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FACTORS OF CLUB DESIGN AND
INDIVIDUAL STRENGTH FACTORS
INFLUENCING THE DISTANCE AND
ACCURACY OF THE GOLF DRIVE

Thesis for the Degree of M. A.
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ABSTRACT

FACTORS OF CLUB DESIGN AND INDIVIDUAL STRENGTH FACTORS INFLUENCING THE DISTANCE AND ACCURACY OF THE GOLF DRIVE

By

James D. Christie

Statement of the Problem

This study was undertaken to determine the effects of strength, swingweight, and shaft flexibility on distance in the golf drive.

Methodology

Seven members of the Michigan State University Golf team and three other golfers of comparable ability were required to hit a total of ten solid shots with each of four different golf clubs. The clubs varied in both swingweight and shaft flexibility as follows: D-3 stiff shaft, D-3 regular shaft, D-6 stiff shaft, and D-6 regular shaft. Variability in swingweight was obtained by weighting with lead tape.

All shots were measured for both distance and accuracy right or left, to the nearest foot.

A three-way mixed model analysis of variance was used to detect any differences between shafts, swingweights, and their interactions.

To determine the relationship between strength and distance, a number of strength measures were taken for each subject. Additional variables were created by dividing the strength variables by height, weight, and the product of height and weight. A series of least squares deletion analyses were run to predict the distance for each club, and the average distance over all clubs, from the independent variables.

Results

1. There were no significant differences in either distance or accuracy between swingweights, shaft flexibilities, or their interactions at .05.
2. None of the strength correlations were significant at the .05 level.

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FACTORS INFLUENCING THE DISTANCE AND
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By

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To Cheryl

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CHAPTER I

INTRODUCTION

In golf, players and coaches are constantly striving to find ways of increasing the distance that a golf ball can be driven off the tee. Unlike most other shots in golf where the primary emphasis is on accuracy, the "tee" shot for the most part emphasizes distance. The player who drives the ball the farthest has a definite advantage in that he can play a higher numbered and more accurate iron for his second shot.

There are many factors which contribute to distance in the golf drive. Some of these factors are intangible. The mechanical factors of swingweight and shaft flexibility, and the human factor of strength are identifiable variables which can be measured. The possibility exists that there may be some relationship between these factors and distance in the golf drive.

Statement of the Problem

The purpose of this study was threefold:

1. To determine the influence of shaft flexibility

and club swingweight on the distance and accuracy of the golf drive.

2. To determine the relationship between strength and the mechanical factors of shaft flexibility and swingweight on the distance of the golf drive.
3. To determine the correlations between distance and certain selected strength measures, and from these correlations to establish a regression equation for each club.

Justification for the Study

Although there is much expert opinion regarding the effects of swingweight and shaft flexibility on distance and accuracy, very little research has been done using human subjects in a controlled study.

This study may enable coaches to prescribe a specific type of club for a player based on the strength characteristics of that particular player.

Furthermore, if it can be determined that there are certain muscle groups which make important contributions to distance in the golf drive, then it is possible that distance can be improved through the development of these muscle groups.

Delimitation

The sample was deliberately composed of seven members of the Michigan State University Golf team and three

other golfers of comparable ability in order to obtain some degree of consistency in the testing procedures.

Limitations

1. The small sample size of only ten subjects.
2. The study was conducted out of doors and temperature and wind factors could be standardized only within certain limits.
3. The variability in swingweight and shaft flexibility was limited by availability.
4. There was no way of controlling the motivational level of the subjects.

Definition of Terms

Swingweighting

This is the standard method of club matching designed to give a common feel to a set of clubs through the establishment of a weight-length relationship.

Swingweight

The club weight in ounces times the distance between the balance point and a point twelve inches from the top of the club. Swingweight is usually expressed in terms of the lorythmic scale. Using this scale, most men select a club in the D-0 to D-6 range. Under this system, the ratio of head weight to overall weight is greater for a D-6 than for a D-5.

Sweetspot

The inserted plate in the face of the driver, which is the optimum hitting area of the club.

Shaft Flexibility

This refers to the bend or whip of the shaft which can be described as being flexible, regular, or stiff. Most men's clubs are either regular or stiff.

CHAPTER II

REVIEW OF LITERATURE

Not all of the articles presented here are of a scientific nature. Some merely express an opinion. However these opinions deserve consideration in that they represent long hours of trial and error practice and many years of experience.

Numerous articles have been written by professionals and teachers of the game as to why they themselves, or some particular player, can hit the ball a long distance.

The delayed hit (last minute uncocking of the wrists) and the importance of a stiff left side are factors frequently mentioned in regard to distance. Bolt (2), and Rodgers (8) emphasize the importance of the delayed hit in developing maximum clubhead speed. Rodgers is of the opinion that strong wrists help to produce a delayed hit.

Professionals who stress the importance of the left side include George Archer, Cary Middlecoff, Bob Toski and Byron Nelson (7). Chi Chi Rodriguez (9) emphasizes a stiff left side and a big body turn, which allows the fullest extension of the left arm and use of the muscles of the upper back.

Tony Jacklin (4) and Byron Nelson (7) also stress the importance of a full shoulder turn in utilizing the muscles of the upper back and shoulders. Jacklin likens the shoulder turn to the coil and recoil action of a coiled spring.

W. E. Lovel (5) in a simplified explanation of the dynamics of maximum distance, points out that the distance a ball travels depends on the amount of energy applied to the ball through the clubhead. The amount of energy applied to the ball is determined by the velocity and mass of the clubhead. Since velocity is raised to the second power in the expression for kinetic energy it is the more important factor. The speed with which we swing, assuming economy of movement is a result of our energy expenditure. Misapplied strength through faulty body motion wastes energy.

In the golf swing, the body initiates movement. The arms move relative to the shoulders, and the hands and wrists move relative to the arms. Thus timing is the most important factor in order to contact the ball with maximum clubhead speed.

Cochrane and Stobbs (3), in a computerized study of the effects on distance of using driver clubheads of different weights, found that the best practical headweight for a driver of standard length was around seven ounces. Between six ounces and ten ounces, there was little variation in distance. This also held true when golf balls

were actually driven. When distance was calculated from clubhead speed without actually hitting the ball, there was little difference in the 5.7 to 12.3 ounce bracket.

In testing three shafts of different flexibility, the authors found that there was little effect on distance but that up to twenty yards variation in accuracy occurred.

Bagmiller (1) conducted a blindfold experiment with golfers to see if a matched set of clubs felt the same. Practically all subjects were able to detect a difference between the number two and number nine irons, indicating that the swingweight method is not entirely satisfactory. In matching clubs by the moment of inertia principle, no significant difference in feel could be detected.

In sampling a group of professionals regarding the swingweight, shaft flexibility, and overall weight of their driver, it was found that most use stiff or extra stiff shafts with driver weight varying between 13 1/4 and 14 ounces and swingweight varying between D-2 and D-6.

Slater-Hammel (10) recorded action currents to provide direct physiological measurements of muscle contraction during the golf swing. Muscle contractions were plotted against movement. A comparison of contraction-movement relationships between subjects showed wide variations in timing and general coordination precluding the idea that there is one accurate kinesiological analysis of the golf stroke. The experimental data also indicated that the downswing was initiated by the right arm with powerful

contractions of the right pectoralis major and latissimus dorsi propelling the arm downward. Other muscles which underwent forceful contraction during the swing were the triceps of both arms and the posterior deltoid of the left arm.

Wiren (11) investigated the human factors influencing the golf drive for distance. Fifty-one subjects ranging in age from seventeen to sixty-nine with handicaps from zero to fourteen, drove three golf balls for distance. The subjects were then tested in the laboratory on thirty-three anthropometric, flexibility, and strength measures. Fourteen of the subjects were filmed during their driving test. Measurements taken from the film provided information on four additional variables. Final analysis showed that the speed of downswing and length of backswing had the highest correlations with distance. These correlations were .798 and .719 respectively. The highest strength correlations were obtained with right wrist palmer flexion, right ankle plantar flexion and left shoulder horizontal extension. These variables correlated with distance .506, .491, and .484 respectively. Overall, twenty-two variables were found to have significant correlations with distance at the .05 level. From these variables a regression equation was developed with a multiple correlation coefficient of .940 and a standard error of estimate of 8.27. In comparing the mean differences between the six longest and six

shortest drivers, left and right wrist flexion, left wrist extension, left shoulder horizontal extension and right grip were significant at the .01 level.

CHAPTER III

METHODOLOGY

Statement of the Problem

This study was undertaken to determine the effects of strength, swingweight, and shaft flexibility on distance and accuracy of the golf drive.

Subjects

The sample was composed of seven volunteers from the Michigan State University Golf team and three acquaintances of the writer known to be of comparable ability. The subjects ranged in age from nineteen to twenty-five. All subjects had handicaps between two and five.

Experimental Design

All subjects were scheduled for testing at their convenience since a randomized testing sequence could not be established due to class schedules.

Testing extended over a three-week period during the late spring term. This was necessitated by the fact that all golfers could not hit on the same day, and because some testing days had to be cancelled due to poor weather conditions.

Weather conditions were standardized as well as possible by testing early in the morning, and only on those days where wind velocity was considered to be negligible and the temperature was at least seventy degrees.

For all tests, each subject was required to hit a total of ten solid shots with each of four different clubs. The clubs varied in shaft flexibility and swingweight as follows:

- | | |
|------------------|-----------------|
| 1. stiff shaft | D-3 swingweight |
| 2. stiff shaft | D-6 swingweight |
| 3. regular shaft | D-3 swingweight |
| 4. regular shaft | D-6 swingweight |

All clubs were made by one manufacturer and weighed out as D-3 before alterations. Additional weight was added to the back of two clubs by means of lead tape to produce the desired variability.

Each subject hit the clubs in a randomized order. All shots were aimed at a center line which extended down the middle of the fairway 250 yards from the hitting area. After each shot, the subject acknowledged whether he had hit the ball solidly within the "sweetspot" of the club, in which case a tongue depressor was used to mark the ball. On each tongue depressor was written the name of the subject, and a number indicating the type of club being hit.

All measurements were taken after all the subjects for that given test day had completed testing. For each

shot the radial distance and the deflection right or left from the midline were recorded to the nearest foot by means of a Lufkin steel chain.

Strength measures for each subject were obtained in the evening of the same day of the distance and accuracy testing. For each subject, height, weight, and the following strength measures were recorded:

1. right and left grip strength
2. right wrist flexion
3. left wrist flexion
4. left shoulder abduction

Three measures for each variable were recorded and the average value was taken as being representative. Additional variables were created by dividing each subject's strength scores by his height, weight, and the product of his height and weight respectively.

Right and left grip strength were determined by means of a hand dynamometer. Clarke's cable tensionmeter was used to assess the other strength measures. All strength testing followed the same sequence for each subject.

Method of Statistical Analysis

To determine the effect of shaft flexibility and swingweight on distance, a three-way mixed model analysis of variance was run using "shaft flexibility," "swingweight," and "subject" as the category variables. No conclusions were to be drawn regarding the subjects, but

"subject" was included as a random factor in order to eliminate the intrasubject dependence between test groups which was caused by testing the same subjects on all clubs. The level of significance was set at the .05 level.

A least squares deletion analysis was used to determine the relationship between the various strength measures and distance.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

The purpose of this study was to determine the effects of strength, swingweight, and shaft flexibility on distance and accuracy in the golf drive.

Results

A three-way mixed model analysis of variance detected no significant differences in either accuracy or distance between shaft flexibilities, swingweights, or the interaction of flexibility and swingweight at the .05 level of significance. The analysis of variance tables for both distance and accuracy can be found in Appendices A and B.

The means and standard deviation of distance and accuracy for each subject by club, are found in Appendix C.

A total of ten least square deletion analyses were run, relating the various strength measures to distance. The initial five analyses analyzed the distance for each club, and the average distance over all clubs, in terms of the seven initial variables and sixteen created variables. The seven initial variables include height, weight, right and left grip strength, right wrist flexion strength,

left wrist extension strength, and left shoulder abduction strength. The created variables were formed by dividing each of the initial variables, by height, weight, and the product of height and weight respectively.

The independent variables were run six at a time due to the small number of degrees of freedom available. A regression equation was obtained, which was significant at the .05 level, for predicting overall distance from all of the primary variables except left shoulder abduction strength. The multiple correlation coefficient for this equation was .993 and the standard error of estimate was 6.71.

No credence was given to this equation as it was felt that the equation was an artifact generated by the small sample and the peculiarity of the height and weight correlations within the sample.

In order to check on the results, a second set of analyses were run using only the five strength variables. The result was that all variables were deleted from the equations for all five analyses, indicating that none of the beta weights were significant at the .05 level.

The raw variables showing the highest correlations over all distance categories were left grip strength ($r = .493$) and right wrist flexion strength ($r = .226$). The simple correlations for all variables are found in Appendix C. The raw strength data for each subject are contained in Appendix D.

Discussion

The lack of a significant difference in distance due to swingweights or shaft flexibilities concurs with the results of Cochrane and Stobbs (3). From this it might be concluded that swingweight and shaft flexibility, within the normal ranges, are important only in the psychological sense of creating a club that feels good to a particular player. This should not be taken too lightly, however, as confidence is a very important aspect of golf.

Lack of significant results might also be explained by the limited variation in the clubs. On the official scale, the difference between a D-3 and a D-6 is only .5 of an ounce. The low correlations found between strength and distance in this study probably are due in part to the small sample size, where one or two extreme values can greatly effect the results. This undoubtedly also explains the negative correlations of height and weight with distance. As it so happened, the second smallest man, both in height and in weight, was the longest hitter. The tallest and second heaviest subject was the shortest hitter. With a larger sample these extreme effects might be modified considerably.

In comparing the strength and distance correlations in this study with those of Wiren's, it is found that they are substantially lower, with the exception of left grip strength. In this study the correlation between left grip strength and distance was $r = .493$, Wiren obtained a

correlation of $r = .410$. Wiren's highest strength distance correlation was with right wrist flexion $r = .586$. The corresponding value in this study was $r = .226$.

With the variables of height and weight deleted, the poor significance probabilities of the beta weights for the strength measures might again be explained by the small sample size. On the other hand, these results concur with the findings of Slater-Hammel (10). Slater-Hammel found that the contraction-movement relationship in the golf swing varied across his subjects. He suggested that the variability could be due to the fact that the golf swing is a complex movement and provides the possibility of a number of different efficient coordinations in the movement sequence. Individual differences in size, posture, and the arrangement of muscles about a joint could result in different timing and coordination relationships.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the effects of strength, swingweight, and shaft flexibility on distance in the golf drive.

Seven members of the Michigan State University Golf team and three other golfers of comparable ability were required to hit a total of ten solid shots with each of four different golf clubs. The clubs varied in both swingweight and shaft flexibility.

All shots were measured for both distance and accuracy, right or left, to the nearest foot.

Analysis of variance was used to detect any differences between shafts, swingweights, and their interactions.

A least squares deletion analysis was used to determine the relationships between the various strength measures and distance.

Conclusions

The following conclusions were drawn within the limitations of the study:

1. No significant differences in distance were found between regular and stiff shaft flexibilities, D-3 and D-6 swingweights, or the interactions of shaft flexibility and swingweight.
2. No significant differences in accuracy occurred between shaft flexibilities, swingweights, or their interactions.
3. No significant relationship was found between distance and any of the strength variables.

Recommendations

1. The relationship between distance and various strength variables should be examined more closely using a larger sample.
2. The relationship between swingweight and distance should be re-examined using a wider range of variability.
3. A study should be undertaken to examine the relationship between swingweight, shaft flexibility and the percentage of successful hits.

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APPENDICES

APPENDIX A.--Three-way mixed model analysis of variance for distance.

Source of Variance	Sum of Squares	D.F	EMS	F	SIG
A	443.10	1	443.10	0.67	0.435
2 = AC	5962.02	9	662.45		
B	1200.62	1	1200.62	0.50	0.498
2 = BC	21638.00	9	2404.22		
AB	1652.42	1	1652.42	0.83	0.387
2 = ABC	18004.30	9	2000.48		
C	271250.26	9	30138.92	46.69	< 0.0005
Remaining Error	232397.70	360	645.55		
Total	552548.44	399			

A = Shaft

B = Swingweight

C = Subject

Z = Error term

APPENDIX B.---Three-way mixed model analysis of variance for accuracy.

Source of Variance	Sum of Squares	D.F	E.M.S.	F	SIG
A	3041.52	1	3041.52	0.73	0.42
2 = AC	37749.40	9	4194.38	0.01	
B	34.22	1	34.22	0.01	0.92
2 = BC	31546.90	9	3505.21		
AB	2415.72	1	2415.72	0.48	0.51
2 = ABC	45625.50	9	5069.50		
C	87153.42	9	9683.71	2.65	0.01
Remaining Error	1317601.30	360	3660.00		
Total	1525168.00	399			

A = Shaft

B = Swingweight

C = Subject

Z = Error Term

APPENDIX C.--Means for distance and accuracy for each subject with each club.

Subject	Shaft	Sw-wt	Distance	Accuracy
DB	1	1	706.20	20.50
	1	2	716.30	41.30
	2	1	688.60	86.80
	2	2	696.50	22.80
SM	1	1	722.00	-8.50
	1	2	715.90	4.30
	2	1	716.20	-2.00
	2	2	720.80	-17.60
JC	1	1	708.90	-2.20
	1	2	708.80	2.70
	2	1	698.90	-1.90
	2	2	699.50	44.00
RW	1	1	716.00	61.30
	1	2	729.10	25.30
	2	1	732.30	34.80
	2	2	719.90	-0.20
DV	1	1	745.50	40.00
	1	2	747.00	35.60
	2	1	758.20	-0.40
	2	2	748.80	17.60
JB	1	1	646.20	18.90
	1	2	655.80	79.60
	2	1	678.20	29.60
	2	2	630.10	9.70
BA	1	1	715.40	4.20
	1	2	733.40	-15.00
	2	1	732.60	6.00
	2	2	701.50	7.00
BF	1	1	683.30	26.20
	1	2	721.40	10.30
	2	1	677.10	-8.40
	2	2	720.10	3.90
GS	1	1	682.20	17.00
	1	2	677.70	24.00
	2	1	665.20	14.70
	2	2	690.40	37.40
BD	1	1	680.80	34.90
	1	2	676.40	34.90
	2	1	678.80	34.50
	2	2	692.50	14.10

Codes: Shaft 1 = Stiff 2 = Regular
Swingweight 1 = D-3 2 = D-6

APPENDIX D.--Simple correlations.

	Var. No.	2	3	4	5	8	9	10	11	12	29
Dist. D3S	2	1.00									
Dist. D3R	3	.84	1.00								
Dist. D6S	4	.89	.79	1.00							
Dist. D6R	5	.86	.63	.86	1.00						
Rt. wrist	8	.36	.37	.29	.11	1.00					
Lt. wrist	9	-.02	.21	.09	-.19	.73	1.00				
Rt. grip	10	.16	.26	.41	.01	.41	.30	1.00			
Lt. grip	11	.31	.36	.63	.52	-.09	.02	.30	1.00		
Lt. shoulder	12	-.09	.04	.01	-.07	.18	.35	-.01	.34	1.00	
Dist. (Ave)	29	.97	.88	.95	.91	.30	.02	.23	.49	-.03	1.00
	Dist. D3S	Dist. D3R	Dist. D6S	Dist. D6R	RT-WR	LT-WR	RT-GR	LT-GR	LT-SH	LT-SH	Dist. (Ave)

APPENDIX E.--Raw strength data.

Subj.	Ht.	Wt.	Right Wrist	Left Wrist	Right Grip	Left Grip	Left Shoulder
D.B.	73.22	189.5	63.33	44.58	160.33	108.00	72.53
S.M.	71.37	224.0	63.33	50.00	113.33	109.00	116.40
J.C.	73.53	181.0	50.00	32.91	124.33	106.00	88.33
R.W.	71.85	182.5	52.08	37.33	143.33	132.33	101.36
D.V.	69.52	151.5	58.75	42.08	134.67	110.00	64.31
J.B.	74.48	196.0	56.67	49.58	136.67	95.67	96.67
B.A.	72.12	165.0	55.41	50.00	136.00	121.00	80.56
B.F.	72.63	185.0	51.25	42.08	134.33	136.00	96.30
G.S.	69.60	139.5	49.16	36.25	113.67	88.33	68.33
B.D.	69.25	188.5	50.83	36.25	101.00	111.33	71.36

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