APPLICATIONS FOR CLUSTER ANALYSIS IN SPORT BIOMECHANICS

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The purpose of this paper is to highlight the use of cluster analysis in sport biomechanics. A cluster analysis is a multivariate statistical technique used to group objects based on their characteristics. This technique was used to identify: (a) Five different movement phases in the hammer throw based on 3D kinematic data of an elite level male athlete; and (b) Three different golf swing styles based on the vertical ground reaction torque produced by twenty-nine male golfers. In both applications the cluster analysis provided valuable information about the skill techniques and highlighted possible deficiencies of previous research. This information can be used to make valid assessments of each skill with relevant feedback provided to coaches and athletes.

KEYWORDS: Cluster Analysis, Classification, Golf, Hammer Throw, Movement Phases

INTRODUCTION:

In sport biomechanics, athletes and their movements are often classified into groups for identification, description and comparison. In golf for instance, players may be classified into different skill level groups (for example: low or high handicap) and the skill is often broken down into different phases of movement (for example: backswing, downswing). While this classification is common, its importance in group based analysis cannot be overstated. To make valid comparisons, the researcher must ensure validity and homogeneity in their groups. If groups have been classified incorrectly, or the researcher has failed to detect the presence of other sub groups in their data, the validity of the comparison can be questioned.
A cluster analysis is a multivariate statistical technique used to group objects based on their characteristics. In the past, this technique has provided an objective method of classifying different movement phases (for example: Wilson and Howard, 1983) and movement styles (for example: Ball and Best, in press) in various skill techniques. However, despite its potential usefulness, cluster analysis has not been widely used in sport biomechanics. This may be due to unfamiliarity and/or concerns among biomechanists regarding procedural problems associated with this technique (Ball and Best, in press).
The aim of this paper is to demonstrate the use of cluster analysis in sport biomechanics to objectively classify: (a) different movement phases within a skill; and (b) different styles of the same skill.

APPLICATION 1 – CLASSIFICATION OF MOVEMENT PHASES WITHIN A SKILL

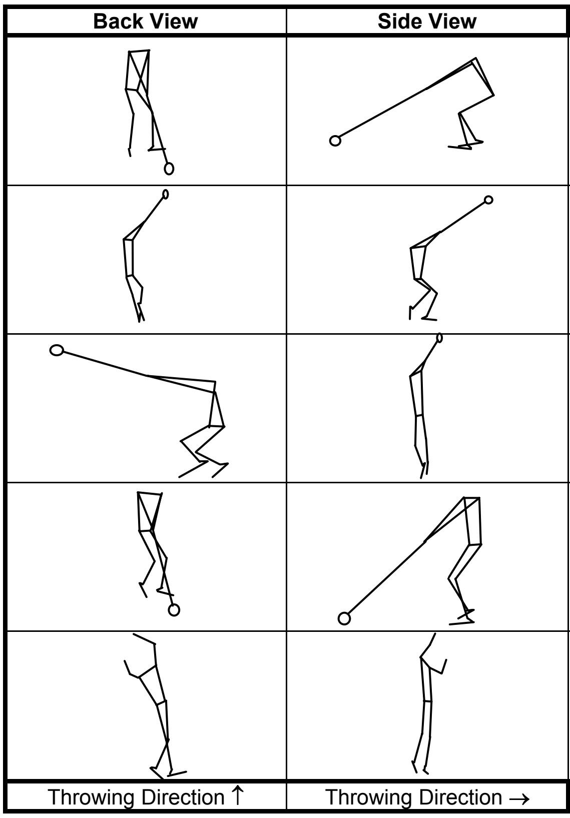
Each 'turn' in a hammer throw is commonly divided into alternate phases of single and double support as the (right handed) athlete lifts and plants their right fight foot on the ground while pivoting around their left foot. As the speed of an athlete's hammer generally increases during periods of double support, Dapena (1985) reports that many practitioners believe in lengthening the duration of this phase. This belief, however, has not been supported in temporal analysis of national level competition (Morriss and Bartlett, 1993) and has been questioned in Dapena's (1985) research. The purpose of this study was to use cluster analysis to identify different movement phases in the hammer throw based on movements throughout the athlete-hammer system.

METHODS:

One elite level male athlete performed five hammer throws during training. During each throw, three 50Hz cameras (above, behind and to the side of the throwing cage) were used with an APAS motion analysis system (Ariel Dynamics, Inc. San Diego, USA) to obtain 3D displacement data on 10 points in the athlete-hammer system (left and right shoulders, hips, heels, toes, hammer and handle; Intra-tester reliability: TE = 0.8cm). Normalised data from the athlete's best throw (79.26m) were used in a hierarchical cluster analysis (Pearson's correlation method) to determine if different movement phases existed in the skill (to avoid biasing, the data were normalised to a percentage of the total range of movement for that point – e.g. for the hammer, the max. x coordinate = 100% and the min. x coordinate = 0%). The optimal cluster solution was determined using visual analysis of the dendrogram, a secondary non-hierarchical cluster analysis and theoretical assessment of the cluster groups (Wilson and Howard, 1983), then validated using a point biserial correlation method (Ball and Best, in press). Briefly, in this procedure each video frame was considered a separate object containing 30 variables (x,y, and z displacement from the 10 points). In the hierarchical cluster analysis, each object starts out as a cluster (group) by itself. The clusters are then repeatedly correlated against each other, with the two most highly correlated (most alike) clusters joined together and the group mean (cluster centroid) of the newly formed cluster used in subsequent correlations. This procedure continues until an optimal solution is found that maximises both the homogeneity of objects within a cluster and the heterogeneity between the clusters (Hair *et al.,* 1995). In this way, video frames in which the athlete is in a similar position will be grouped together into the same cluster, thereby creating distinct phases of movement in the hammer throw.

RESULTS AND DISCUSSION:

Cluster analysis identified five different movement phases (A – E) in the hammer throw (figure 1). The temporal sequencing of these phases relative to the single/double support phases in each turn is compared in figure 2.



Movement Phase 'A'
The thrower rotates through positions that face away from the intended throwing direction with the hammer swinging low to the ground. During this phase the thrower lifts their right foot off the ground, shifting from double to single support.

Movement Phase 'B'
The thrower rotates through positions that face in intended throwing direction, while the hammer moves from a low to a high position. This phase occurs while the thrower remains in single support.

Movement Phase 'C'
The thrower rotates through positions that face side-on to the intended throwing direction while the hammer moves from a high to a low position. During this phase the thrower plants their right foot on the ground, shifting from single to double support.

Movement Phase 'D'
This phase occurs in turns 3-4 and 4-release, replacing phase A. While the movements of this phase are similar to those of phase A, the athlete has adopted a more upright stance and begins to prepare for release.

Movement Phase 'E'
During this phase the thrower releases the hammer and proceeds into their follow through

- Diagrams represent the athlete's body position at the middle frame of each movement phase
- Data were collected from at the start of the first turn. Information on the athlete's wind-up was not included in this analysis

Figure 1: Diagrams and brief descriptions of five movement phases in the hammer throw.

This analysis provides an insight into the progressive development of the athlete's movements throughout the skill and further questions the validity of single/double support phase analysis. The transition between single to double support occurs during phase C (All turns), while the transition between double to single support occurs during phase A (Turns 1-3) or phase D (Turns 3-4). As the cluster analysis groups those positions of the athlete-hammer system that are most similar, this suggests that during the transition between the support phases the athlete is not altering their actions or position enough to warrant a different movement phase. Also of note is that while facing away from the intended throwing direction, the athlete moved through phase A during turns 1-3, but then progressed into phase D during turns 3-4. This suggests that the athlete changed their movement in this part of the turn as they had progressed through the skill.

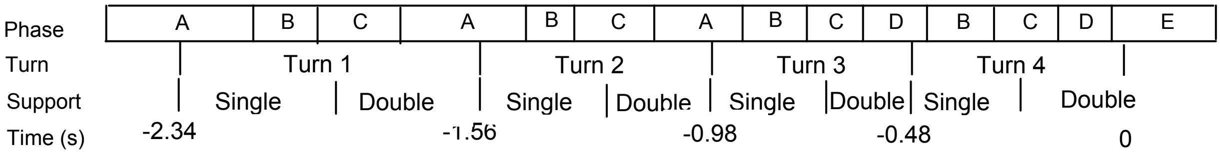


Figure 2: Temporal sequencing of phases in the hammer throw

Cluster analysis was useful in the identification of five different movement patterns in the hammer throw. While further research is required to generalise this result to the wider population, it provided information about the movements of the athlete-hammer system that question the validity of traditional single/double support phase theories and may permit more accurate assessments of the skill technique.

APPLICATION 2 – CLASSIFICATION OF DIFFERENT STYLES OF THE SAME SKILL

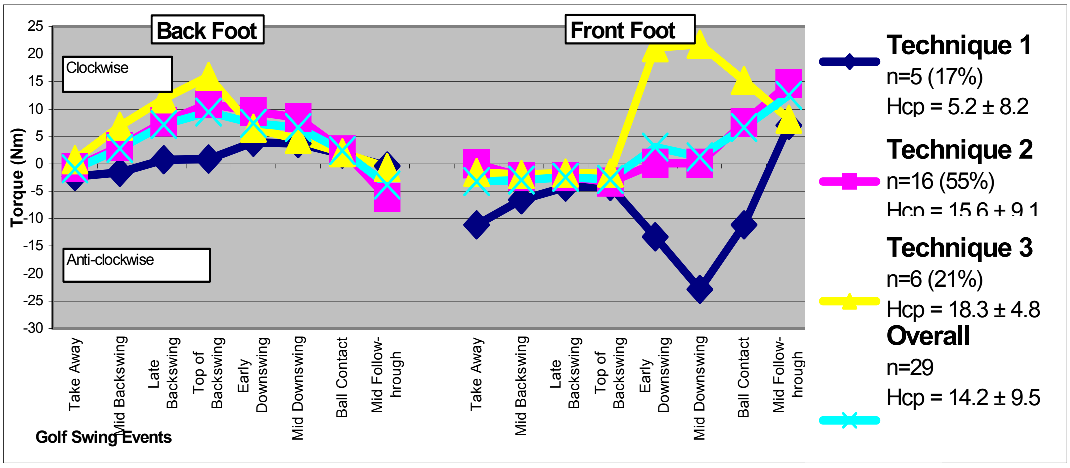
Recent studies have supported the common belief that different styles exist in the golf swing (Ball & Best, in press). This may highlight a major limitation in past golfing research and account for the conflicting and inconclusive results reported in weight transference studies to date. Many studies in golf have grouped subjects on the basis of their handicap level in the assumption that only one technique exists. If this assumption is false, failing to account for different skill techniques within a sample will increase group variability and may lead to type I and / or type II errors in data analysis (Ball & Best, in press). The purpose of this study was to use cluster analysis to identify different rotational styles in the golf swing based on the vertical ground reaction torques produced by players.

METHODS:

Twenty-nine male golfers (Age: 36.8 ± 13.9 yrs, Height: 179.9 ± 7.1cms, Mass: 82.9 ± 10.2 kgs) of different skill levels (professional to social golfers) performed 10 simulated golf drives within a laboratory. During each trial, a 200Hz video camera, located perpendicular to the intended shot direction, was used to determine the time of 8 different events throughout the swing (as described in Ball and Best, in press). The vertical torque (Tz) produced by the golfer at these events was measured via two synthetic grass covered AMTI force plates (Advanced Mechanical Technologies Inc., Massachusetts, USA), one under each foot. These data were sampled at 500Hz using an AMLAB 16-bit ADC system (AMLAB technologies, Sydney) and smoothed using a 15 Hz Butterworth digital filter (Error estimate: Tz ± 0.04Nm). Mean Tz values from each golfer were used in a hierarchical cluster analysis (squared Euclidean distance method) to determine if different rotational techniques existed. The optimal cluster solution was derived and validated using methods described in Application 1.

RESULTS AND DISCUSSION:

Cluster analysis identified three main styles (Tz profiles) within the sample (figure 3). Style 1 was characterised by a smaller than average clockwise torque produced on the back foot during the backswing (0.9Nm at top of backswing), and a large anticlockwise torque produced on the front foot during the downswing (22.9Nm at mid downswing). Interestingly, while only five golfers (17%) used this style, there were a high proportion of low handicap golfers in this group (Hcp: 5.2 ± 8.2). In almost direct contrast six higher handicapped golfers (21%; Hcp: 18.3 ± 4.8) used style 3, characterised by a larger than average clockwise torque produced on the back foot during the backswing (16.0Nm at top of backswing), and a large clockwise torque produced on the front foot during the downswing (21.8Nm at mid downswing). Style 2 lay between styles 1 and 3 with a mean Tz profile similar to that of the mean for the overall sample. Further analysis of these styles is required to explore the underlying mechanics producing these Tz profiles and to determine why style 1 is used by a higher proportion of low handicapped golfers. Clearly however, important information would have been lost if the mean Tz profile of the overall sample was used exclusively as the results would only be relevant to golfers using style 2 (55% of the sample).



- Tz profiles are in reference to a right handed golfer. Positive values = Tz produced in a clockwise direction (seen from above).
- Two outlying cases could not be classified into a style group though was still included in the overall sample mean.

Figure 3: Mean Tz profiles and subject characteristics of the three main style groups.

Cluster analysis was useful in identifying three different styles in the golf swing based on the Tz produced by players. This result provided an insight into the rotational strategies used by golfers' and, in particular, identified a technique used by predominately low handicapped golfers. Future research in golf should identify and account for different swing styles within a sample.

CONCLUSION:

Cluster analysis provided a valid and objective method of identifying: (a) five different movement phases in the hammer throw; and (b) three different golf swing styles based on the Tz produced by players. In both applications the cluster analysis provided valuable information about the skill techniques and highlighted possible deficiencies of previous research. This information can be used to make valid assessments of each skill with relevant feedback provided to coaches and athletes

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