RELIABILITY AND VALIDITY OF A GOLF SWING ANALYSIS SOFTWARE DURING A STATIC AND A DYNAMIC TASK

PROPOSAL

Submitted to the Faculty of the School of Graduate Studies and Research of California University of Pennsylvania in partial fulfillment of the requirements for the degree of Master of Science

BY

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1. Means and Standard Deviations for the Dynamic Test
2. Means and Standard Deviations for the Static Test
3. Single Measures Intraclass Correlation Coefficient
4. Mean Scores and Standard Deviations for Professional Golf Management (PGM) Students and Novice Golfers
5. One-Way Repeated Measures ANOVA
INTRODUCTION

Golf is one of the most widely popular activities in the world. There are millions of people who play golf on approximately 32,000 golf courses worldwide.\(^1\)\(^2\) In 2005 5.8 billion dollars were spent in the United States market for golf equipment. The vast majority of people who play golf want to lower their scores and a fair amount of those golfers are willing to pay a substantial amount of money on various gadgets or lessons in an attempt to improve their game. Technique can have a large effect on a golfer’s performance where the object of the game is to hit the golf ball into a small hole in as few shots as possible.\(^3\)

One way to improve someone’s golf swing is by understanding the swing and its components. For reference in this study the golf swing has six components; the address, backswing, peak backswing, downswing, impact, and follow-through.\(^3\)\(^4\) This study will spend the most time looking at the peak backswing. The peak backswing is the moment in a golfer’s swing between the backswing and the downswing. In order to better understand the golf swing and its components, motion analysis can be utilized. When analyzing high speed movements, video-based motion-measurement systems provide a means of analyzing these
actions with minimal inconvenience to the subjects. The most common ways to capture data are with high-speed cameras, video cameras, or radiographic systems.\textsuperscript{5-8} Once the data is captured on a camera it can be analyzed by various programs.

When working with new technology one of the first steps that need to be taken is to test the reliability and validity of the instrument. If the measurements recorded do not remain constant as the experiment is repeated then the tool is not reliable and therefore not useful.\textsuperscript{9} Also, the instrument must be comparable to an already proven instrument otherwise it is considered ineffective.

There are no previous studies that examine the use of Dartfish Connect Version 4.5. The purpose of this study is to test the reliability and validity of the motion analysis software Dartfish in measuring joint angles during a golf swing. In order to accomplish this, the joint angle at the elbow of the lead arm at peak backswing will be measured during a static and a dynamic task. Also, the measurements taken utilizing Dartfish will be compared to measurements taken by a goniometer. The reliability of a goniometer has been previously tested and found to have high reliability and validity.\textsuperscript{10,11}
This study will attempt to answer the following questions: 1) What is the test – retest consistency between range of motion measures utilizing the motion analysis software Dartfish? 2) What is the relationship between goniometric measurements and the Dartfish motion analysis software measurements?
METHODS

The methods section will give an overview to how the experiment was conducted. It includes sections dedicated to Research Design, Subjects, Pilot Research, Instruments, Procedures, Hypotheses, and Data Analysis.

Research Design

An experimental test-retest design was used for this study. The dependent variables are the range of motion measures taken using Dartfish and the goniometer. The independent variable is the test or retest session. The strength of this study is the reliability of goniometric measurements to use in a comparison. Limitations of this study are that all the subjects are only from California University of Pennsylvania and that only one joint was measured and analyzed.

Subjects

The subjects in this study consisted of students from the Professional Golf Management (PGM) Program at California University of Pennsylvania (n = 8) and novice
golfers from the California University of Pennsylvania (n = 8). The method of sampling used was on a volunteer basis where the subjects performed a golf swing. The subjects participated in a static measurement as well as a dynamic measurement. All subjects read and signed an Informed Consent Form (Appendix C1) which included the purpose of the study, researchers involved, and the right to remove themselves from the study at any time without penalty. The subjects also read and signed a photo/audio tape/video tape release form (Appendix C4) which allows the researcher the right to use the photographic/audio/video material as part of the study.

Instruments

The following instruments were used in this study; Dartfish, a goniometer, and a video camera. Dartfish is a motion analysis software program used to analyze the golf swing and break it down frame by frame. A goniometer refers to the measurement of angles, in particular the measurement of angles created at human joints by the bones of the body and has been found to be of high reliability (r = .88 to .99).10,11 Finally a video camera was used to
record the movement of the golf swing and transfer the data collected into Dartfish.

Procedure

The research study was approved by the Institutional Review Board (IRB) (Appendix C2) at California University of Pennsylvania before collecting any data. The subjects came in for two tests, following the test/re-test experimental design. Subjects were free from any injury. They read and signed an Informed Consent Form (Appendix C1) and a photo/audio tape/video tape release form (Appendix C4) approved by the IRB (Appendix C2).

All subjects wore a tank top exposing their entire arm from the acromion down. Markers were placed by the primary researcher on the lateral epicondyle of the humerus, the center of the acromial process, and the ulnar styloid process. All markers were placed on the skin of the subject. A digital video camera was positioned approximately perpendicular to the axis of rotation of the subject’s elbow.

When the subjects came in for their test they began with a five minute warm-up. The markers were placed on the subjects followed by the subjects hitting five golf balls.
Next the subjects began the static test which consisted of the subject holding their golf swing at the peak backswing while a goniometric measurement was being taken of elbow flexion of the lead arm. The goniometer connects the three bony landmarks in order to calculate an angle. Then the investigator then stepped out of the field of vision of the camera and the subjects were asked to hold the position for two seconds. A random frame was chosen from the two seconds of video and the joint angle at the elbow was measured using Dartfish. From the random frame of video Dartfish connects the three bony landmarks and calculates an angle at the elbow. This was repeated for three trials.

The subjects took five swings while hitting golf balls to act as a warm up. Then the subjects began the dynamic test. The subjects hit ten golf balls with the investigator indicating when to begin each golf swing. There was a 10 second delay from when the subjects finished their golf swing and when the investigator instructed the subjects to approach the golf ball for the next swing. The subjects then had 2 seconds to get comfortable in their stance before being instructed to hit the next golf ball. Dartfish was used to measure the joint angle of the elbow at the peak backswing by stopping the video at the closest possible moment of peak backswing. From the frame of video
Dartfish connects the three bony landmarks and calculates an angle at the elbow.

The static and dynamic measures previously described were repeated using a test–retest model to assess intrarater reliability. The retest portion of the test–retest model was conducted 7 to 14 days after the test portion. No subject’s names were recorded for the use in this study; instead each subject was assigned a subject number at random. All of the data collected was recorded on the Data Collection Form (Appendix C3).

Hypotheses

The following hypotheses were based upon the review of the literature, observations, and intuitive judgment of the researcher.

1) Hypothesis 1: There will be no significant difference between the range of motion measures taken on subsequent trials utilized Dartfish.

2) Hypothesis 2: There will be a moderate to high positive relationship between the measurements taken with a goniometer and the motion analysis software measurements.
Data Analysis

The researcher will use an alpha level of 0.05.

1) A Cronbach’s Alpha and an Intraclass Correlation Coefficient were used to determine if there is a difference between the scores for the trials of Dartfish. A Pearson-Product Moment Correlation was used to determine if there is a relationship between day 1 and day 2 of the dynamic test.

2) An Intraclass Correlation Coefficient was used to determine if there is a difference between the scores for the trials using the goniometer and those using Dartfish during the static test. A Pearson-Product Moment Correlation was used to determine if there is a moderate to high positive relationship between the measurements taken with a goniometer and the motion analysis software measurements.
RESULTS

The results found that Dartfish is a reliable and valid tool for measuring joint angles. More specifically the results showed no significant difference of the scores during the dynamic test – retest and that there was a high positive relationship between goniometric measurements and measurements made utilizing Dartfish. Additional findings found that there was a significant difference of elbow angle between PGM golfers and novice golfers at California University of Pennsylvania.

Demographic Data

The sample for this study included 16 students from California University of Pennsylvania. The sample consisted of all males. The age range for this study ranged from 19 - 39 years of age with a mean of 23.25 years of age with a standard deviation of 2.93. All participants were considered healthy and reported no injuries throughout the study.
Hypothesis Testing

The level of significance used for testing in this study was set at an alpha level of .05.

Hypothesis 1: There will be no significant difference between the range of motion measures taken on subsequent trials taken with Dartfish.

Cronbach’s Alpha, an Intraclass Correlation Coefficient, and a Pearson-Product Moment Correlation were used to determine if there was a difference between the scores for the trials of Dartfish.

Cronbach’s Alpha was calculated comparing all the trials of the dynamic test on day 1 and day 2 of the dynamic test. There was no significant difference found between the mean scores of day 1 and day 2 of the dynamic test showing good internal consistency ($r = .961$). An Intraclass Correlation Coefficient also showed no significant difference between the mean scores of day 1 and day 2 of the dynamic test ($F_{15,15} = 25.680; P < .001$), where $r = .925$ with a 95% confidence interval ranging from .799 to .973 (see table 3). A Pearson-Product Moment Correlation was calculated comparing the mean score of day 1 of the dynamic test to day 2 of the dynamic test. The Pearson-Product Moment Correlation found a strong positive
correlation between the mean scores of day 1 to those of
day 2 of the dynamic test \(r(16) = .937, P < .001\),
indicating a significant linear relationship between the
two variables. The mean score in degrees for day 1 \(m =
136.35, sd = 15.17\) was not significantly different from
the mean score in degrees for day 2 \(m = 130.81, sd =
17.85\) (see table 1).

<table>
<thead>
<tr>
<th>MEAN</th>
<th>SD</th>
</tr>
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<tbody>
<tr>
<td>DAY 1</td>
<td>136.35</td>
</tr>
<tr>
<td>DAY 2</td>
<td>130.81</td>
</tr>
</tbody>
</table>

Hypothesis 2: There will be a moderate to high
positive relationship between the measurements taken with a
goniometer and the motion analysis software measurements.

Cronbach’s Alpha was calculated to show the
reliability \(r\) of the measurements. No significant
difference was found therefore the measurements were found
to have good internal consistency on day 1 \(r = .965\) as
well as day 2 \(r = .970\). The Intraclass Correlation
Coefficient found no significant difference between the
measurements taken by the goniometer and the motion
analysis software on day 1 \(F_{15,15} = 57.024; P < .001\), where
$r = .966$ with a 95% confidence interval ranging from .904 to .988 or day 2 ($F_{15,15} = 36.650; P < .001$), where $r = .947$ with a 95% confidence interval ranging from .855 to .981 (see table 3). A Pearson-Product Moment Correlation was computed to compare the mean score for the goniometer measurements during the static test to the mean score for the Dartfish measurements during the static test. A strong positive correlation was found between the mean score for the goniometric measurements during the static test on day 1 to the mean score for the Dartfish measurements during the static test on day 1 ($r(16) = .973, P < .001$), indicating a significant linear relationship between the two variables. There was also a strong positive correlation between the mean score for the goniometric measurements during the static test on day 2 to the mean score for the Dartfish measurements during the static test on day 2 ($r(16) = .947, P < .001$), indicating a significant linear relationship between the two variables. The mean score for the goniometer measurements during the static test on day 1 ($m = 133.66, sd = 17.67$) was not significantly different from the mean score for the Dartfish measurements during the static test on day 1 ($m = 136.16, sd = 15.63$) (see table 2). The mean score for the goniometer measurements during the static test on day 2 (m
= 134.13, sd = 15.57) was not significantly different from the mean score for the Dartfish measurements during the static test on day 2 (m = 133.75, sd = 15.06) (see table 2).

Table 2. Means and Standard Deviations for the Static Test.

<table>
<thead>
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<th>SD</th>
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<tr>
<td>DAY 1 GONIOMETER</td>
<td>133.66</td>
<td>17.67</td>
</tr>
<tr>
<td>DAY 1 DARTFISH</td>
<td>136.16</td>
<td>15.63</td>
</tr>
<tr>
<td>DAY 2 GONIOMETER</td>
<td>134.13</td>
<td>15.57</td>
</tr>
<tr>
<td>DAY 2 DARTFISH</td>
<td>133.75</td>
<td>15.06</td>
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</table>

Table 3. Single Measures Intraclass Correlation Coefficient.

<table>
<thead>
<tr>
<th>Test</th>
<th>F Value</th>
<th>r</th>
<th>95% CI</th>
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<tr>
<td>DYNAMIC TEST</td>
<td>25.680</td>
<td>.925</td>
<td>.799 - .973</td>
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<tr>
<td>STATIC TEST DAY 1</td>
<td>57.024</td>
<td>.966</td>
<td>.904 - .988</td>
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<tr>
<td>STATIC TEST DAY 2</td>
<td>36.650</td>
<td>.947</td>
<td>.855 - .981</td>
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</table>

*CI = Confidence Interval

Additional Findings

A one-way repeated measures ANOVA was calculated to determine if there was variance between the subjects from the Professional Golf Management (PGM) Program at
California University of Pennsylvania (n = 8) and the novice golfers from the California University of Pennsylvania (n = 8). A one-way repeated measures ANOVA compared the mean scores of the PGM golfers and novice golfers (see table 4) for the three tests: dynamic, static goniometer, and static Dartfish. A significant effect was found (F(1,14) = 3332.29, p < .001) (see table 5). There were significant differences between the two groups, PGM and novice, for the dynamic, static goniometer, and static Dartfish scores (see table 4).

**Table 4. Mean Scores and Standard Deviations for PGM Golfers and Novice Golfers.**

<table>
<thead>
<tr>
<th></th>
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<th>Novice</th>
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<tbody>
<tr>
<td><strong>DYNAMIC</strong></td>
<td>144.64 +/- 9.53</td>
<td>122.55 +/- 13.99</td>
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<tr>
<td><strong>STATIC GONIOMETER</strong></td>
<td>146.67 +/- 7.40</td>
<td>120.11 +/- 11.73</td>
</tr>
<tr>
<td><strong>STATIC DARTFISH</strong></td>
<td>146.94 +/- 5.38</td>
<td>122.98 +/- 11.52</td>
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**Table 5. One-Way Repeated Measures ANOVA.**

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<tr>
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<th>df</th>
<th>F</th>
<th>Sig</th>
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<td>3331.288</td>
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</tr>
<tr>
<td>Skill</td>
<td>7030.100</td>
<td>1</td>
<td>27.181</td>
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</tr>
<tr>
<td>Error</td>
<td>3621.004</td>
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*Type III S of S = Type III Sum of Squares
DISCUSSION

Discussion of Results

This study examined the validity and reliability of a motion analysis software program, Dartfish. The study considered the elbow angle of the lead arm during a golf swing at peak backswing. More specifically the study compared goniometric measurements to measurements made using Dartfish as well as comparing measurements of Dartfish in a test-retest design.

Hypothesis 1 stated that the range of motion measurements taken with Dartfish would not differ on subsequent trials. The researcher proposed that the results would not have significant variance when the subjects were tested on subsequent trials.

No significant difference was found with respect to the Dartfish measurements on day 1 to those taken on day 2. The average elbow angle of the lead arm at peak backswing on day 1 was 136.35 degrees with a standard deviation of 15.17 degrees. The average elbow angle of the lead arm at peak backswing on day 2 was 130.81 degrees with a standard deviation of 17.85 degrees.

Hypothesis 2 stated that the measurements taken with a goniometer would not differ from the measurements taken
with the motion analysis software Dartfish during the static test. The researcher proposed that the results would not have significant variance when comparing the measurements taken with a goniometer and those taken with Dartfish.

No significant difference was found with respect to the goniometric measurements and the Dartfish measurements on day 1 and on day 2. The average elbow angle of the lead arm at peak backswing on day 1 using the goniometer was 133.66 degrees with a standard deviation of 17.67 degrees. The average elbow angle of the lead arm at peak backswing on day 1 using Dartfish was 136.16 degrees with a standard deviation of 15.63 degrees. The average elbow angle of the lead arm at peak backswing on day 2 using the goniometer was 134.13 degrees with a standard deviation of 15.57 degrees. The average elbow angle of the lead arm at peak backswing on day 2 using Dartfish was 133.75 degrees with a standard deviation of 15.06 degrees.

As discussed previously the range of motion measures between using a goniometer and using Dartfish had no significant difference. This is exactly what the researched hypothesized would occur. The only difference in obtaining the results was the method used. The subject’s joints were the same, as where the bony landmarks
used to identify the angle; therefore it was hypothesized and found that the 2D motion analysis software returns similar results as a goniometer and therefore is a valid measure of joint angles. Now that Dartfish has been found a reliable and valid measure of range of motion it can not only be used in similar circumstances as a goniometer but can also be used in a wider range of situations than a goniometer can. A goniometer and most methods to obtain joint position measures have to be done while the joint remains stationary. However, with 2D motion analysis the joint can be measured during movement. For Dartfish to obtain accurate measurements, bony landmarks must be identified and marked so that they can be easily identified when using the motion analysis software.

In a previous study by Gribble\textsuperscript{12} where he compared a 2D motion analysis software system to a goniometer by having subjects perform the star excursion balance test while measuring the hip, knee, and ankle joints. An ICC was calculated to determine interrater reliability and the results ranged from .60 to .92 for the static task performed and from .76 to .89 for the dynamic task performed.\textsuperscript{12} Therefore, the results showed moderate to strong reliability of the motion analysis system tested. Another study tested the isokinetic muscle performance of
knee extension and flexion to see if reliable measures could be obtained. ICC’s for peak torque ranged from .90 to .96 and total work ranged from .90 to .95, showing high reliability. Hertel et al also found relatively high reliability during the Star Excursion Balance Tests. The ICC’s for intratester reliability ranged from .78 to .96. Dartfish showed a high reliability with a single measures ICC which ranged from .904 to .988 for day 1 and ranged from .855 to .981 for day 2 of the static test, and an ICC that ranged from .799 to .973 for the dynamic test. Also Cronhback’s Alpha (ranged from $r = .961 - r = .970$) and the Pearson-Product Moment Correlation (ranged from $r(16) = .937, P < .001 - r(16) = .973, P < .001$) proving the high reliability.

Traditionally motion analysis has been used as mostly a teaching tool. The mechanics of a golf swing or another activity can be broken down and analyzed in order to better ones performance. However, this technology can be utilized in other ways. Dartfish could be used to track a patient’s progress throughout his or her rehabilitation. It could also be used as a teaching tool for student athletic trainers. In the athletic training room Dartfish could be used in place of the goniometer and it can measure active
range of motion during an activity such as walking or running on a treadmill.

There were significant differences between the Professional Golf Management golfers and the novice golfers during both the dynamic and static tests. The difference in elbow angle of the lead arm at peak backswing during a golf swing between the PGM golfers and the novice golfers during the static and dynamic tests ranged from 20.77 degrees to 26.75 degrees with a mean score of 23.87 degrees. For the golfers with more ability to have elbow angles that are closer to 180 degrees or straight is logical due to the fact that a golfer tries to keep his lead arm straight throughout the swing. Therefore the better ones swing is then theoretically the better golfer one should be and the closer ones elbow angle of the lead arm at peak backswing should be to 180 degrees or straight.

Conclusions

The results of the study revealed the following two major conclusions. First, the motion analysis software, Dartfish is a valid tool to determine the elbow angle of the lead arm at the peak of the golf backswing. Second, the motion analysis software Dartfish has good internal
consistency and produces a reliable measure of the elbow angle of the lead arm at peak backswing during a golf swing.

From this study it can be concluded that 2D motion analysis can be used to study the quality and quantity of motion in slow speed motions. The motion analysis software Dartfish is a satisfactory means of acquiring range of motion measures during activity.

Recommendations

Based on the results of this study, the following research recommendations were made. When marking the subject’s ulnar styloid process, lateral epicondyle, and the acromion make sure the lighting is optimal so that there are no shadows on the subject’s arm. Also future studies should see if elbow angle effects performance. Future studies should examine the accuracy and reliability of measuring range of motion at higher speeds as well. Based on the findings of the study Dartfish can be used as a means of monitoring improvement. Such as, during a number of teaching lessons a golf pro can show a client how they are improving.
REFERENCES


APPENDICIES
APPENDIX A

Review of the Literature
Review of the Literature

The purpose of this project is to test the reliability and the validity of a two dimensional video analysis system in measuring elbow joint angle during the golf swing. This literature review will examine reliability and validity studies as well as review motion analysis. Also included is a general overview of golf and a look at the biomechanics of the golf swing. Previous studies will be examined to obtain the best way to test the two dimensional motional analysis software, Dartfish, and to identify if it is reliable and valid.

Plenty of money is spent every year by golfers trying to improve their golf games, and this study will test only one system. This literature review is divided into four sections: 1) Golf participation, 2) the biomechanics of the golf swing, 3) motion analysis, and 4) reliability and validity testing. A summary of the literature is also included at the end of the literature review.

Golf Participation

Mark Twain once famously called golf “a good walk spoiled.” In 2002, 502 million rounds of golf were played
while in 2003 just 495 million rounds were played in the United States alone. 59% of the 32,000 courses worldwide are located in the United States. There are an estimated 35 million golfers worldwide with approximately 26.5 million golfers in the United States. In 2005, 5.8 billion dollars were spent in the United States market for golf equipment. Which includes golf clubs ($1.3 billion), golf balls ($762.9 million), golf bags, golf carts and other accessories ($1.4 billion) including: apparel, footwear, gloves, tees, and training devices for putting and driving ($1.4 billion). With so much money spent on golf equipment the golf industry spends millions of dollars and thousands of hours on research and development. Nike golf has a 31,500 square foot building dedicated to the advancement of the golf industry.

The game of golf is extremely popular all across the world. Technology, research, and development of new equipment are a big part of the golf industry. As long as there are avid golfers trying to improve their game with larger club heads, graphite shafts, longer and softer golf balls, and quick fix items, the golf industry will continue to supply the demand. Various equipment companies all claim that their products are the world’s greatest; however, with all the money involved in golf, more
objective research on the new technology is needed to test their reliability and validity.

The Biomechanics of the Golf Swing

Most golfers want consistency out of their swings as well as their game. A golfer tries to commit his or her swing to muscle memory in order to reproduce the same swing each time they hit a golf ball. Technique can have a large effect on golf performance where the object of the game is to hit the golf ball into a small hole in as few shots as possible.\textsuperscript{3} Golfers are constantly looking for ways to improve their performance. One way to improve one’s golf swing is to understand the swing and its components. The biomechanics of the golf swing have been reported by several authors.\textsuperscript{3-9}

There are several components in which the golf swing can be broken down into. First is the address, which is the instant before the club begins to move toward the backswing. The address phase also includes the grip, posture, stance, and ball position. Maddalozzo stated that the grip is the foundation of a good golf swing. The primary purpose of the grip is to insure that the hands and wrist work together in order to transfer the force
generated by the body and leg action during the swing to the ball. Posture and alignment affect the ability of a golfer to rotate properly and directly affecting the plane of swing and the club head path. Transferring weight and maintaining good balance are key throughout the swing. The stance sets up the basis for movement. It is the only aspect of the golf swing where the golfer has 100% conscious control. The basic objective in positioning the golf ball is to place the ball at the lowest fulcrum point of the full swing.4

The next phase of the golf swing is the backswing, which takes place the moment the golfer starts to move the golf club away from the ball to where the club is parallel to the ground. The purpose of the backswing is to establish a perfectly balanced, powerful position at the top of the swing. During the backswing the golf club head, the hands, and the shoulders must start in one motion and the golfer transfers their weight from a neutral position to their back foot. The shifting of weight increases the range of hip rotation as well as flattening the arc of the swing. At the top of the backswing, the shoulders are coiled, the hands are swung high, and the arms are extended. If the shoulders, arms, and hands follow the correct motion, it insures that the upper body will be
properly inter-aligned when the swing reaches that critical point where the backswing ends and the downswing begins. This critical point is called the peak backswing and it is where the club changes direction from backswing to downswing.\textsuperscript{3,4}

The next phase in the golf swing is the downswing. This phase begins by the rotation of the hips and as a result of the downswing, an increased acceleration of the club head is achieved. Almost simultaneously with the hip turn is a transfer of weight from the back foot to the front foot. This flattens the swing arc which in turn increases the impact area. Ideally, the hands and arms move the club and the swinging of the arms turns the shoulders and the rotating of the hips unwinds the upper part of the body allowing the shoulders, arms, and hands to flow easily into the swing. The downswing leads directly into impact where the club strikes the ball. At impact, the wrists straighten and with the rest of the body a maximum hitting effort is accomplished.\textsuperscript{3,4}

The last phase of the golf swing is the follow through. The golf swing maximum effort has subsided and the right arm begins to rotate and the right hand begins to climb over the left. The golfer’s head which remains stationary throughout the swing is finally pulled up and
rotated forward by the turning trunk and the momentum of the swing. Although maximum effort has subsided, it is still important to accelerate through impact.\(^3,^4\)

**Motion Analysis**

"Analysis of the dynamic forces of sport movements enables therapists and trainers to design programs that enhance performance and prevent injuries."\(^{10}\) One of the most common means in measuring motion is by using a goniometer. It takes about 0.123 seconds at an angular velocity of 2200 degrees per second for a skilled golfer to take a swing. Therefore it is difficult to obtain accurate joint position results during dynamic movement. When analyzing high speed movements, video-based motion-measurement systems provide a means of analyzing these actions with minimal inconvenience. This form of sport analysis has aided therapists, athletic trainers, exercise physiologists, and other professionals to better understand the complex movements that occur in sports.\(^{10}\)

The most common ways to capture data are with high-speed cameras, video cameras, or radiographic systems. Motion analysis in sports has been limited to motion measurement and analysis of injuries and is limited because
of low accuracy and precision of the motion data. The goal in most instances of biomechanical or motion analysis is to apply the results to improve performance or to prevent injury. It is also difficult to perform an analysis of separate extremities in the same movement due to the lack of symmetry from the limbs. \(^{11-14}\)

Research and technology are two areas that have grown considerably in recent years. With more technology available it has made it possible to dive into areas that at one time where never dreamt of. The ability to utilize motion analysis of dynamic tasks has opened numerous doors for therapists, athletic trainers, exercise physiologists, and other professionals. Preventing injuries and improving performance are two factors that every athlete should want in the athletic world. Due to that fact, a lot of time and money are put into those areas; motion analysis and the capability to break down high speed dynamic tasks has been a crucial factor in what kinds of research can be performed.

Reliability and Validity Testing

When working with new technology one of the first steps that need to be taken is to test the reliability of
the instrument. If the measurements recorded do not remain constant as the experiment is repeated then the tool is not reliable and therefore not useful.\textsuperscript{15}

Dartfish is a digital motion analysis program. It has the ability to slow a golf swing down to a frame-by-frame video in order to measure key angles in the body at key moments in the golf swing. The reliability of this system has not previously been established.

An important factor in establishing reliability is intratester reliability. For the system to be valuable the same tester needs to consistently record the same measure when taken repeatedly.\textsuperscript{15}

The most common method of assessing reliability in athletic training research is interclass correlation.\textsuperscript{35} The interclass correlation coefficients (ICC) have a range from 0 to 1, 0 indicates no linear relationship or no reliability and 1 indicates a perfect positive linear relationship or perfect reliability. Therefore results that appear to be consistent have a high interclass correlation coefficient value. While the interclass correlation gives information on the consistency of a measurement, it does not provide information regarding the precision. The results will vary because of measurement
error. The standard error of the measure (SEM) is used to find out how much a measure varies from random error.\textsuperscript{16}

For instance the isokinetic muscle performance of knee extension and flexion was tested to see if reliable measures could be obtained. ICC’s for peak torque ranged from .90 to .96 and total work ranged from .90 to .95. SEM’s for peak torque ranged from 8.9 to 13.3 Nm while total work ranged from 11.3 to 16.8 Nm.\textsuperscript{17}

Hertel et al found relatively high reliability of both intratester and intertester reliability during testing of the Star Excursion Balance Tests. The ICC’s for intratester reliability ranged from .78 to .96. The SEM’s for intratester reliability estimates ranged from 1.77 to 3.38. When intertester reliability was looked at the ICC’s ranged from .35 to .93 and the SEM’s ranged from 2.27 to 4.96 cm.\textsuperscript{18}

One study took a look at the reliability of a two dimensional video digitizing system. Gribble et al found in both static positioning and Star Excursion Balance Test performance that high intratester reliability (ICC .60 to .92) was demonstrated. A small SEM was found however it was very consistent throughout the measurements.\textsuperscript{19}

Validity deals with the degree to which there is proof that a measure actually measures what it is supposed to
measure. Does Dartfish actually analyze the golf swing properly and effectively? The validity of an instrument is determined by a couple of factors. First, the elements within the instrument must relate to each other the way you would expect them to. Second, the measurements that the instrument takes must relate to other measurements taken by other instruments in the way you would expect them to. The easiest method to test validity is referred to as face validity. It is not very sophisticated because all you have to do is inspect an instrument to see if it looks like you expect it to. When the angle of the joint at the elbow is taken any measurement lower than 180 degrees would be expected. Content validity is used mostly when a number of discreet elements are added together to form a measure. Face and content validity are both nonempirical methods however, there are empirical methods for assessing validity as well. Criterion validity uses some other measure as a criterion against which to judge the instrument. For example when a goniometric measurement is taken of the joint angle of the elbow it can then be compared to a measurement taken by a golf swing analysis software of the same elbow.¹⁵

When criterion validity is used the reliability and validity of the instrument being used as a measuring stick
must already be established. Gajdosik and Bohannon state, “Physical therapists judge the validity of most ROM measurements based on their anatomical knowledge and their applied skills of visual inspection, palpation of bony landmarks, and accurate alignment of the goniometer.” Generally, the accurate application of knowledge and skills, combined with interpreting the results as measurement of ROM only, provide sufficient evidence to ensure content validity.” The best gold standard used to establish validity of a goniometer is with radiography. Gogia et al measured the knee position of 30 subjects with radiography and with a large 360 degree plastic universal goniometer marked in 1 degree increments. Knee positions ranged from 0 to 120 degrees. High correlation and agreement were found between the two types of measurements. Therefore goniometric measurements of knee joint position were considered to be valid. Ahlbach et al found that a joint-specific goniometer used to measure hip flexion and extension closely agreed with radiographic measurements.

The measurement of joint position and ROM of the extremities with a universal goniometer has generally been found to have good to excellent reliability. The reliability of goniometric ROM measurements varies somewhat depending on the joint and motion. ROM measurements of
upper-extremity joints have been found to be more reliable than ROM measurements of lower-extremity joints. The American Academy of Orthopaedic Surgeons and the American Medical Association measured motion at the elbow and found that flexion was 150 and 140 degrees respectively and whereas extension was 0 degrees from both. Rothstein et al showed that intratester reliability for flexion and extension of the knee and the elbow joints was high ($r = .91$ to $.99$). In order to minimize error while taking goniometric measurements it is essential to assess potential sources of error in goniometry. Bony landmarks should be identified and labeled prior to the collection of data. Also proper alignment must be used when using a goniometer to insure minimized error.

Gribble et al tested the validity of a two dimensional video system by taking measurements of the ankle, knee, and hip by means of a standard goniometer and the video system by the same examiner. Measurements at the ankle and the knee resulted in an error of less than four degrees, and the results at the hip were associated with error between 4.5 degrees and 11 degrees.

Piland et al evaluated the factorial and construct validity of a head injury scale by analyzing baseline data from preseason concussion testing and scores of athletes
after a concussive episode. The tests used exhibited strong evidence of factorial validity as well as construct validity.\textsuperscript{29}

Summary

Interest in golf is a world wide phenomenon. With such a high interest level for the game, the golf industry is a multi-billion dollar business. Roughly 500 million rounds of golf are played each year in the United States. Those who love the game of golf are always trying to get better and lower their scores. It all starts with a golfer's swing. There are six phases to the golf swing; the address, backswing, peak backswing, downswing, impact, and the follow through. One way to improve the golf swing is by breaking the movement down and analyzing it. Motion analysis also aides athletic trainers, therapists, biomechanists, and other professionals to better understand the complex movements that occur in sports. The most common way to capture the complex movements that occur in sports is by using high-speed cameras, video cameras, or radiographic systems. When working with new technology the reliability and validity must be tested to ensure its effectiveness. Dartfish is a two dimensional digital
motion analysis program. In order to test the reliability of the software program the test-retest method will be used to test its internal consistency. The validity of the software program will be tested by comparing data results against a goniometer when measuring the elbow angle of the lead arm at the peak backswing during a golf swing.
APPENDIX B

The Problem
The Problem

Statement of the Problem

Golf is one of the most widely popular activities in the world. Millions of dollars have been spent on technology to improve golf balls and golf clubs. NASA scientists work for companies in the golf industry improving the technology in the sport. Golf courses can be found in practically every area of the world as well as golf simulators and golf swing analysis programs. To determine how well two-dimensional motion analysis software works, the reliability must be tested. Now that the reliability is determined research studies will be able to determine if the technology can be used to help golfers improve. The purpose of this study is to test the reliability and validity of the motion analysis software Dartfish. Furthermore, this study examined any differences in the lead arm elbow flexion at the peak backswing in students in the Professional Golf Management program and novice golfers at California University of Pennsylvania.
Definition of Terms

The following are operational definitions of key terms for increased understanding of this study:

1) **Dartfish Connect Version 4.5** – an instrument used to measure the elbow angle of the lead arm at peak backswing during a golf swing.

2) **Dynamic Test** – where the subjects hit golf balls by performing a golf swing while being video recorded.

3) **Golf Swing** – the movement involved in striking a golf ball, can be broken down into six steps; the address, backswing, peak backswing, downswing, impact, and follow-through.\(^3\)\(^4\)

4) **Goniometer** – an instrument used to measure the joint angle at the elbow of the lead arm during the static test.

5) **Joint Angle** – the amount of arm bend at the elbow when the lines from the acromion and ulnar styloid process connect at the lateral epicondyle. 180 degrees is when the arm is in full extension.

6) **Motion Analysis** – the breakdown of a movement in order to better understand that particular movement.

7) **Reliability** – the extent to which a measurement remains constant as it is repeated under conditions taken to be constant.\(^15\)
8) **Static Test** – where the subjects hold their golf swing at the peak backswing while the instructor takes measurements.

9) **Validity** – confirmation that an instrument measures what it was set out to measure.\(^{15}\)

**Basic Assumptions**

For the purpose of this study, the following considerations will be assumed:

1) Subjects will provide their best effort in each trial, provided that they are instructed properly.
2) Goniometric recordings are a valid and reliable measure of joint angles.
3) Subjects will produce the same amount of joint angle at the elbow during static and dynamic testing.

**Limitations of the Study**

The following factors may be a limitation to this study:

1) All subjects are limited to being from California University of Pennsylvania.
2) Only one angle (joint angle of the elbow at the peak backswing) will be analyzed.
3) A three dimensional structure will be measured using a two dimensional video capture system and will be captured in only one plane.

Significance of the Study

This study examined the reliability and validity of the motion analysis software Dartfish. When an instrument is used for measurement it has to be tested for reliability. If an instrument is found to be reliable it is considered to yield a measurement that remains constant as it is repeated under identical conditions. Validity deals with the degree to which there is evidence that an instrument actually measures what it is supposed to measure. The reliability or validity of data is also dependent on the characteristics of the subjects, the environment where the measurements are taken, the exact procedures used, and the skills in using the instrument. Once the motion analysis software Dartfish has been deemed reliable and valid, future research can be conducted. A variety of different experiments can be conducted to determine how to improve one’s golf game and or decrease the chance of injury.
This study also observed if there are any differences between members of the Professional Golf Management program and novice golfers at California University of Pennsylvania. More specifically it examined the amount of lead arm elbow flexion at the peak backswing. Keeping the lead arm straight during the backswing is as widely stated during lessons as is keep your eye on the ball is used in a baseball swing. Measuring this will help determine if there is any variance in golfers with different ability levels. A difference was found between PGM golfers and novice golfers therefore future research can dwell deeper into why this occurred.
APPENDIX C

Additional Methods
APPENDIX C1

Informed Consent Form
Informed-Consent Form

1. Matthew W McKelvey, a certified athletic trainer, who is a Graduate Assistant Athletic Training Student at California University of Pennsylvania, has requested my participation in a research study at the University. The title of this research is *Reliability and Validity of a Golf Swing Analysis Software During a Static and a Dynamic Task*.

2. I have been informed that the purpose of this research is to determine the reliability and validity of Dartfish motion analysis software. The study will only require subjects to participate in the gathering of data for two sessions.

3. My participation will involve performing and holding a golf backswing and hitting 10 golf balls while being video taped.

4. There are no foreseeable risks or discomforts that may occur in this study beyond those related to participation in golf.

5. I understand that in case of injury I can expect to receive treatment or care in Hamer Hall’s Athletic Training Facility which will be provided by the Graduate Assistant Athletic Training Student conducting the research. This student, Matthew W McKelvey is a Certified Athletic Trainer and is qualified to administer emergency care. Additional services needed for prolonged care past 3 days will be referred to my family physician or orthopedic doctor.

6. There are no feasible alternative procedures available for this study.

7. There are no foreseeable benefits from my participation in the research study.

8. I understand that the results of the research study may be published, however the results and my name or identity are confidential and will not be revealed. In order to maintain confidentiality of my records, Matthew W McKelvey will maintain all documents in a secure location in which only the student researcher and research advisor can access. This includes measurements, personal history or any personal information.

9. I have been informed that I will not be compensated for my participation.

10. I have been informed that any questions I have concerning the research study or my participation in
it, before or after my consent, will be answered by Matthew W McKelvey ATC, MCK1490@CUP.EDU, 670 Park St. California, PA 15419, (248) 379 - 8479 and Thomas West PhD, ATC, California University of Pennsylvania, West_T@CUP.EDU, 250 University Ave. California, PA 15419, (724) 809 - 1321.

11. I have read the above information. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

Subject’s
Signature__________________________________________________________

Date________________________

12. I certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature.

13. I have provided the subject/participant a copy of this signed consent document if requested.

Investigator’s
Signature__________________________________________________________

Date________________________

Approved by the California University of Pennsylvania IRB
APPENDIX C2

Institutional Review Board
Reliability and Validity of a Golf Swing Analysis Software During a Static and a Dynamic Task

Project Title: 

Researcher/Project Director: Matthew Warner McKelvey

Phone: (248) 379-6479 E-mail Address: MCK1490@CUP.EDU

Faculty Sponsor (if required) Dr. Thomas West

Department: Health Science and Sport Studies

Project Dates: March 2006 to April 2007

Sponsoring Agent (if applicable): 

Project to be Conducted at: California University of Pennsylvania

Project Purposes: [ ] Thesis [ ] Research [ ] Class Project [ ] Other

Keep a copy of this form for your records.

Required IRB Training

The training requirements can be satisfied by completing the online training session at https://www.trialxls.com. A copy of your certification of training must be attached to this IRB Protocol. If you have completed the training at an earlier date and have already provided documentation to the California University of Pennsylvania Grants Office, please provide the following:

Previous Project Title:

Date of Previous IRB Protocol:

Approved, September 12, 2005
Please attach a typed, detailed summary of your project AND complete items 2 through 6.

1. Provide an overview of your project-proposal describing what you plan to do and how you will go about doing it. Include any hypothesis(es) or research questions that might be involved and explain how the information you gather will be analyzed. For a complete list of what should be included in your summary, please refer to Appendix B of the IRB Policies and Procedures Manual.

This study will test the reliability and validity of a 2D motion analysis system. There are two hypotheses for this study. First, there will be no difference between the range of motion measures taken on subsequent trials taken with Dartfish. Lastly, there will be no difference between the measurements taken with a goniometer and the golf swing analysis software measurements. Measurements will be recorded during two sessions. The subjects will come in and warm up for 5 minutes prior to participating in the static test. During the static test the subjects will hold their golf swing at peak backswing while measurements of elbow angle are taken with a goniometer while simultaneously being video recorded. During the second session the subjects will warm up for 5 minutes prior to the dynamic test. The subjects will hit 10 golf balls at full speed during the dynamic test. The subjects will be video taped while performing the static and dynamic tests (See attached methods section for more information). A cronback’s alpha and standard error of the measure will be used to determine if there will be no difference between the scores for the trials of Dartfish. Also, A Pearson-Product Moment Correlation will be used to determine if there will be no difference between the measurements taken with a goniometer and the golf swing analysis software measurements.

2. Section 46.11 of the Federal Regulations state that research proposals involving human subjects must satisfy certain requirements before the IRB can grant approval. You should describe in detail how the following requirements will be satisfied. Be sure to address each area separately.

   a. How will you insure that any risks to subjects are minimized? If there are potential risks, describe what will be done to minimize these risks. If there are risks, describe why the risks to participants are reasonable in relation to the anticipated benefits.

      There are no foreseeable risks or discomforts involved in this study beyond those related to participation in golf. In the case of injury the investigator will care for and treat the injured subject using the facilities available at the California University of Pennsylvania.

   b. How will you insure that the selection of subjects is equitable? Take into account your purpose(s). Be sure you address research problems involving vulnerable populations such as children, prisoners, pregnant women, mentally disabled persons, and economically or educationally disadvantaged persons. If this is an in-class project describe how you will minimize the possibility that students will feel coerced.

      Subjects to be used in this study will be professional golf management students at California University of Pennsylvania as well as novice golfers at the California University of Pennsylvania. Subjects will be attained through a volunteer basis for participation.
c. How will you obtain informed consent from each participant or the subject’s legally authorized representative and ensure that all consent forms are appropriately documented? Be sure to attach a copy of your consent form to the project summary.

A meeting will be held where the subjects will be able to read a written copy of the informed consent, ask any questions, sign the consent form, etc.

d. Show that the research plan makes provisions to monitor the data collected to insure the safety of all subjects. This includes the privacy of subjects’ responses and provisions for maintaining the security and confidentiality of the data.

The Data Collection Form (C3) will only be viewed by the investigator and will only contain numbers not names to identify the subjects. At all other times the data collection form will be kept in a safe location in the investigator’s place of residence.

3. Check the appropriate box(es) that describe the subjects you plan to use.

- Adult volunteers
- CAL University Students
- Other Student
- Prisoners
- Pregnant Women
- Physically Handicapped People
- Mentally Disabled People
- Economically Disadvantaged People
- Educationally Disadvantaged People
- Fetuses or fetal material
- Children Under 18
- Neonates

4. Is remuneration involved in your project? Yes or No. If yes, Explain here.

5. Is this project part of a grant? Yes or No. If yes, provide the following information:

Title of the Grant Proposal

Name of the Funding Agency

Dates of the Project Period

6. Does your project involve the debriefing of those who participated? Yes or No. If Yes, explain the debriefing process here.

7. If your project involves a questionnaire interview, ensure that it meets the requirements of Appendix ___ in the Policies and Procedures Manual.

Approved, September 12, 2005
Project Director's Certification
Program Involving HUMAN SUBJECTS

The proposed investigation involves the use of human subjects and I am submitting the complete application form and project description to the Institutional Review Board for Research Involving Human Subjects.

I understand that Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects. If the Board grants approval of this application, I agree to:

1. Abide by any conditions or changes in the project required by the Board.
2. Report to the Board any change in the research plan that affects the method of using human subjects before such change is instituted.
3. Report to the Board any problems that arise in connection with the use of human subjects.
4. Seek advice of the Board whenever I believe such advice is necessary or would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board in its effort to provide a continuing review after investigations have been initiated.

I have reviewed the Federal and State regulations concerning the use of human subjects in research and training programs and the guidelines. I agree to abide by the regulations and guidelines aforementioned and will adhere to policies and procedures described in my application. I understand that changes to the research must be approved by the IRB before they are implemented.

Professional Research

Project Director's Signature

Student or Class Research

Student Researcher's Signature

Supervising Faculty Member's Signature if required

Department Chairperson's Signature

ACTION OF REVIEW BOARD (IRB use only)

The Institutional Review Board for Research Involving Human Subjects has reviewed this application to ascertain whether or not the proposed project:

1. Provides adequate safeguards of the rights and welfare of human subjects involved in the investigations;
2. Uses appropriate methods to obtain informed, written consent;
3. Indicates that the potential benefits of the investigation substantially outweigh the risk involved.
4. Provides adequate debriefing of human participants;
5. Provides adequate follow-up services to participants who may have incurred physical, mental, or emotional harm.

☐ Approved ☐ Disapproved

Chairperson, Institutional Review Board

Date

Chairperson, Institutional Review Board

Date
APPENDIX C3

Data Collection Form
## DAY ONE

### STATIC TEST

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## DAY TWO

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APPENDIX C4

Photo/Audio Tape/Video Tape Release Form
Photo/Audio Tape/Video Tape Release Form

Project Title:
Reliability and Validity of a Golf Swing Analysis Software During a Static and a Dynamic Task

Protocol Number: 06-048

Principle Investigator Name: Matthew W. McKelvey

Photo/Audio Tape/Video Tape Release

We request the use of (photographic/audio/video) material as part of our study. We specifically ask your consent to use this material as we deem proper. The material will be used for the research project as we have described it in the informed consent document you have signed. These materials may be used for news releases, professional publications, professional conferences, websites, and pictorial exhibits related to our study.

We also emphasize that the appearance of these materials on certain media (websites, professional publications, news releases) may require the transfer of copyright of the images or audio materials. This means that other individuals may use your image or voice. Regarding the use of your likeness in photographs, tapes, or recordings, please check one of the following boxes:

I do…
I do not…
Give unconditional permission for the investigators to utilize photographs/recordings of me.

_________________________________________  ______________
Signature Date

Note: Even should you choose not to allow your image to be used, we can still benefit from your inclusion as a research study participant.
REFERENCES


ABSTRACT

Title: RELIABILITY AND VALIDITY OF A GOLF SWING ANALYSIS SOFTWARE DURING A STATIC AND A DYNAMIC TASK

Researcher: Matthew Warner McKelvey

Advisor: Dr. Thomas West

Date: May 2007

Research Type: Master’s Thesis

Purpose: The purpose of this study is to test the reliability and validity of the motion analysis software Dartfish.

Problem: The 2D motion analysis software must be confirmed reliable and valid before it can be used in further research.

Method: Sixteen subjects from California University of Pennsylvania participated in a static test and a dynamic test. The tests were repeated following the test-retest experimental design. Both tests measured the elbow angle of the lead arm at peak backswing during a golf swing. The static test compared goniometric measurements to the motion analysis software Dartfish to establish validity. The dynamic test compared subsequent trials to establish reliability of the motion analysis software Dartfish.

Findings: The motion analysis software Dartfish was found to be both a reliable and valid measure of elbow angle of the lead arm at peak backswing during a golf swing.