NON-LINEAR ANALYSIS OF CENTRE OF PRESSURE PATTERNS IN THE GOLF SWING – POINCARE PLOTS

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Little research exists in the golf swing examining shot to shot differences in the short or long term. The aim of this study was to use Poincare plots to examine if short and long term patterns exist among golfers. Five golfers performed 50 golf swings hitting a ball into a net while standing on two AMTI force plates. Centre of Pressure in the direction of the swing (CPy) was calculated for each swing. Poincare plots with CPy Range at swing N on the x-axis and CPy Range at swing N + 1 on the y-axis were constructed for each golfer. Plots were individual specific with short and long term variability highlighting interesting differences between golfers. Interesting shot to shot patterning existed, especially for one golfer. The use of Poincare plots in future work can provide useful information to the golfer and coach.

KEYWORDS: Golf, Centre of pressure, Poincare plot

INTRODUCTION:

While single or mean swing data have been examined in golf, there has been little research into how performance alters between shots or over longer periods of time. The question of how performance changes from shot to shot and across shots over time is very important to the golfer. For example, is there a pattern of progression in performance leading up to a poor shot? Is there a pattern of performance after a poor shot is performed? Non-linear techniques, such as Poincare plots, could answer these questions. A Poincare plot is a nonlinear dynamic technique that plots a parameter value against its next value and this technique has been used to highlight nonlinear patterns in data such as heart rate variability (e.g. Brennan *et al*., 2001; Kamen *et al*., 1996; Woo *et al*., 1992). The aim of this study was to use a non-linear technique in analysing weight transfer in the golf swing to evaluate if useful information was provided.

METHODS:

Five golfers with different skill levels performed 50 drives hitting a ball into a net while standing on two AMTI force plates (Advanced Mechanical Technologies Inc., Massachusetts, USA), one under each foot. This data was sampled at 500Hz using an AMLAB 16-bit ADC system (AMLAB technologies, Sydney) and smoothed using a 15 Hz butterworth digital filter. For each swing, the smoothed force data was used to calculate centre of pressure in the direction of the hit (CPy, equation 1).

Overall CPy (Force plate 1 and 2 combined)

$$CPy = \frac{(Fz1 * CPy1) + [Fz2 * (CPy2 + Df2)]}{Fz1 + Fz2} \qquad \textbf{Equation 1}$$

Where CPy1 = CPy for force plate 1
CPy2 = CPy for force plate 2
Fz1 = force in the z-axis for force plate 1(vertical)
Fz2 = force in the z-axis for force plate 2 (vertical)
Df2 = distance between the centre of force plate 1 and force plate 2 (centre of force plate 1 = zero)

From this data, CPy Range was calculated (CPy Range = maximum CPy - minimum CPy: chosen as it was found to correlate with clubhead velocity by Ball and Best, in press). Poincare plots were generated with CPy Range at swing N on the x-axis and CPy Range at swing N+1 on the y-axis for each golfer. Poincare plots were quantified using R^2 values, 95% ellipse area encompassed by the dot cloud (E95%; using axes P1 and P2 where P1 is the line of identity, x = y, and P2 is perpendicular to P1), short term variability (ST; standard deviation of perpendicular distances from P1 to each [N,N+1] datapoint; Brennan *et al.*, 2001) and long term variability (LT; standard deviation of perpendicular distances from P2 to each [N,N+1] datapoint; Brennan *et al.*).

RESULTS:

Figure 1 shows Poincare plots and table 1 reports quantified plot data for each golfer.

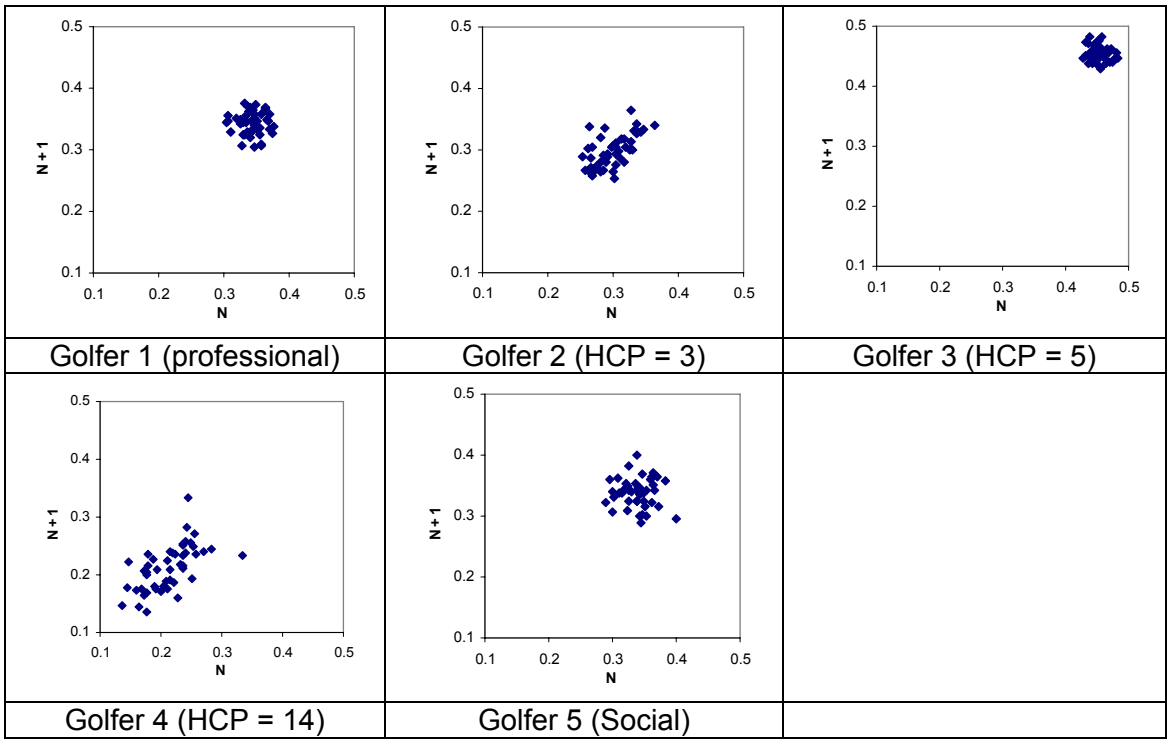


Figure 1: Poincare plot for CPy Range values (in m) across 50 consecutive golf swings for each individual golfer.

Table 1: Mean, SD, R^2, Ellipse area (E95%), short term variability (ST) and long term variability (LT) for CPy Range for each golfer (HCP = handicap).

	HCP	*CPy Range Mean (m)*	*CPy Range SD (m)*	*R^2 (p)*	E95%	ST (m)	LT (m)
Golfer 1	Pro	0.34	0.02	0.00 (0.84)	0.015	0.017	0.018
Golfer 2	2	0.30	0.03	0.40 (0.00)	0.029	0.016	0.035
Golfer 3	5	0.21	0.04	0.00 (0.47)	0.008	0.012	0.013
Golfer 4	14	0.45	0.01	0.37 (0.00)	0.061	0.024	0.050
Golfer 5	Social	0.34	0.02	0.00 (0.83)	0.029	0.024	0.025

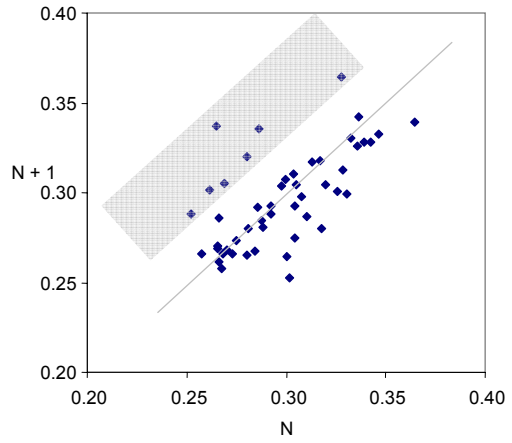
DISCUSSION:

Poincare plots were individual-specific. Three golfers produced random fluctuations about their mean CPy Range value as indicated by rounded clouds (Golfer 1, Golfer 3 and Golfer 5), although the different size of the point 'clouds' shows how the variability differed. The elongated clouds of Golfer 2 and Golfer 4 indicated more long term compared with short term

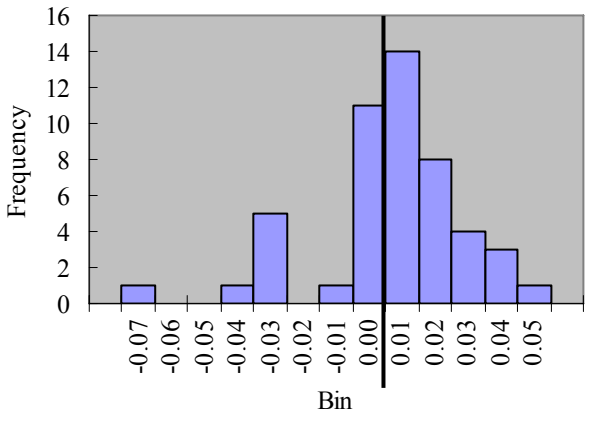
variability (also supported by data in table 1) and the significant R^2 value suggested that consecutive shots were related to each other (i.e. the next shot might be influenced by the previous shot). Specifically, larger CPy Range values tended to follow other large values and small CPy Range values tended to follow smaller values but over a period of time these values drifted. This drift was largely unidirectional (not back and forth within the sample) and from larger to smaller values for both gofers.

The separation of short and long term variability showed important individual differences. For example, Golfer 2 and Golfer 5 produced a similar standard deviation (Golfer 2 = 0.026m; Golfer 5 = 0.024m) indicating similar variability. However, this variability was produced in distinctly different ways. For Golfer 2, long term variability was relatively large (0.01m larger than Golfer 5) while short term variability was relatively small (0.008m less than Golfer 5). Conversely Golfer 5 produced similar short and long term variability. This indicated that Golfer 2 was more variable in the long term compared to short term, while Golfer 5 was equally variable in both short and long term.

Poincare plot analysis provided interesting short term shot to shot patterning information for Golfer 2. The distribution of jumps from relatively smaller to larger CPy Range values differed from the distribution of jumps from large to small CPy Range values. Jumps from relatively smaller to larger CPy Range values tended to be either small (less than 1 mm) or large (greater than 3 mm) large. This compared with jumps from relatively larger to smaller CPy Range values that were distributed normally. This was evident in the Poincare plot (figure 2i - seven points relating to large jumps denoted by a shaded area), and in the histogram of difference in CPy Range between shots (figure 2ii). The histogram, with more data to the right of the distribution, is indicative of the general trend for a drift from larger to smaller CPy Range values. The lack of data in the –0.01 to –0.03 range for this golfer was surprising. The higher negative values could be due to a conscious or sub-conscious effort by the golfer to increase CPy Range (or Clubhead Velocity) after a smaller than desired CPy Range for the previous swing, or it could be natural variation. However, no data was collected to indicate if this golfer was making conscious control or change, an aspect of this type of analysis that could be included in future work.



i. Poincare Plot



ii. Difference in CPy Range between shots Histogram

Figure 2: Poincare plot and histogram of the difference between consecutive shots for CPy Range [N-(N+1)] for Golfer 2. Negative values mean the next swing produced a larger CPy Range value. Bin numbers = upper end of bin range values. The line on (ii) indicates the separation between increasing and decreasing CPy Range values.

Based on the interesting findings and the useful information provided by separating short and long term variability, it would be worth continuing to explore Poincare plots in future research. These need to include examining technical aspects 'on site' where the actual result of the

swing (distance and accuracy) can be provided to the golfer and researcher. One obvious limitation of this testing was the laboratory environment and the repeated shots with the same club. How this relates to the golf course environment and performing a game-like sequence of shots should be assessed if possible. A larger number of shots would be useful in this study's non-linear analysis, although this would create its own issues of fatigue/boredom and conscious technique changes. Other techniques such as detrended fluctuation analysis which look at short and long term patterns across a large *N* (e.g. Hausdorff *et al*., 2001) may also hold useful information.

CONCLUSION:

Poincare plots offer useful information in analysis of CPy patterns in the golf swing and the information is individual specific. Short and long term variability measures and histogram analysis provided useful information on shot to shot relationships. Further examination of short and long term variation within an individual is recommended.

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