a side view. The reference point at zero exactly corresponds to the position of the head sensor during calibration. The dotted line represents backswing and the solid line forward swing. The black spot is the address position. The red arrow to the left indicates that some of the data is found out of the graph limits to the left.

In this example, the head position at address is inconsistent in the up / down direction. As said before, the head is turned to the left after impact. At impact, the head is moving with 57 mm/s to the left. The head is also moved down during backswing and then again up during follow through. The velocity of head curves in the middle show the movement slightly up through impact with 26 mm/s and left with 57 mm/s. At impact, the position of the head is 7 mm under the calibration position and 34 mm left of calibration position. In contrast, the small graph at the right shows a stable head position during the stroke.
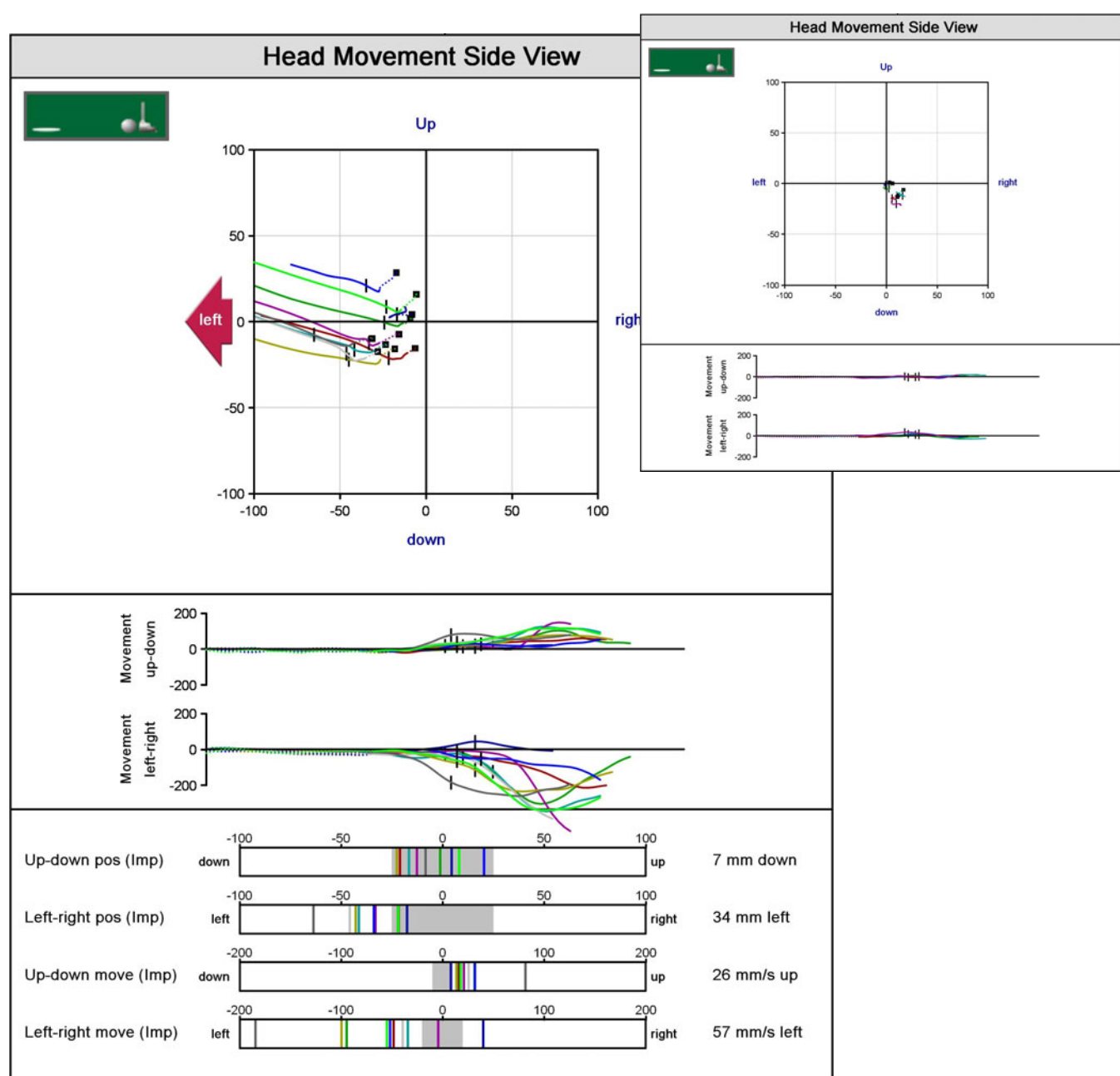
14 Wrist Movement Report (Pro Edition only)

The additional marker may both be used for head or for hand / wrist measurement. The wrist is important in particular in the measurement of Yips problems. Although the jerking of the hand can also be observed in the rotational signals, the additional measurement of the wrist can provide information on jerking, especially if the hand is only slightly gripping the putter (i.e. in a saw or claw grip). The wrist marker will normally be mounted to the right hand which is most affected by Yips.
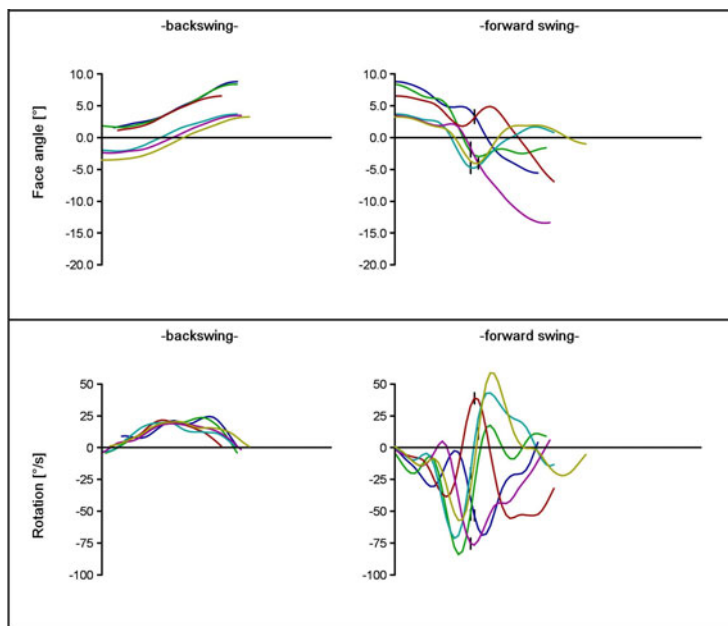

Yips problems before training

The first page of the *WristPrintReport* shows face angle (up) and face rotation (down) in the backswing (left) and the forward swing (right).

The report shows the severe disturbance in face angle and face rotation. Face rotation is more sensitive to Yips and will show a disturbance also in mid forms of Yips.

The different levels of the face angle curves in the backswing correspond to the inconsistent face aim.
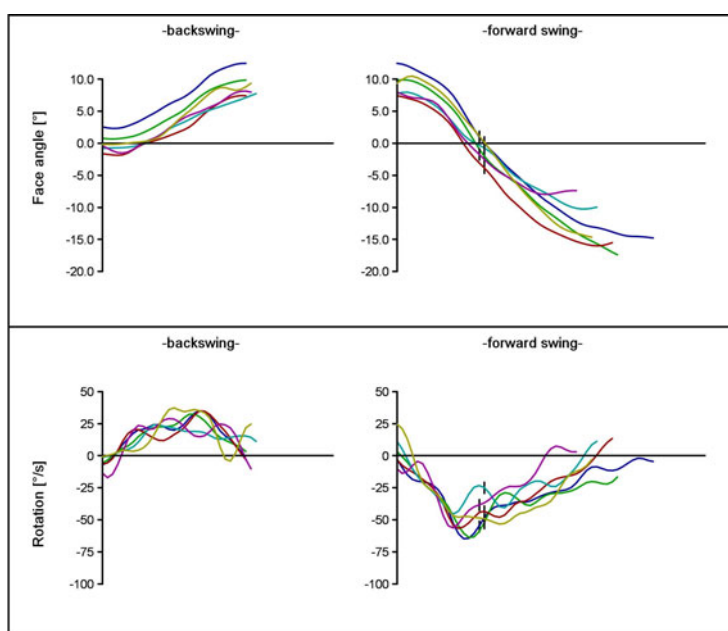
Same player after 2 hours of Yips training

The lower report shows the result after two hours of Yips training. The face angle now looks almost regular. The rotation curves show that the problem is not completely solved. The face rotation could still be more smooth.

The second page of the *WristPrintReport* shows movement dynamics of the wrist (up) and the putter head (down) for backswing (left) and forward swing (right). The levels of velocity and acceleration of the wrist amount to approximately 40% of the putter movement. Please note the different scaling of wrist and putter graphs (factor 2).
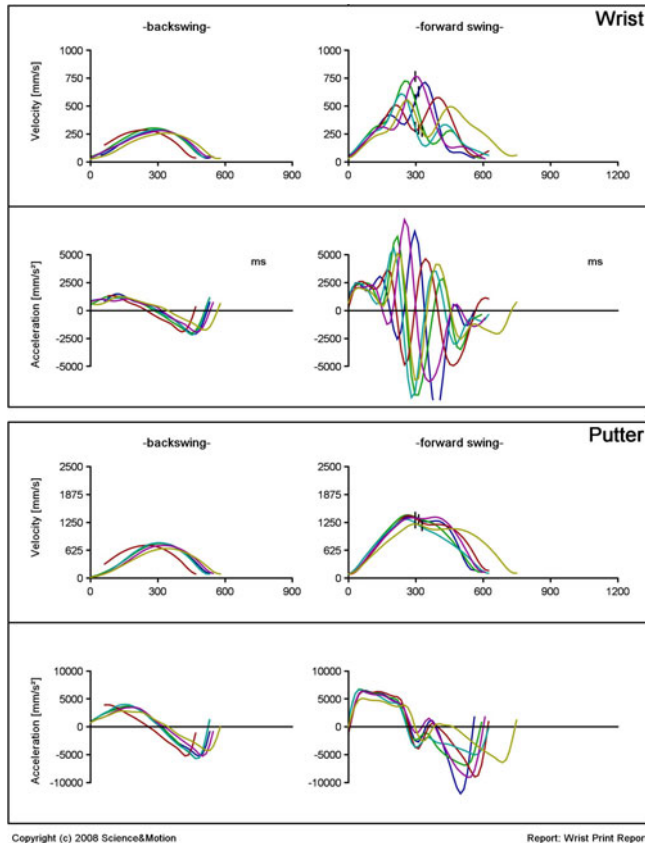

Wrist movement before training

The upper left report (before training) shows a dramatic disturbance and oscillation in the wrist velocity and acceleration data. In contrast, the backswing looks quite regular.

Very interestingly, the movement dynamics of the putter (left down) look far more regular. This means that it might be very difficult to identify the Yips in the putter movement data itself. Yips is a problem of control of face rotation. Impaired movement speed and acceleration is rather a consequence of the jerking. The Yips can only be clearly identified in the wrist movement data and the rotation data.

Same player after 2 hours of Yips training

The report at the right shows the result after the two hours of Yips training. All curves now look very regular if not to say perfect. In particular the high consistency of the movement is surprising. The characteristics of wrist movement and putter movement look pretty much the same.
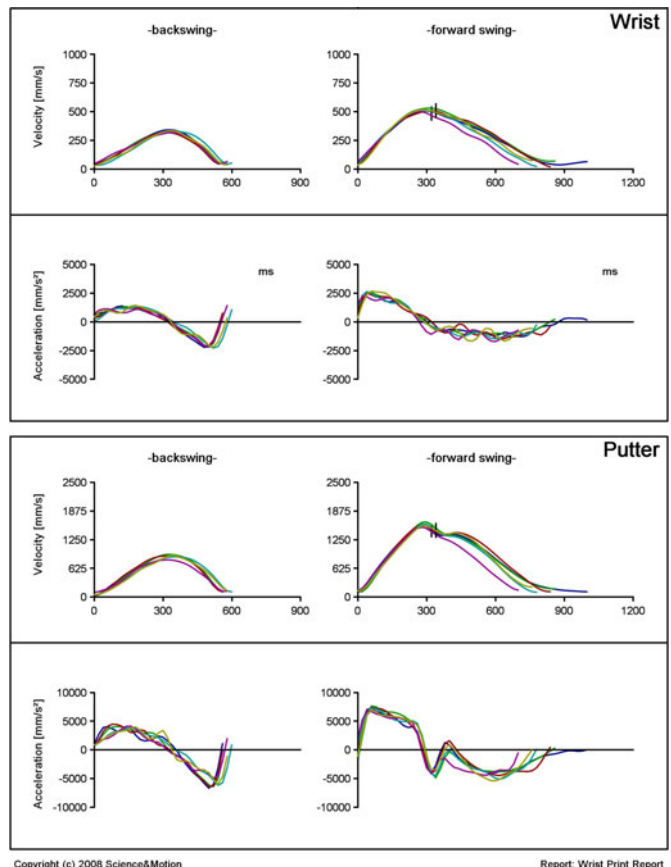
15 Example of Tour performance

15.1 Aiming

The Putter Face angle describes the alignment of the putter face in relation to the intended target line. The face can be open (pointing right), square or closed (pointing left) as compared with the true putting line. The face angle at address is measured exactly before he putter is moved away from the address position to the right. At aim the putter face should point to the target. In repetitive aiming the consistency of the aim angle is of highest importance for control of face angle at impact.

Deviations from square aim can be consistently corrected as long as the deviation is also consistent. The aim angle should not deviate more than 2 degrees from the true target direction. If we translate mis-aiming to putt distance, than an error of 1 degree in face angle will point the face to the left or the right edge of the hole for a 12 feet putt.

Data analysis:

- Slightly closed at address 0.7°

- This deviation results in a Technical Score of 88%

- The repeatability of the aiming is very high

- This repeatability results in a Consistency Score of about 92%

- The left aiming is corrected to impact. The face change from aim to impact is small with 0.8° opening

- The consistency of the face change is also high.
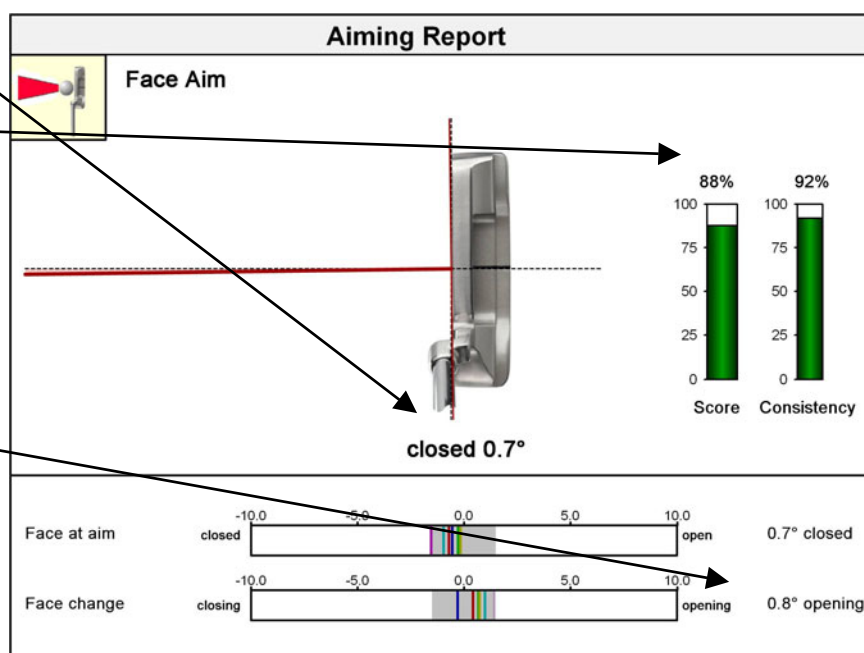
15.2 Face and Path Direction

Generally face angle at impact and path direction determine the direction of ball travel. Putter path direction and face angle compensate each other. For an open face the path have to run inside left to make the ball roll straight, or the other way round.

The face angle at impact has considerably more influence on the direction of the ball as compared with the putter path direction. The face angle at impact determines ball direction to 83% and is thus about 5 times more important than the putter path. An open face of about 1 degree can only be compensated with path cutting left 5 degrees.

If we correlate path errors to putt distance, than an error of 1 degree in face angle will result in missing the hole in a 4 meters putt (if the putter path is square at the same time). For half distance in a two meters putt the error can be double with about 2 degrees. This means that missing putts is mainly because of misaligned face angle. The ball direction as calculated with the PuttLab is considering face to 83% and path direction to 17%.

Data analysis:

This player is one of the best putters on the PGA Tour. He shows a perfect control and consistency of all direction parameters. All data values are inside of the preferred grey data ranges.

- The face is in average absolutely square at impact. This results in 100% Score. Consistency is high with 93%

- The path is slightly left with 0.2°. Consistency is high with 95%.

- The face is almost square relative to path at impact with 0.2° open, again with high consistency.

- The resulting ball direction is in average 0° and also very consistent.
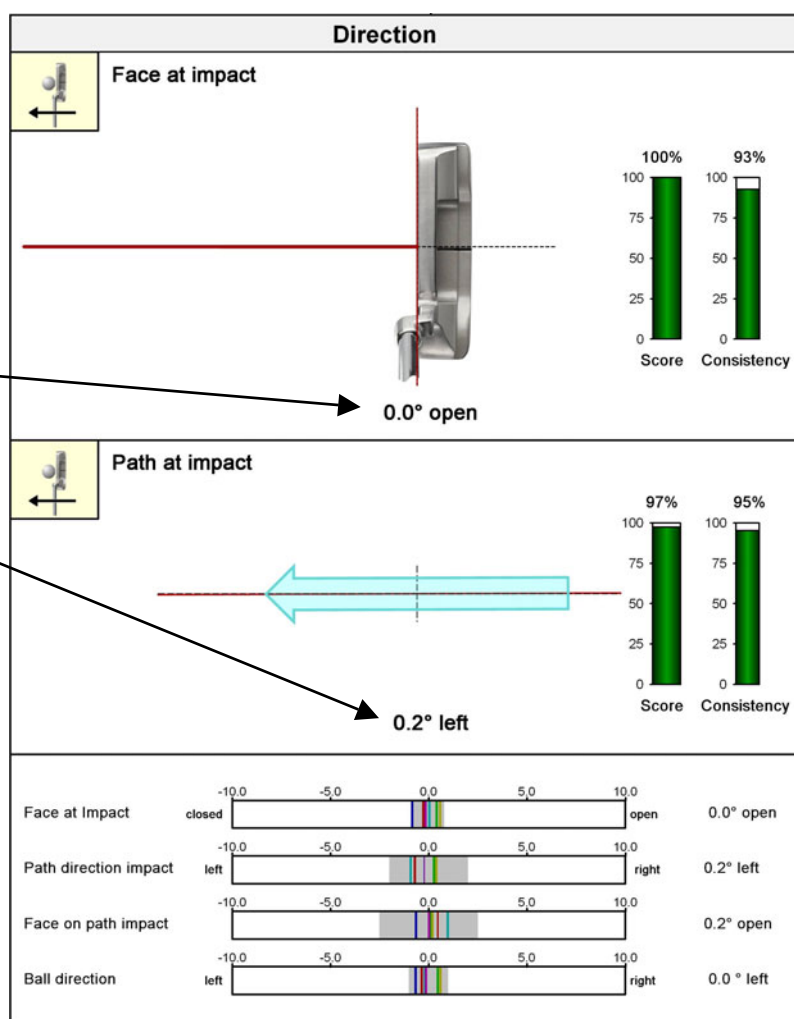
15.3 Putter path and Impact spot

Path geometry
The putter is naturally moved back and forth on a *tilted* swing plane. If projected down to the target line a tilted swing plane results in an ellipse form, so the putter will slightly move inside in the backswing, then match the target line through impact and then again will move inside in the forward swing. The more the swing plane is tilted, the more this ellipse will be curved.
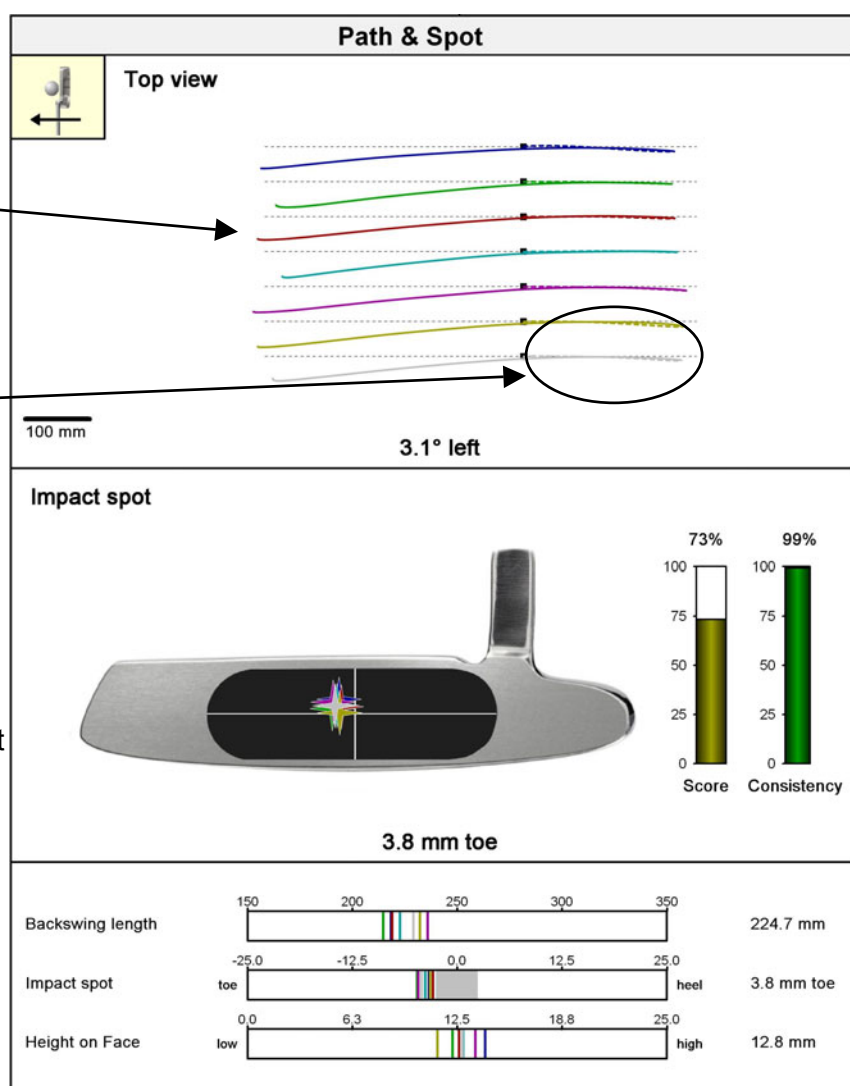The consistent length of the back swing is very important. The amplitude of the movement determines the length of the putt, as swing timing tends to be constant also for different lengths. Consistent length of backswing means consistent distance control. Very often the end of the forward swing is also neglected. Consistent length of forward swing is also important for a solid stroke and proper timing of speed.

Impact Spot
The setup position and putter path in the backswing will determine where you will hit the ball on the face. Very often an inconsistent hit spot is directly related to poor balance and a backswing which is too long.

Data analysis:

- A natural movement path is slightly curved inside at begin and end

- In plane backswing (dotted), no loop

- Backswing is shorter (35%)

- Very consistent length of backswing

- Forward swing length is also consistent

- The impact spot is 3.8 mm at the toe, which often happens for paths cutting left through impact

- The highly consistent impact spot corresponds to the smooth and consistent path

- Inconsistent spot is often a setup/balance problem

Path & Spot

Top view

100 mm   3.1° left

Impact spot

73%   99%

Score   Consistency

3.8 mm toe

	150	200	250	300	350	
Backswing length						224.7 mm

	-25.0	-12.5	0,0	12.5	25.0	
Impact spot	toe				heel	3.8 mm toe

	0,0	6,3	12.5	18.8	25.0	
Height on Face	low				high	12.8 mm

15.4 Dynamic Loft & Rise

Depending on the static loft on the putter and the hand position at impact, the dynamic loft applied to the ball is determined. For neutral hands a static loft of 2 degrees will result in 2 degrees dynamic loft to the ball. If the hands are in front of the ball (forward press) then a putter with higher loft might be ending up with the same amount of dynamic loft (static loft of 4 degrees, delofting 2 degrees, results in dynamic loft of 2 degrees). In contrast, if the hands are behind the ball thus adding loft to the static loft of the putter, the dynamic loft and the launch angle may end up with very high numbers.

Ball spin
The difference between dynamic loft applied to the ball and angle of attack (Rise) determines ball spin. If rise angle of the putter through impact (3-4 °) is higher than the dynamic loft at impact (2°) then the ball will immediately start launching with some amount of topspin. If the rise angle is less than the dynamic loft then the ball will start with some backspin.

Launch angle
The dynamic loft applied to the ball primarily determines launch angle of the ball, like face angle determines ball direction. There is some additional minor influence of vertical angle of attack (Rise) on launch angle of the ball. High speed video shows that on fast greens (stimp 11) a launch angle of about 2 degrees is enough for proper ball launch.

Data analysis:

- Loft imparts backspin on the ball, rise angle of the path imparts top spin

- Flat backswing

- Hitting the ball up through impact

- Slightly elevated dynamic loft (1.5 ° addloft)

- Predicted launch 4.1 ° up is high for fast greens (stimp 11 requires 2° launch)

- Rise angle 2.9 degrees upward

- Resulting spin is slight backspin because of high dynamic loft of 4.5 degrees
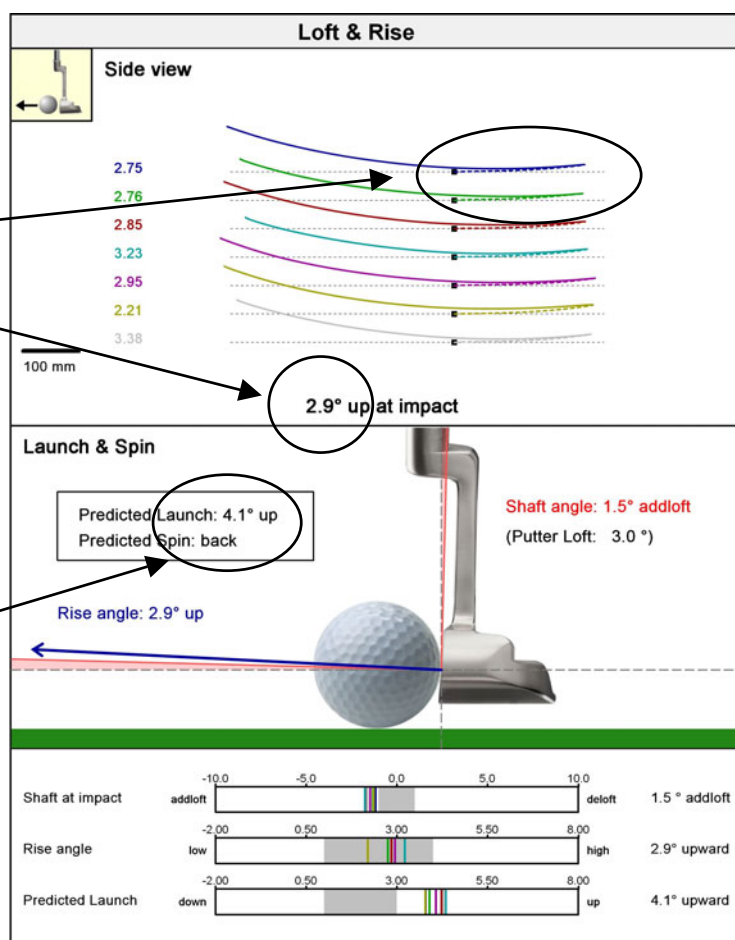
15.5 Face rotation

Face rotation is a consequence of moving the putter back and forth on a *tilted* swing plane. In a natural plane stroke the face will ALWAYS be square relative to movement path direction. Only if projected down to the target line a tilted swing plane will result in an ellipse form, but still will be square at impact. This means that rotation inside of a swing is NOT necessarily consequence of hand or wrist action but a normal consequence of the amount of tilt of the swing plane.

For upright stand there will always be more rotation in the stroke as the swing plane will be more tilted. In contrast, for a truely vertical swing plane, there will be no rotation inside of the stroke. The amount of face rotation is an issue of putter fitting.

In amateurs you often find additional hand and wrist action adding more rotation to the stroke. On the other hand, a lot of the skilled players tend to reduce rotation by blocking the face through impact. These are both not very helpful strategies, as they alter the normal pattern of rotation and add some amount of inconsistency.

Data analysis:

- The graph shows forward swing only

- Naturally open to square to closed

- Slight and symmetric rotation in the impact zone

- Total rotation depends on length of swing

- If the stripe meets the zero axis, then the face is exactly square at impact

- Flat and stable rotation at impact

- High consistency if all putts show exactly the same profile
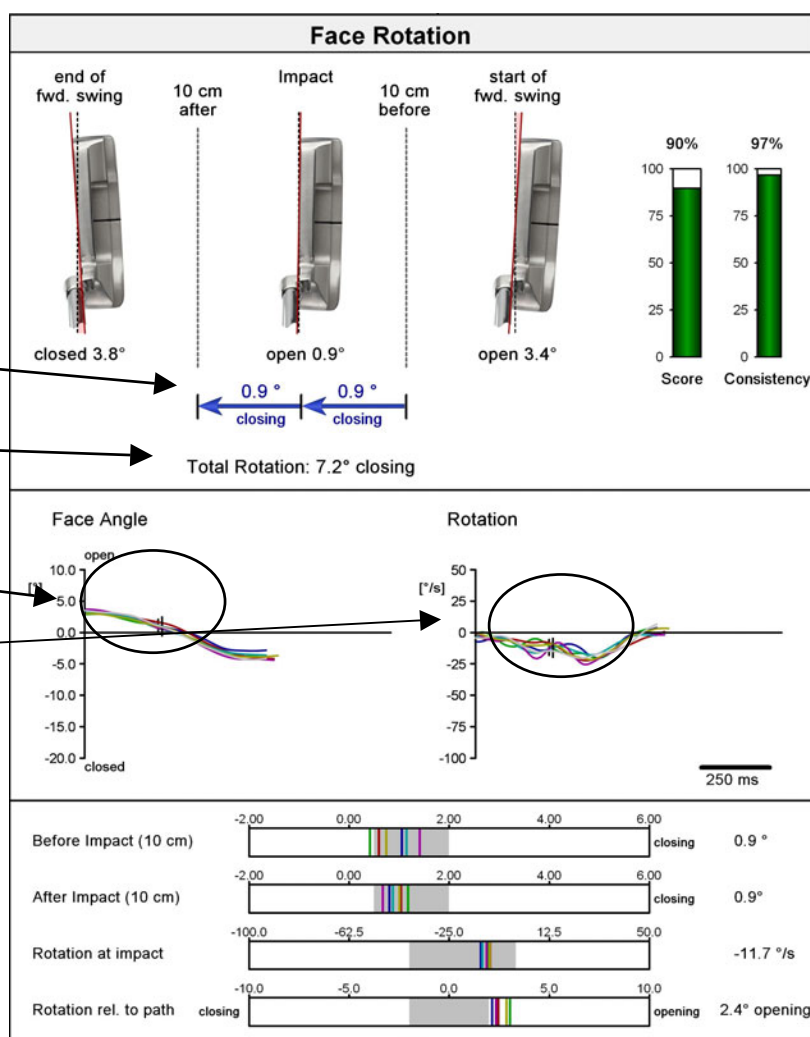
15.6 Movement dynamics

The PuttLab movement dynamics data directly reflect the movement of the putter face. This data is extremely sensitive and shows even smallest changes of the movement. For repetitive skilled and automated movements the trajectories, the velocity and acceleration curves, the height of the peaks and the timings will always be exactly the same. So if looking at the dynamic data, we always look at smooth and coherent curves. All the curves should be superimposed and look alike.

Generally, the backswing movement should start smoothly. The backswing should not be initiated through the hands rather than with the upper right arm. To end of backswing the acceleration is becoming more steeply with a sharp edge at the top of the backswing. The transition from deceleration at top of backswing to acceleration at begin of forward swing is associated with the change of movement direction. Backswing and forward swing should not be separated by stopping at top of the backswing. Backswing and forward swing should be ONE movement.

Until impact acceleration is then constant for **swing putters.** Constant acceleration means that the speed of the putter is constantly increasing. This is represented by a constantly ascending curve of velocity at begin of forward swing (upper right graph). In contrast, acceleration is steeply ascending for **hit putters**.

Impact reduces the energy of the putter moved and can be identified by a sharp peak downwards in the acceleration signal. After impact the acceleration is approaching back the zero acceleration for swing putters. For hit putters the acceleration is changing more steeply from positive acceleration before impact to negative acceleration after impact.

Data analysis:

- Consistent curve shapes and timings show high degree of movement automation

- Smooth start of backswing

- Same acceleration before / after transition

- Constant acceleration to impact (swing putt)

- Steep transition from backswing to forward swing (commitment)

- Acceleration would steeply increase for a hit putt
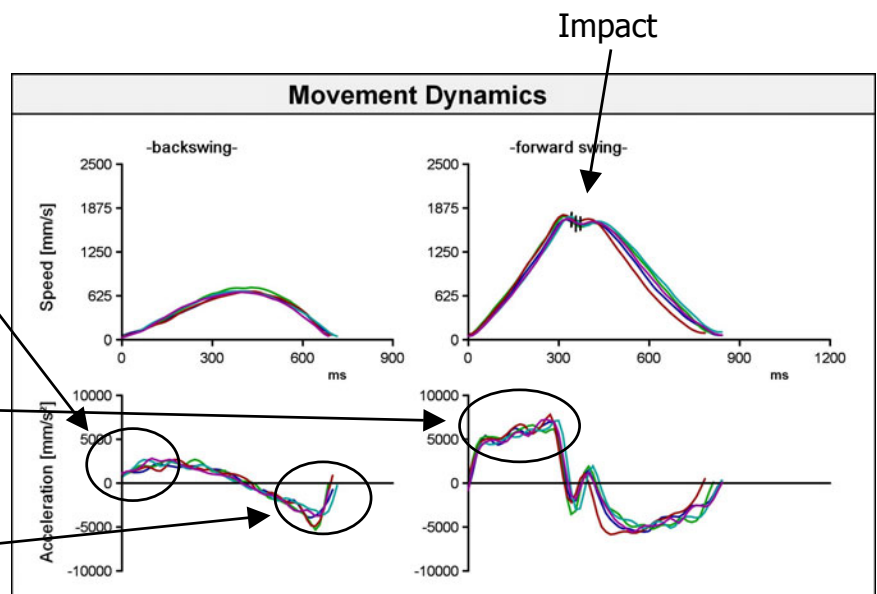
15.7 Rhythm and Timing

Rhythm and timing are generally guiding human movements. In skilled and automated movements we try to keep this sequence of action and the underlying timing constant. This principle is called the *isochronic* principle.

Movement duration will tend to be constant irrespective of movement amplitude. What will be adapted is just the amount of activation, more activation for longer putts, less activation for shorter putts. This results in a movement behavior where rhythm and timing will be almost independent from putt length.

Consistent rhythm and timing are also crucial for high consistency of the complete stroke. With a good rhythm and timing often everything seems to be in place automatically. While executing the stroke, we *feel* the rhythm which is guiding us through the process of moving. Good feel in fact means that timing is perfect, everything is in place, everything happens as planned.

More than that, feeling the rhythm is also helping the brain to relax and to more focus on the task. In other words you will be more connected to the task. The more you automatically execute the movement, the more you will be able to connect yourself to the task – holing the putt.

Backswing Rhythm:

- Backswing time should be 100-200 ms shorter than forward swing time

- Consistent timing controls the complete stroke
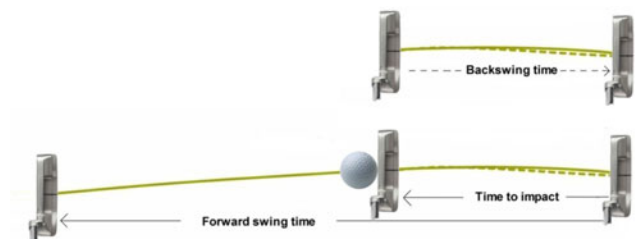
Backswing rhythm =
Ratio of backswing time / time to impact

Data analysis:

- Regular backswing time (697 ms)

- Regular impact time (354 ms)

- Regular forward swing time (826 ms)

- Backswing time is double as compared with time to impact (ratio 1.97)

- Time to impact is about 43% of forward swing time