
# Center of Vertical Force and Swing Tempo in Selected Groups of Elite Collegiate Golfers

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The importance of consistency in weight transfer and tempo in golf is frequently addressed in popular magazines and books with little supportive scientific data.

**Purpose**: The purpose of this study was to compare center vertical force (CVF) placement at ball contact and swing tempo among college golfers.

**Methods:** College-aged athletes (N=28) who had qualified for the National Collegiate Athletic Association (NCAA) National Tournament in 2003 volunteered for the study and were grouped based on their average competitive golf scores for the season: Group 1 = 70-71 (n=9), Group 2 = 72-73 (n=7), Group 3 = 74-75 (n=12). Following warm-up, subjects performed 5 swings each with a pitching wedge (PW), 5-iron (5I), and driver (DR) in random club order. Movement patterns of the golfers' CVF were recorded in two dimensions: lateral deviation (Dx) and anterior/posterior movement (Dy). Swing tempo was recorded from the onset of the approach (reverse in direction of lateral shift) to ball contact. Statistical analyses included ANOVA and Levene's test of homogeneity.

**Results:** Results indicated that Group 1 recorded significantly greater consistency (less variance) in Dx than did Groups 2 and 3. Swing tempo was significantly longer in Group 1 in comparison to Groups 2 and 3, and swing tempo consistency was significantly greater for Group 1 in comparison to Groups 2 and 3.

**Conclusions:** Results based on comparisons of variance instead of means among groups indicate that ***success in the game of golf may be more dependent on individual consistency in weight transfer and swing tempo rather than the strict adherence to text-book technique*.**

The game of golf remains physically and mentally complex despite thousands of articles dealing with analysis of the performance. Analyses of the biomechanics of the golf swing not withstanding, little research can be found that compares selected physical technique among golfers with different skill levels. Some researchers have compared foot wear (Gatt, Pavol, Parker, & Grabiner, 1998) and knee joint kinetics during a golf swing, while others sought to improve golf accuracy through timing skills Libkuman, Otani, & Steger, 2002), still many others have addressed selected golf related injuries. By far the greatest abundance of literature on golf is found in popular magazines and books. Popular magazines abound with expert advice ranging from grip to swing, but with little or no empirical data or scientific backing. According to Adlington (1996), claims made on the cover of golf magazines are as fantastic as those found in investment magazines.

Perhaps the most frequently used word associated with successful play is consistency. Critical to success on the golf course is a swing that can be consistently repeated (Adlington, 1996). Consistency in all phases of the skill (swing, stance, balance, and weight transfer) are topics often addressed in magazines, but few studies exist which specifically address these factors. Adding to the complexity of golf-related study is the array of club lengths, shaft selections, and weights, all of which may yield dissimilar data associated with swing and weight transfer.

Egret and associates (2003) found that "high level of skill" players swung the pitching wedge, the 5 iron, and the driver with identical timing (movement time and proportion for each swing phase) among the three clubs. However, kinematics and club-head speeds differed. Further, the driver was distinguishably different from the 5 iron and pitching wedge (Libkuman, Otani, & Steger, 2002). Muscular function as it relates to the golf swing was investigated in professional golfers. Using dynamic surface EMG, contractions of three paired trunk muscles and the upper and lower abdominis were recorded for five phases of the golf swing. Results provided reproducible patterns of the trunk muscles (Watkins, Uppal, Perry, Pink, & Dinsay, 1996). Another study concluded that lead knee flexion and internal rotation moments as recorded by both video and force plate was significantly correlated to skill level and also suggested that each subject possessed individual characteristic in patterns of knee loading (Gatt, Pavol, Parker, & Grabiner, 1998) .

Proper and timely weight transfer during the swing is an integral part of successful golf. Critical to the technique is that at set-up, body weight is evenly distributed over the base of support (centered), subsequently transferred to the rear foot at the top of the backswing, followed by a shift toward the front of the body at impact (Koslow, 1994). Investigating patterns of center of gravity (COG) motion, hip and shoulder rotation in sub-10 handicap players during the drive, Burden and associates (1998) found that shoulders rotate in excess of 90º during the backswing and typically continues to rotate as the hips begin to rotate in the opposite direction. ***The author also concluded that the speed of the swing was influenced by the COG shifting exclusively in the intended direction of the flight of the ball during club impact.***

Weight shift patterns of beginning golfers were investigated (Koslow, 1994) while swinging a driver and an 8 iron. Results showed that ***84% and 73% of the subjects swinging drivers and 8 irons respectively, exhibited weight shifts that did not conform to the commonly prescribed weight-shift patterns*** (i.e., from centered, to rear foot, to front foot). The author concluded that the lack of proper and consistent weight shift of beginning golfers prevented significant transfer of forces to the club head and prevents the "squaring" of the club head at impact.

Both anecdotally derived coaching points and empirically generated data suggest that successful golf performance is, in part dependent on the consistency of such factors as weight transfer and tempo (timing) when attempting to strike the ball. As a comparison measure, weight transfer can be plotted from beginning to end of the golf swing. However, with vast individual variance, a convenient method of comparison is to mark the center of vertical force (CVF) at the moment of impact.

The purpose of this study was to compare consistency of body position (CVF) at ball contact and downswing tempo among grouped, elite golfers and to further compare these variables among three individual clubs.

**Methods:**

Varsity golfers who qualified for the National Collegiate Athletic Association (NCAA) National Golf Tournament were solicited to participate in this study in the Spring 2003. Of the 156 competitive golfers qualifying for the national tournament, 28 right-handed golfers from 10

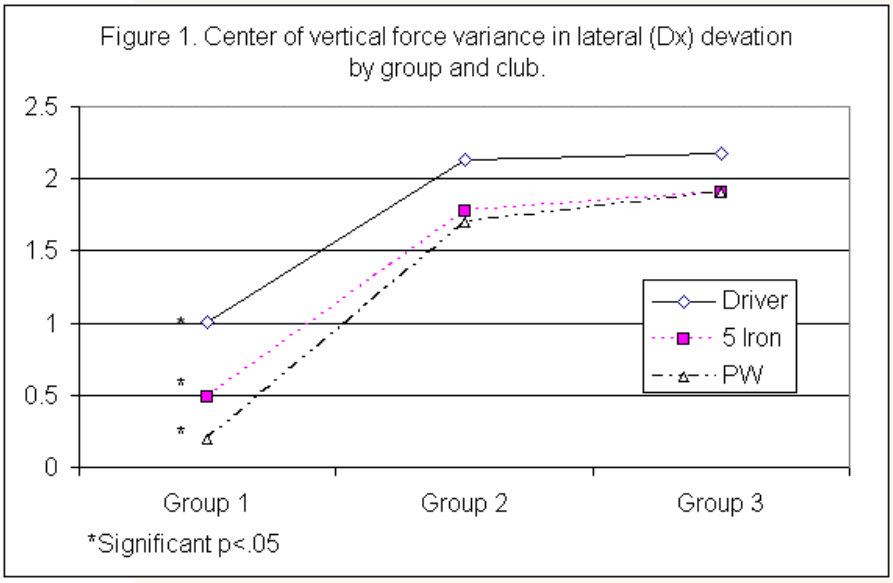
Division I Universities volunteered to participate in the study. Players were grouped 1-3 based on their average season-length golf scores (Range = 70-75) in the following categories: 70-71= Group1 (n=9), 72-73= Group 2 (n=7), 74-75= Group 3 (n=12). Data were collected during 2 days preceding competition. After reading and signing an informed consent document, subjects completed a questionnaire containing demographic and physical items (i.e., age, height, weight, foot size, dominant hand, etc.). Prior to data collection, subjects warmed up ad libitum. Subsequently, golfers were asked to perform five swings each with their own pitching wedge (PW), 5 iron (5I), and driver (DR) in random order.

Data were collected using a force platform (Dynamic Balance System [DBS™]) placed in a golf instruction bay which allowed balls to be hit toward targets on the driving range. The force platform provides static and dynamic weight-bearing and weight transfer feedback during the golf swing motion. The force platform has the capability to monitor right/left (lateral) and anterior/posterior (AP) movement while tracking Center of Vertical Force (CVF). During the swing the DBS recorded the golfers' CVF for 3 seconds in 1/100 sec intervals: 2 seconds before and 1 second after ball contact. For data collection, each subject was positioned on the DBS and provided the opportunity to hit balls until they felt comfortable. Every swing was performed without performance feedback.

Clubs were randomly ordered for each subject and five consecutive, full swings were performed while positioned on the force platform and while hitting balls off a Fiberbuilt™ hitting mat equipped with a microphone sensor to monitor ball contact position. The hitting mat contains a grid to provide consistency of ball placement.
For each swing, data revealing lateral (Dx) and anterior/posterior (Dy) movement was digitally and graphically recorded. Data used for the present study were the two-dimensional coordinates (X & Y) of the golfers' CVF location at ball contact. Lateral movement, represented as X-deviation (Dx) of the CVF, was recorded as the side-to-side weight transfer between the rear foot and the front foot. Anterior/posterior movement, represented as Y-deviation (Dy) of the CVF, was recorded as the weight transfer between heel and toe. Variance in the coordinates of both Dx and Dy at the moment of ball contact was recorded and compared by club and group.

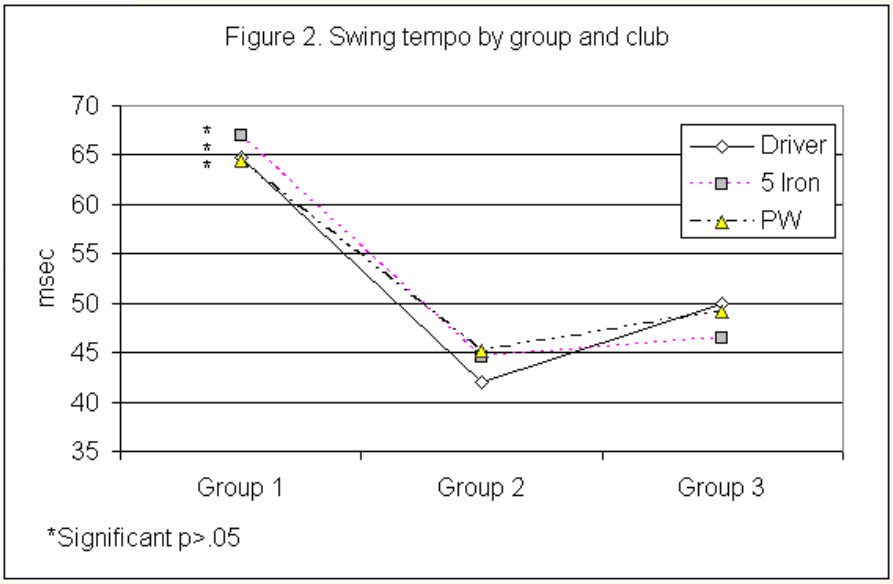
The tempo for downswing was recorded as a single number. Specifically, the downswing begins subsequent to the retardation movement of the backswing, which lasts until the top of the backswing. The end of backswing retardation initiates a change in direction of the reaction moment which is illustrated by a backward directed force by the rear foot (Carlsöö, 1967). The downswing represented the allotted time in milliseconds (1/100 sec) from the subject's extreme weigh shift to the right (top of backswing) until ball contact. Levene's test of homogeneity of variance was used to compare consistency among groups. Analyses of variance (ANOVAs) with Newman-Keul post-hoc tests were performed to compare group means.

**Results:**
Subjects' age ranged between 18 and 23 years with an average of 20.6 + 1.29 years, height ranged between 172.7 and 195.6 cm with an average of 181.8 + 5.2 cm., and weight ranged between 63.6 and 92.7 kg with an average of 77.3 + 8.1 kg.



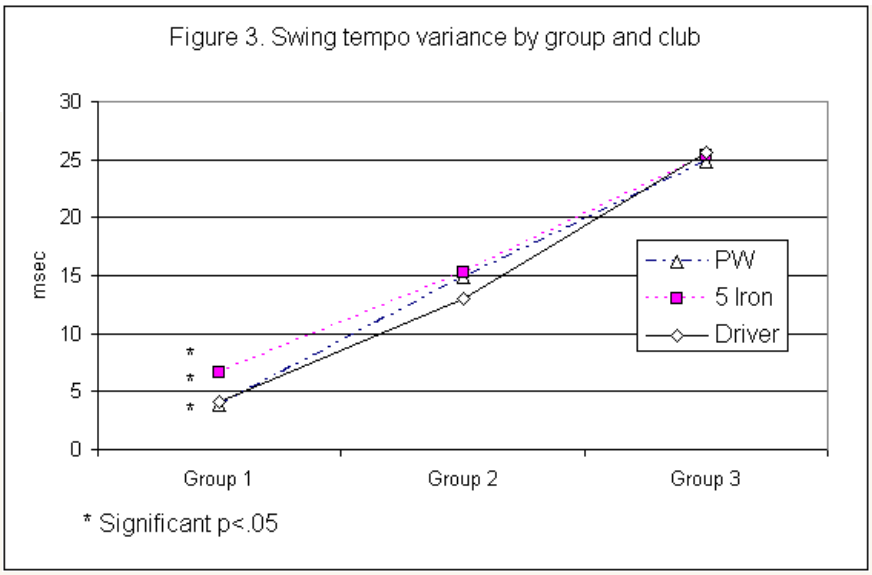

**CVF Variance in Lateral (Dx) and Anterior/Posterior (Dy) Location at Ball Contact:**

Consistency (minimal variance) in CVF (Dx) and (Dy) location at ball contact among the three groups was compared using the Levene's test of homogeneity of variance. Results indicated that the variance in CVF location at ball contact was significantly different (p=.03) for lateral (Dx) deviation, but not for anterior/posterior (Dy) deviation (p=.18) among groups. A post hoc analysis to isolate significance in variance among groups revealed that Group 1 had significantly greater consistency (less variance) in lateral (Dx) deviation than did Groups 2 and 3 for all clubs (Figure 2).




**Swing Tempo:**

Swing tempo means, as measured from the initiation of the forward swing to ball contact, were significantly (p=.001) different among the three groups. Post-hoc analysis revealed that Group 1 recorded significantly longer mean tempo than did Groups 2 and 3 (Figure 3). However, in comparing tempo among clubs (pitching wedge, 5-iron, and driver) no significant difference (p=.922) was found between any of the clubs as separated by group. These data suggest that each group's swing tempo did not change with club use, but that the more skilled group (Group 1) used a significantly slower swing tempo in comparison to Groups 2 and 3.




**Swing Tempo Variance:**
Consistency in swing tempo was compared among groups by using Levene's test of homogeneity of variance. Results indicated that the variance in tempo differed significantly (p=.001) among groups. Further, analysis revealed that Group 1 recorded significantly less (p=.001) swing tempo variance than did Groups 2 and 3 for all club selections (Figure 3).

**Discussion**
It has been suggested that skilled golfers generate reproducible patterns in muscle activity during the swing (Egret, et al., 2003). Beginning golfers have been found to lack consistency in weight shift between swings (Koslow, 1994). Results from the current study indicated that **elite college golfers also possess distinct consistency differences in CVF location at ball contact, in mean swing tempo, and in tempo consistency.**

The **lateral** ( D x) **CVF location at ball contact** of the most skilled group (Group 1) was found to be significantly more consistent for the driver, 5 iron, and pitching wedge when compared to Groups 2 and 3. These results support the contention that better golfers display greater swing consistency. For instance, Richards and associates (1985) found that accuracy of groups categorization (handicap <10 vs. handicap >20) predicted from weight transfer was 85%.

It is possible that individual differences within generally acceptable principles (Adlington, 1996) are allowable if the results in ball distance, direction, and placement are desirable. For instance, rather that encouraging the teaching of a one-size-fits-all technique, focus on the most desirable outcome, and how to consistently replicate the technique that contributed to the outcome with consideration toward minimizing unwanted stress on the body. Adlington (1996) suggests that **golf swings are as unique as fingerprints** and that it is risky to assume that one technique will work for all individuals. A recent article by Hall (2004) illustrates the importance of consistency over textbook technique when describing U.S. Open champion Jim Furyk's swing as "like an octopus falling out of a tree".

**Swing tempo** (also called timing) is largely **individually based and may depend on several factors such as anatomical structure, strength, and technique.** Initial comparison of tempo by skill level (Group) revealed that Group 1 recorded significantly slower tempo than Groups 2 and 3. Also, while tempo was slower for Group 1, tempo was not significantly different within groups, among the selected clubs. For example, each group exhibited similar timing for all three club swings, but Group 1 recorded slower tempo when compared to Groups 2 and 3. This agrees with Egret and associates (2003) who also

concluded that there was identical timing among three clubs tested (driver, 5 iron, and pitching wedge) in both movement time and proportion for each phase of the swing within "high skilled" gofers. Budney and Bellow (1982) also determined that maximum driving force is essentially the same for any one golfer regardless of club use.

**Perhaps a more revealing aspect of comparison was that of swing tempo consistency**. Group 1 exhibited significantly less variance (greater consistency) in swing tempo than Groups 2 and 3, which provides evidenced that consistency rather than technique is a more desirable factor in successful play.

These results support much of the anecdotal literature regarding the importance of consistency in swing, specifically, **consistency in weight transfer and in swing tempo.** Many players of the game are capable of hitting several well-placed shots during a round, but those who are the most consistent in replicating the technique necessary to place the ball in intended locations (distance, direction) are the most successful. It is axiomatic that once a skill has been developed and perfected, consistent replication of the skill, equates to exceptional performance. While little research exists to support the numerous suggestions and recommended to improve performance printed in popular magazines, these data provide evidence that consistency in weight transfer and tempo may be more closely related to successful golf than text-book technique.

Recommendations for further study include the comparisons of a wider skill range of golfers to attempt to determine a variance in multiple areas between golfers of different skill levels. Once variance in selected areas of the technique has been established, a more focused attempt to develop specific areas of the golf swing may be made so that consistency in those areas of greatest discrepancy can be developed in order to improve overall skill.

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