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# A METHOD TO QUANITIFY MOVEMENT VARIABILITY OF HIGHLY SKILLED GOLFERS PERFORMING DRIVER SWINGS

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Variability has been described as inherent in the golf swing (Bradshaw *et al*., 2009), yet its impact on outcome is not understood. It is necessary to quantify the levels of movement variability before this relationship can be examined effectively. Thus, the aim of this study was to develop a method to quantify movement variability of golfers performing driver swings. 16 highly skilled golfers each performed 10 swings wearing retro reflective markers which were tracked by a 3D motion analysis system operating at 400Hz. Movement variability was calculated for each marker using scalene ellipsoid volume methods; a score representative of the 3D variability over 10 trials was then calculated. The variability levels calculated using this method showed increasing variability from the closed end of the chain (malleoli) to the open end of the chain (wrists).

**KEY WORDS:** golf, three-dimensional variability, ellipsoids.

**INTRODUCTION:** For the seemingly simple task of hitting a ball with the club, the golf swing is an extremely complex multi-segmental movement, where the player has to constrain and coordinate many degrees of freedom in order to achieve the goal of hitting the ball with accuracy and consistency. As a result of the individual-specific performer, environmental, biomechanical and task constraints (Higgins, 1997), the notion of a common optimal movement pattern or invariance in certain key technical positions toward which each individual golfer must aspire, is not strongly supported in the literature. Movement variability has been described as being inherent in the golf swing (Bradshaw *et al*., 2009) yet there has been a dearth of literature which both quantifies and examines in depth, the levels of intra-subject variability across golfers. To understand resulting performance, it is important to quantify movement variability and examine the effect of this variability on the outcome, i.e. launch characteristics of the ball. The aim of this study was to quantify movement variability in the golf swing from positional coordinate data.

**METHODS:** Six male and ten female (n=16) highly skilled golfers (age 26.3 ± 5.6 years, body mass 67.0 ± 10.3 kg, height 1.7 ± 0.1 m, handicap 2.8 ± 3.0) were recruited to participate in this study. All subjects were right-handed golfers. Ethical approval for this study was obtained from the University's relevant research board. All testing sessions took place in a purpose-built indoor golf testing facility. For the testing session, each player performed 10 shots with their own driver into a net 5 metres away. Each player had a number of reflective markers placed at 14 various anatomical landmarks. The motions of these markers were recorded using 6 Eagle digital cameras (Motion Analysis Corporation Ltd., Santa Rosa, California) operating at 400Hz. Each trial was then cropped to remove any extraneous data such that all that remained was the data from address to the end of the swing. These motion curves were then filtered with a fourth-order low-pass Butterworth filter with a cut-off frequency of 12Hz (Mitchell *et al.,* 2003). The filtered coordinates were then processed to calculate the variability of each markers' x (medio-lateral direction), y (anterior-posterior direction), and z (vertical direction) coordinates over the ten trials, in a custom written programme in LabVIEW (v. 9.0.1, National Instruments, Austin, Texas).
To counteract the effect of the player standing in slightly different positions between shots the data was transformed. The mean position of the ball (calculated from a small flat marker on the ball) at address for the 10 trials was calculated. The difference between the position of the ball for each trial and the mean position was calculated. The coordinates of all 14 markers for each trial were then transformed according to this difference.
After transformation, each trial was normalised to 1001 points using a cubic spline algorithm.

Following normalisation, the variability measure was calculated for the x, y, and z coordinates at each of the 1001 points over the 10 normalised trials. This resulted in a standard deviation score for each of the 1001 points for all 3 axes for each player. To represent the three-dimensional aspect of variability of movement at each point in one number, the respective x, y, and z standard deviation scores were multiplied together, following similar principles to those used in balance studies such as that of Lin *et al.*, (2009) where a 95% confidence ellipse area is calculated from centre of pressure excursion in the medio-lateral and anterior-posterior direction by multiplying the COP values in both directions together. The approach outlined here takes the next logical step and progresses this concept such that the volume of an ellipsoid is calculated by multiplying the $sd_x$, $sd_y$ and $sd_z$ together (see equation below for exact calculation procedure). This calculates the volume of a scalene ellipsoid representative of the three-dimensional nature of variability for that subject at each of the 1001 points. The equation for calculation of variability over 10 trials is:

$$\frac{\sum_{n=1}^{1001} \sqrt[3]{\frac{4}{3}\pi(sd_x \times sd_y \times sd_z)}}{1001}$$

In order to provide a result which is meaningful in practice, the cube root of this volume was then calculated such that a linear number is provided (mm and not $mm^3$). The average of these variability scores (n=1001) was calculated resulting in one number representing the average variability of movement of that marker for that specific player.

**RESULTS AND DISCUSSION:** Figure 1 illustrates the variability score for each subject as outlined previously. The development of this method has allowed the quantification and examination of which body markers are most variable across the golf swing. The results of this as shown in Figure 1 suggest that movement variability increased from the closed end of the chain (i.e. malleoli at feet) to the open end of the chain (i.e. wrists).

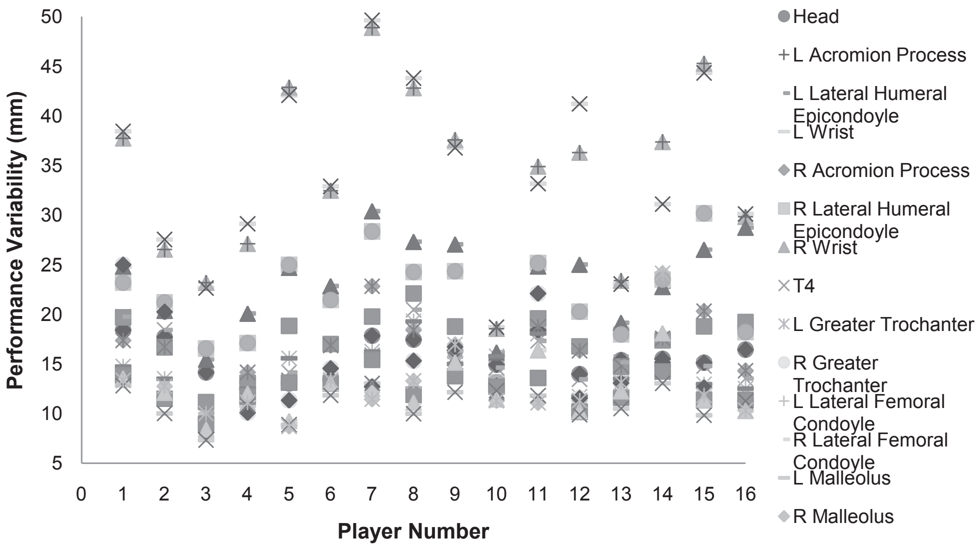


**Figure 1: Variability scores for each marker for all subjects**

**CONCLUSION:** A method has been developed to quantify average movement variability over the entire swing using the standard deviations of normalised three-dimensional

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coordinate data. The aforementioned method can produce ellipsoid volumes representative of the body position variability in 3D space. The results we have reported have used the linear quantities as calculated using cube root of the ellipsoid volume values thus demonstrating that this method can provide many uses in examining variability of human movement. Future work will examine the relationship between these levels of movement variability calculated using this method and a performance outcome such as ball velocity

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