THE INTERRELATIONSHIPS OF STRENGTH, SPEED, POWER AND ANTHROPOMETRIC MEASURES IN COLLEGE AGED WOMEN

THESIS

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By

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The purpose of the investigation was to determine the interrelationships of strength, speed, power and anthropometric measures in women. Sixty females ranging in ages from 18 to 25 volunteered as subjects. Subjects were measured for strength on the bench press, leg extension and leg curl, power vertical jump, speed--a 40 yard dash, body weight (BW) and fat weight (FW) using a scale and skinfold tests. The correlations for strength and power (.35 to .53), strength and speed (-.37 to -.56) and speed and power (-.45) were significant ($p < .01$). Partial correlations with (BW) and (FW) held constant were also significant, but were not significantly greater than their zero-order correlations.

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CHAPTER I

INTRODUCTION

In athletic competition, power and speed are deemed as important factors in most court and field games. Thus, information which contributes to the knowledge of the factors which affect power and speed, may also determine the extent to which a performer may gain an advantage over the opponent.

A number of investigators have studied the relationships between maximal strength and speed; however their conclusions are rarely in agreement (e.g., Clarke, 1960; Henry, 1960; Lotter, 1963; Nelson & Fahrney, 1963). While the speed-strength relationship may not be clearly evident, when it is evaluated in its mathematical form the relationship is apparent.

Power is defined as the ability to do work against time (i.e., Power = force x distance / time). Thus, when distance is held constant, power may be increased by: increasing the force, or decreasing the time, or a combination of both. Strength is defined as the maximum ability to apply force or resist it (Wilmore, 1982). Therefore, if speed is held constant (i.e., Speed = distance / time), an increase in strength must also result in an increase in power. Thus, it may be concluded that strength is related to power (DeVries, 1980), and any modifications in strength should likewise affect power.

This conclusion is not overwhelmingly supported by the results of earlier investigations (e.g., Clarke & Henry, 1961; Henry, 1960; Henry & Whitley, 1960). Previous investigations have examined the speed-strength relationship using isolated speed skills such as a straight leg kick (Henry, Lotter, & Smith, 1962), adductive arm swing (Clarke, 1960; Henry & Whitley, 1960), vertical jump (Tweit, Gollnick, & Hearn, 1963) and the rotary arm crank (Lotter, 1961). These investigations have used isometric measures as the index of maximal strength. The correlations have generally been low or non-significant, thereby suggesting that speed and strength are independent of each other. In comparison, low yet significant correlations have been reported between isotonic measures of strength and speed of an isolated limb (Clarke & Henry, 1961; Masley, Hairabedian, & Donaldson, 1953).

The inconsistencies in results may be accounted for in part by variations in strength inducing modalities (Clarke & Henry, 1961; Masley, Hairabedian, & Donaldson, 1953), as well as differences in procedures used to measure strength and speed (Clarke, 1960; Nelson & Fahrney, 1963). In reference to strength, only a limited number of investigations have attempted to study the relationship between isotonic strength and speed. Moreover, the investigations which have examined the relationships between strength (i.e., isotonic or isometric) and speed have almost exclusively concerned themselves with male subjects (Clarke, 1960; Henry & Whitley, 1960; Whitley & Smith, 1963). Consequently, the conclusions derived from these studies may only be inferred to their respective population.

The relationships between body weight, body composition and speed have not been extensively researched. Jackson and Van Duser (1984) found that the speed-strength relationship is increased when body weight and fat weight are statistically controlled in male subjects. Thus, by controlling and maintaining an optimum level of fat weight, the speed-strength interaction can be maximized. In regard to the opposite sex, the implications are more profound because of the proportionately high percentage of fat weight; however, adequate research is lacking.

In light of the lack of agreement concerning the speed and strength relationship, as well as an overall lack of research dealing with the female population, this study was proposed.

Purpose of the Study

The purpose of the investigation was to determine the interrelationships between maximal isotonic strength, relative power, speed, body weight and body composition in college aged women.

Hypotheses

To satisfy the purposes of this study, the following hypotheses were formulated.

1. There is a significant relationship between running speed, strength and power.

2. The relationships between strength-power, strength-speed and speed-power increase when the effects of body weight and body composition are held constant.

Definition of Terms

The following terms were referrred to in the investigation.

Absolute Isotonic Strength is the strength required to move an external object, whereby resistance is constant; yet the muscle does not contract at its capacity, or constant percentage of its capacity throughout the entire range of motion (Wilmore, 1982).

Fixed Resistance is resistance which is constant throughout a specific exercise and in which the muscle force varies in relation to the joint angle (Wilmore, 1982).

One Repetition Maximum (1 RM) is the amount of weight with which only one lift is possible using maximal muscular force (Berger, 1982).

Relative Power is the strength or force in moving body weight quickly and explosively (Berger, 1982).

Strength/Mass Ratio is a ratio of the weight of effective arm mass as measured in a supine position, to isometric strength of the limb (Henry & Whitley, 1960).

Whole Body Movement in the present study will be defined as a motor skill which involves the use of two or more limbs which are used to project or propel the body.

Limitations of the Study

The following factors were considered limitations of the investigation and were weighed when deriving conclusions from the results.

1. The present investigation utilized volunteers from physical education classes. Consequently, the sample may not be representative of the general population.

2. The investigator used a hand held stop watch to measure speed. Test-retest measures (Jackson & Van Duser, 1984) have produced reliability values of $r = .91$. In any event, speed values may be affected by experimental measurement error.

3. The strength assessing device which was used in the investigation, measures strength in 5 pound increments. Test-retest measures (Jackson, Watkins, & Patton, 1980) have produced reliability values of $r = .82$ to $.99$. In spite of the high reliability values, the true maximal

strength values may be distorted as a product of tool accuracy.

4. In the present investigation, the vertical jump was used to assess power. A 36 inch ruler was used to measure jumping height. Test-retest measures (Johnson & Nelson, 1979) have produced reliability values of r = .97. However, due to the limited accuracy of the measuring device, the power values may fail to truly represent the subject's jumping power.

Delimitation of the Study

The present investigation dealt exclusively with females. Therefore, the results were confined exclusively to this sex.

CHAPTER II

REVIEW OF THE LITERATURE

Some of the Relationships Between Isometric Strength and Speed

Recent investigations concerning the speed-strength interaction have indicated mixed results (Henry, 1960; Henry & Whitley, 1960; Rasch, 1954; Wilkin, 1962). Zorbas and Karpovich (1951) found that weight training improved speed of movement, while Pierson and Rasch (1962) found both factors to be independent of each other. Such discrepancies in results may be attributed to variations in experimental methodologies.

The majority of the speed-strength investigations have dealt with measures of static strength (Clarke, 1960; Henry, 1960; Pierson & Rasch, 1963; Whitley & Smith, 1963) and were correlated with isolated limb movements. The results have generally been low (Clarke & Henry, 1961; Henry, 1960; Pierson & Rasch, 1963; Smith, 1961) with the highest correlation being $r = .79$ (Nelson & Fahrney, 1965), which was found to be significantly different from zero.

Numerous speed-strength investigations have concerned themselves with horizontal arm adduction measures of speed (Clarke, 1960; Clarke & Henry, 1961; Henry, 1960; Henry & Whitley, 1960; Smith, 1961; Whitley & Smith, 1963). These studies have indicated non-significant correlations between speed and isometric strength, as well as speed and the isometric strength/mass ratio. Moreover, the results support the concept of the independence of strength and speed.

The failure to find a significant relationship between isometric strength and horizontal arm adduction speed, prompted Nelson and Fahrney (1965) to investigate the speed-strength relationship of elbow flexion. Elbow strength was measured isometrically at a 135° angle, and speed was defined as the time required to flex the elbow. A sample of college aged males (N = 73) was divided into three groups. Based on their data, the investigators obtained significant ($p < .001$) coefficients of .73, .79, and .75 respectively.

In a similar study, Chui (1964) investigated the effects of isometric and dynamic exercises upon strength and various speed movement tasks. While not specifically concerned with speed of elbow flexion, he concluded that gains in strength exerted in performing a movement are accompanied by gains in the speed of execution of the same movement measured against no resistance. He also found that gains in speed of movement measured against no resistance made by use of the isometric contraction method, are not significantly greater ($P = .05$) than gains made by the dynamic contraction method.

In short, much of the literature has dealt with comparisons of the strength/mass ratio, isometric strength and speed of horizontal arm adduction. These studies have resulted in non-significant correlations. However, the studies by Nelson and Fahrney (1965) and that of Chui (1964) found significant relationships between isometric strength and speed. It is evident that the procedures used in the latter experiments differed from earlier studies in that the strength and speed movement tasks utilized skills other than the horizontal adductive arm swing.

Studies of the Specificity and Generality of Speed

Lotter (1961) pioneered the earlier studies dealing with specificity and generality. He argued that motor abilities including speed are specific to individual movements and tasks. Based on a sample of 80 college aged males, he concluded that there is a significant relationship ($r = .39$) between total upper limb and total lower limb speed abilities. The investigation also revealed that there is approximately 85% specificity and 15% generality of individual differences in speed ability.

In a similar study, Clarke (1960) examined the relationship between the strength/mass ratio and arm movement speed in 48 male college aged students. He concluded that a high degree of specificity is exhibited in movements requiring the exertion of muscular force in a coordinated manner.

Smith (1961) expounded upon the concept of specificity. He investigated the maximal speeds of the arm swing in the horizontal plane and stiff leg kicks in the vertical plane. It was concluded that individual differences in maximal speed of limb movement are highly specific to the limb and to the direction of movement (i.e., forward or backward). Moreover, speed of limb movement ability as an entity for characterizing the individual does not exist to any large extent. He adds that individual differences in the speed of a limb movement are almost completely unrelated to the static strength of the limb or its strength/mass ratio.

In a follow up study, Whitley and Smith (1963) investigated the relationship between static strength and strength in action (i.e., speed) under several conditions of artificially increased limb mass. It was reasoned that if a limb was artifically loaded by a heavy mass, the muscle action would tend to be somewhat like the static situation. The results support this view $r = .73$ compared with .37 for the control condition where the limb was lightly loaded and moved more than twice as fast. In terms of specificity of speed, the results support the notion that various speeds of movement against varying loads require different neuromotor coordination patterns. The implications of the findings are: (1) static strength is not a good predictor of strength in action (i.e., speed). This may be due to the fact that both factors may involve separate and distinct neural coordination patterns (DeVries, 1980). (2) It has been shown that when the muscle action approximates the strength situation (i.e., isometric strength), a moderate to high significant relationship is found. Given this, logic dictates that high correlations may be demonstrated when speed is correlated with isotonic strength which approximates the muscle action.

In summary, the investigations suggest that speed of movement is highly specific to the limb and to the direction of movement. Thus, conclusions derived from isolated measures of limb speed may not be inferred to other limbs or other motor tasks. Finally, in spite of the fact that speed was determined to be minimally related to static strength, it is logical to conclude that since muscle action is the only volitional method for achieving body movement, the strength of the muscles must have some relationship to the force which accelerates the limbs of the body (Eckert, 1964). Consequently, subsequent investigations sought to examine the relationship between isotonic strength and speed.

Studies of the Relationship Between Isotonic Strength and Speed

With respect to specificity of speed, Lotter (1962) determined that there is a small generality component in speed ability. Given this, Clarke and Henry (1961) examined the possibility that speed of movement might be increased by strengthening the muscles which cause the movement. The investigators used 62 college aged males, of which half underwent a 10 week progressive resistance exercise regimen as advocated by De Lorme. The results indicated that weight training exercises cause an increase in the mean arm strength in the test position, as well as an increase in the mean speed ($r = .405$) of the test movement.

In a similar study, Masley, Hairabedian and Donaldson (1953) examined the effects of weight training exercises upon strength, speed and coordination. The sample ($N = 69$) was comprised of three groups: volleyball players, weightlifters and a control lecture group. Following a 6 week training period, it was concluded that a larger increase in speed and coordination resulted from weight training, as opposed to volleyball or activity of the like.

The work by Smith and Whitley (1965) support the results of Masley, Hairabedian and Donaldson. Moreover, they found that by incorporating isotonic and isometric exercises, the subjects displayed a 6% increase in speed over an 8 week period. Similar results are supportive of these investigations (Smith, 1964; Wilkin, 1952; Zorbas & Karpovick, 1951).

In short, the investigations concerning isotonic strength and speed have indicated that a low positive relationship exists when speed is measured in an isolated limb. However, as cited earlier (Smith, 1961), speed is specific to the limb and the direction of movement. Thus, the isotonic speed-strength interaction may not be inferred to complex movement patterns. This dilemma prompted investigators to study the relationship between strength and human performance.

Studies of the Relationship Between Isotonic Strength and Running Speed

The area of strength and running speed has not been exhaustively investigated. Henry and Trafton (1951) found that strength is an important determiner of speed of movement in the sprint run. In a similar study, O'Shea (1969) used 30 students to study the effects of varied short term weight training programs on the 400 meter run. He found that any method of short term progressive weight training which involves large muscle groups, is effective in improving performances of the 400 meter run.

While not specifically concerned with running speed, Clarke and Glines (1962) investigated the relationships of reaction time, movement time and completion time to strength and certain motor performance tasks. Based on a sample of 13 year old boys, they determined that total body and arm movement times for short distances are more of a general trait. Moreover, these movement times have a fairly high association with measures of gross strength, speed, agility and power. The highest multiple correlation obtained was r = .76. The value was derived between body completion time as the criterion, and compared to the shuttle run and standing broad jump as the experimental variables.

In summary, while evidence concerning the interrelationships of isotonic strength and running speed is lacking, the current literature shows that a positive relationship does exist. However, the degree to which running speed may be amended as a product of strength training, has yet to be determined. In any event, Clarke and Glines (1962) have demonstrated that the strength-running speed relationship described in other investigations is equally applicable to young adolescent males.

Studies of the Relationship Between Anthropometric Measures and Speed

In regards to running speed, anthropometric factors as possible elements which might influence overall speed have been investigated. Pierson (1961) studied the relationships between height, lean body mass, body fat, reaction time and overall body speed of untrained subjects. Based on a sample of 21 subjects, he concluded that overall body speed as measured in a sprint start is not related to any of these factors (r = .03, .00, -.01 and .05 respectively).

In two separate but related studies, Coleman (1940) and Rarick (1937) used male subjects to examine the factors which affect athletic performance. In evaluating the relationship of strength, speed, height and dead weight (i.e., weight which does not facilitate strength) upon speed, they concluded that dead weight acts as an opposing force to speed of muscular contraction. These results bear great implications upon the female population. The literature overwhelmingly shows that women have a lower percentage of lean body tissue when compared to her male counterpart (Wilmore, 1982). Likewise, they also tend to have a high percentage of body fat. Logic dictates that if the physical law $F = 2\ md\ /\ t^2$ (DeVries, 1980) conforms to the speed-strength phenomena (i.e., F = force, m = mass, d = distance, t = time), then one must conclude that in human performance, an increase in mass (i.e., other than lean body tissue) must also increase force. As indicated earlier, Eckert (1979), Rarick (1937), and Coleman (1940) found this not to be the case.

In view of the above, Jackson and Van Duser (1984) investigated the interrelationships of running speed, strength, body weight and fat weight upon 43 college aged males. Partial r's were calculated in order to determine the effects of the anthropometric variables on the speed-strength relationship. The partial r's between the bench press and the 20 and 30 yard dashes were -.25 and -.48 when body weight was controlled. The partial r's between the leg press and the dashes were -.36 and -.44 while body weight was held constant ($p < .05$). It was concluded that the speed-strength relationship is increased when body weight, particularly fat weight, is controlled and manipulated.

In regards to female athletic performance, it is realistic to surmise that women stand more to gain in terms of strength and whole body speed. This is based on the premise that of the factors governing speed, strength and lean body mass are proportionately more amendable as compared to the male counterpart. However, the literature to date has yet to support such a conclusion; this is mainly due to the fact that the mass of the literature has concerned itself with males.

Of the studies which have used females in their investigations, Henry and Rogers (1960) concluded that for the college age group, reaction and movement times are slower in women by approximately 14 and 30% respectively. In another study, Henry (1960) concluded that while women have slower maximal speeds than men, when equated for differences in arm length (i.e., in respect to angular speed of movement), the differences are small and of questionable significance. Henry's results exemplify the fact that the information derived from the male population may not be inferred to the female population, as a result of differences in physiological parameters (e.g., strength, limb length, body composition).

In summary, the investigations reviewed in this chapter have demonstrated that isometric strength is a poor predictor of limb speed, whereas isotonic strength correlates moderately with limb speed. Similar results are found when isotonic strength is compared to running speed. In spite of the lack of agreement concerning the relationships between anthropometric factors and running speed, it is likely that a relationship does exist based on the theoretical formula for force. However, the mass of the literature has failed to deal with the female population. Moreover, the studies which have incorporated women in their investigations have failed to demonstrate unequivocally that interrelationships exist between isotonic strength, anthropometric measures, relative power and speed. Thus, a study which determines whether or not a relationship exists, as well as the degree of relationship would prove to be of both practical and theoretical importance.

CHAPTER III

METHODS AND PROCEDURES

Subjects and Test Administration

The experimental procedures were the same for all subjects. In order to insure reliability and validity, subjects were instructed of the proper techniques and procedures prior to testing.

Sixty college aged females ranging in ages from 18 to 25 participated as subjects. All subjects were volunteers from North Texas State University's physical education classes.

The battery of tests were administered in a counter-balanced fashion. They were administered on two separate days; the second set of tests were given within one week of the initial test.

Measurement of Strength

A Spartacus model Universal Gym with fixed resistance was used to measure isotonic strength. Strength was measured by obtaining a one repetition maximum value (1-RM) on the leg extension, leg curl and bench press stations. The sites chosen to measure strength were based on previous experimental work done by Clarke and Glines (1962), Jackson and Van Duser (1984) and O'Shea (1969).

The initial weight lifted in determining the 1-RM, was arrived at by having the subject estimate the maximum amount of weight they could lift. Following each attempt, the weight load was adjusted accordingly (i.e., raised or lowered) and a new weight load was attempted. Between lifts, a rest period of 2 minutes (Berger, 1982) was awarded in order to insure reliability and minimize the effects of fatigue on the final strength value. Prior to each measurement, the subject was cued to initiate the lift, at which time they initiated the movement at will.

Leg Extension

The subject was instructed to sit on the leg extension machine and lean back slightly (i.e., not to exceed a 45° angle from vertical) with the hands grasping the sides of the bench behind the body. The subject was instructed to lift the weight by extending the legs forward and upward, keeping the buttocks on the bench till the legs were fully extended.

Leg Curl

The subject was instructed to lie in a prone position on the leg curl machine. The legs were positioned such that the heels were hooked underneath the roller pads with the kneecaps extended immediately beyond the edge of the bench. The subject was instructed to grasp the bench braces for additional support. The weight was curled and lifted till the lower legs demonstrated an angle at least perpendicular to the floor; the feet remained dorsiflexed throughout the motion.

Bench Press

The subject was instructed to lie in a supine position with the knees bent and feet resting flat on the bench. The subject was positioned such that the bench press handles bisected the middle of the chest thereby resting directly over the nipple line. A narrow grip (i.e., shoulder width) was used during the maximal lift.

Measurement of Power

The "Power Vertical Jump" protocol described by Johnson and Nelson (1979) was used to assess relative power. A 36 inch ruler, chalk dust and Acme Chair scale were used to obtain data for the test.

All subjects were dressed in shorts, a light shirt and tested without shoes. The subjects were instructed to assume a standing position facing laterally to the wall. The preferred arm was restricted by having it placed on the subject's back while grasping the waist band. The opposite arm was extended vertically overhead with the fingers extended and palm turned out facing the wall.

An initial measurement was recorded with the subject standing as tall as possible on the toes. The distance between the floor and the height of the extended middle finger of the raised arm was recorded. Chalk dust was placed on the middle finger and the subject assumed a squatting position while maintaining the head and back erect; the body was balanced. The subject was instructed to jump as high as possible and touch the ruler at the top of the jump. All jumps were initiated by the subject pending their state of readiness.

The best of three attempts were recorded. A 2 minute rest period was awarded between trials. The distance between the height of the chalk mark and the floor was measured and recorded. Power was calculated using the following formula for the highest jump (Johnson & Nelson, 1980).

$$\frac{(\text{Jumping ht - reaching ht}) \times \text{body wt}}{12}\ \text{lbs.} = \underline{\quad\quad}\ \text{ft lbs}$$

Any jumps which were initiated while the subject was off balance or mal-positioned were repeated.

Anthropometric Measures

Two anthropometric measurements were recorded, body weight and percent body fat. Body weight was measured on the Acme Chair scale. All subjects were dressed as described in the power test. Measurements were recorded to the nearest hundredth of a pound.

A skinfold test was used to estimate percent body fat. The Harpenden calipers were used to assess body composition as described in the protocol derived by Jackson, Pollock and

Ward (1980). All measurements were made on the right side of the body. Each site was measured three times; the average of the three measurements was recorded. The following sites were assessed while the subject remained in the standing position and the limb was held in a relaxed state.

Tricep

A vertical skinfold on the posterior surface of the arm, halfway between the acromion and oleocranon processes was measured. The subject was instructed to allow the arm to hang beside the body while keeping it relaxed.

Suprailiac

A vertical skinfold over the iliac crest within the mid-axillary line was measured and recorded.

Thigh

A vertical skinfold on the anterior midline of the thigh, halfway beween the inguinal ligament and top of the patella was measured and recorded. Prior to the measurement, the subject was instructed to shift the body weight onto the opposite leg while resting the non-weight bearing leg.

Pilot study. In an effort to determine the objectivity and reliability of the experimenter's testing procedures, a pilot study was conducted. The subject's (N = 13) body fat was assessed as described above. A correlation of .98 was established between the experimenter's measured values and an experienced laboratory technician's values. The correlational value was deemed sufficiently high to assure reliability.

Measurement of Running Speed

The speed test was administered on an outdoor cinder track. The test consisted of a 40 yard dash. All subjects were briefed on the procedures of this test. Emphasis was placed on accelerating through the finish line.

The subject began from a standing position. The command was, "Take your mark," the whistle sounded. The time elapsed from the starting signal to the crossing of the finish line was measured and recorded using a digital readout stop watch. All measures were recorded to the nearest hundredth of a second.

Statistical Computations

All test data were intercorrelated using zero order and/or partial (i.e., first-order) correlations. The concept of partial correlation holds that the correlation of two variables may be calculated while holding a third variable constant (i.e., partialed out). The present investigation calculated a series of partial correlations in order to determine the effects of the anthropometric variables on the speed-strength relationship. The following first-order correlations were calculated: (1) the partial r's between strength and speed as well as strength and power while controlling for fat weight, (2) the partial r's between strength and speed as well as strength and power while controlling for body weight, and (3) the partial r's between strength and speed as well as strength and power while controlling for lean weight.

A complete set of descriptive statistics were performed on the test data. Alpha was set at .01 in order to test for significance.

CHAPTER IV

RESULTS

The purpose of this chapter is to present and describe the results obtained from this study. In doing so, the analysis of the data will be used in determining whether to accept or reject the hypotheses presented in Chapter I. The research hypotheses were restated as null hypotheses for statistical treatment. A significance level of 0.01 was required for rejection of the null hypothesis for all computations. A set of descriptive statistics were calculated for all measured variables. These results are provided first, followed by the correlational results.

Descriptive Statistics

The mean ($\overline{X}$), standard deviation (S.D.) and standard error (S.E.) were calculated for all measured variables and are presented in Table I. It is important to note that three additional variables were created from the pre-existing variables. They are (1) total leg strength, (2) ratio and (3) total strength. This was done in order to determine if these variables would produce significantly higher prediction coefficients than the pre-existing variables. These variables were derived from the maximal strength values and were calculated based on the following formulas:

TABLE I

SUMMARY OF DESCRIPTIVE STATISTICS FOR
ALL VARIABLES MEASURED

Variable	$\overline{X}$	S.E.	S.D.
Age	21.1 yrs	.26	2.00
Height	64.2 in	.34	2.62
Weight	127.8 lbs	2.06	15.94
% Fat	23.6	.62	4.83
Fat Weight	30.7 lbs	1.21	9.38
Lean Weight	97.1 lbs	1.11	8.59
Leg Extension	99.7 lbs	3.04	23.51
Leg Curl	44.3 lbs	1.51	11.70
Total Leg	144.1 lbs	4.24	32.86
Ratio	2.3	.07	.54
Bench Press	79.6 lbs	1.93	14.95
Total Strength	223.7 lbs	5.58	43.22
Forty 1	6.6 sec	.07	.53
Forty 2	6.6 sec	.06	.51
Speed*	6.6 sec	.07	.51
Power	91.8 ft-lbs	2.52	19.49

*Speed = (Forty 1 + Forty 2) ÷ 2

Total leg = leg extension + leg curl

Ratio = leg extension ÷ leg curl

Total strength = leg extension + leg curl + bench press

Brief analysis of the means for age, height, percent fat and body weight variables, shows that the values are in agreement with past research measurements and therefore are representative of the average college aged female (McArdle, Katch, & Katch, 1981; Smith, 1984; William, 1983).

Pearson's r and Coefficient of Determination for Power and Speed When Correlated with Strength Variables

Pearson's r for strength measures when correlated with power and speed were calculated and are presented in Table II. These values were squared to produce the coefficient of determination and are present in the same table.

Careful examination of the correlations show that all the variables were significantly related ($p < .01$) to power and speed, excluding the ratio-power and ratio-speed correlations. Moreover, the inverse relationships between the strength measures and speed are in agreement with previous studies (Chui, 1964; Masley, Harabedian, & Donaldson, 1953; Zorbas & Karpovich, 1951), however it must be noted that these studies dealt exclusively with all-male populations.

TABLE II

SUMMARY OF PEARSON'S (ZERO ORDER) CORRELATIONS AND COEFFICIENT OF DETERMINATION FOR POWER AND SPEED WHEN CORRELATED WITH STRENGTH MEASURES

Variable	Power		Speed	
	r	r^2	r	r^2
Leg Extension	.44*	.19	-.37*	.14
Leg Curl	.35*	.12	-.45*	.20
Total Leg	.44*	.19	-.43*	.18
Ratio	.02	.0004	.22	.05
Bench Press	.53*	.28	-.56*	.31
Total Strength	.52*	.27	-.52*	.27
Speed	-.45*	.20	-	-

* = non-significant ($p < .01$)

Partial Correlations for Power and Speed While Controlling for Body Weight

In order to determine the effects of anthropometric variables upon the speed-strength and power-strength relationships, partial r's were calculated while controlling for body weight. A summary of these partial r's are presented in Table III.

Analysis of the data reveals that all the strength variables--excluding ratio, are significantly related ($p < .01$) to power and speed. These findings are consistent with past research (Capen, 1950). The inverse relationships

TABLE III

SUMMARY OF PARTIAL CORRELATIONS AND COEFFICIENT OF DETERMINATION FOR POWER AND SPEED WHILE CONTROLLING FOR BODY WEIGHT

Variable	Power		Speed	
	r	r^2	r	r^2
Leg Extension	.46*	.21	-.47*	.22
Leg Curl	.34*	.12	-.52*	.27
Total Leg	.46*	.21	-.53*	.28
Ratio	.02	.0004	.22	.05
Bench Press	.53*	.28	-.56*	.31
Total Strength	.53*	.28	-.59*	.35
Speed	-.46*	.21	-	-

* = non-significant ($p < .01$)

demonstrated between strength and speed support the conclusions of previous investigators (Costill et al., 1967; Jackson & Van Duser, 1984). It is important to note that the effects of body weight upon the speed-strength relationships were numerically and systematically higher than the zero order r values, however the results were non-significant at the .01 level. It was concluded that the statistical power of the test could be increased if a larger sample size were used.

Partial Correlations for Power and Speed While Controlling for Fat Weight

A series of partial r's were calculated in order to determine the speed-strength and power-strength relationships while controlling for fat weight. A summary of the partial r's along with the coefficients of determination are presented in Table IV.

TABLE IV

SUMMARY OF PARTIAL CORRELATIONS AND COEFFICIENT OF DETERMINATION FOR POWER AND SPEED WHILE CONTROLLING FOR FAT WEIGHT

Variable	Power		Speed	
	r	r^2	r	r^2
Leg Extension	.48*	.23	-.50*	.25
Leg Curl	.36*	.13	-.52*	.27
Total Leg	.47*	.22	-.55*	.30
Ratio	.12	.01	.20	.04
Bench Press	.53*	.28	-.56*	.31
Total Strength	.54*	.29	-.60*	.36
Speed	-.46*	.21		

* = non-significant ($p < .01$)

With the exception of the ratio-power and ratio-speed values, all other partial correlations were found to be significant at the .01 level. In comparing the zero order r values for speed and strength with that of the partial r values with fat weight held constant, it was found that the speed values were once again systematically higher when fat weight was held constant. This is consistent with the findings of Jackson and Van Duser (1984), however in this case the differences were not found to be statistically significant.

Summary of Findings

A set of descriptive statistics were performed on 16 variables. Zero order correlations were performed between power and strength as well as speed and strength. Partial r's were calculated using the same variables with fat weight and body weight held constant. The results can be summarized briefly in the following manner.

1. The sample of female subjects are representative of the average college aged female. This was substantiated using the age, height, body weight and percent fat values.

2. The zero order correlations between power and strength as well as speed and strength were found to be consistent with previous investigations.

3. The partial r's for the power-strength and power-speed relationships while holding fat weight and body weight constant, were systematically higher than the zero order correlations, however these values were found to be non-significant at the .01 level. Additional calculations

showed that it would have taken three times as many subjects to obtain an increase in the statistical power of the test.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Studies concerning the degree of influence of anthropometric variables and strength upon power and speed have produced inconsistencies in results among investigators. These inconsistencies can be partially accounted for as a product of differences in modes for measuring strength (Clarke, 1960; Smith & Whitley, 1965), speed (Clarke, 1960; Lotter, 1961) and power (Capen, 1950; Eckert, 1964).

It was the purpose of this study to determine the interrelationships between maximal isotonic strength, relative power, speed, body weight and body composition in college aged women. In addition, body weight and body composition were statistically controlled (i.e., partailed) in order to determine its effects upon the three performance measures.

Sixty college aged females, ranging in ages between 18 to 25, were measured on the parameters as stated above. The tests were administered in a counterbalanced fashion. The tests were divided such that the second set of tests were administered within one week of the initial test.

All students were volunteers from physical education classes.

A set of descriptive and correlational statistics were calculated for all variables. The mean values for age, height, percent fat, power and body weight were found to be in agreement with previous investigations (Johnson & Nelson, 1979; McArdle, Katch, & Katch, 1981; Smith, 1984).

Three separate sub-tests comprised the strength test; they were the leg extension, leg curl and bench press. In each instance, the mean values were in agreement with past research (Baumgartner & Jackson, 1982; Gibson, 1983). Two leg strength values were used to comprise the variable ratio. The value was derived by dividing the 1-RM leg extension value by the 1-RM leg curl value. The mean ratio value for the sample was 2.32 which was consistent with the ratio 2.27 obtained by Goslin and Chartens (1984). It must be noted that these investigators measured the ratio value isokinetically, whereas the values in the study were determined through isotonic measures.

The majority of running speed studies which have used the 40 yard dash as the index for speed, have dealt exclusively with male football players; thus direct comparison cannot be made. Moreover, only high school age grouped norms (i.e., ages 14 to 17) exist for females for the 50 yard dash (Kirkendall, Gruber, & Johnson, 1980). Nevertheless, if average speed is calculated (i.e., average speed =

total distance ÷ total time), the mean values for 17 year old females and college aged females, 6.32 and 6.06, respectively, are deemed comparable with each other. Finally, based on the data presented in Table I and the investigations cited, it may be concluded that this sample is representative of the average college aged female.

Two hypotheses were tested in an effort to determine the degree of relationship between variables. The hypotheses for the study were as follows.

<u>Hypothesis 1</u>

It was hypothesized that there are statistically significant relationships between strength, running speed and power. Table II summarizes the findings relative to Hypothesis 1.

The correlations for strength and power range from .35 to .53. With the exception of the ratio-power value ($r = .02$), all strength-power correlations were found to be significant at the .01 level. Several investigators (Costill et al., 1968; McClements, 1966) have found dynamic strength to be significantly related to leg power, with the highest correlational value being .71 (Berger & Henderson, 1965); however males were used in the sample population. Harris (1937) used female junior high subjects and found a correlation of .215 between leg strength and the

Sargent vertical jump. Her findings are comparable with the findings of this investigation (r = .44).

The correlational values for strength and speed obtained in this study range from -.37 to -.56. All correlations were found to be statistically significant, except the ratio-speed value r = .22. These findings are in agreement with previous investigations (Masley, Harabedian, & Donaldson, 1953; Wilkin, 1952; Zorbas & Karpovich, 1951).

Speed was defined as the average of two 40 yard dash times. This value was correlated with power and a value of r = -.45 was derived from the sample. This correlation is in agreement with the value derived by McArdle, Katch, and Katch (1981) r = -.48, and is consistent with other investigations (Carpenter, 1938a; Cureton, 1939).

In summary, all zero order correlations concerning strength, speed and power were found to be statistically significant--except when correlated with ratio. Since there is an overall lack of literature concerning the ratio-speed and ratio-power interaction, no comparisons were made to previous investigations. In light of the above, the null hypothesis was rejected and Hypothesis 1 was accepted.

Hypothesis 2

It was hypothesized that the interrelationships between strength-power, strength-speed and speed-power increase when the effects of body weight and body composition are held constant. Tables III and IV summarize the findings relative to Hypothesis 2.

In examining the strength and power correlations with body weight held constant, it may be noted that the values range from .34 to .53. With the exception of the ratio-power value, all correlational values were found to be statistically significant at the .01 level. The majority of partial correlations examined in this investigation had not been studied before. However, one investigator (Carpenter, 1938), while using slightly different tests, found a partial r value of .37 when controlling for body weight. Strength was defined as the sum of scores for the Physical Fitness Index (PFI). The PFI is a measure of relative strength and endurance (i.e., push-ups, chin-ups, leg lifts). In any event, her findings are consistent with the values obtained in this investigation.

The strength and speed relationship with body weight held constant has been examined by previous investigators (Carpenter, 1938; Jackson & Van Duser, 1984). The partial correlational values in this study for strength and speed ranged from -.47 to -.59. These values are comparable with the findings of Jackson and Van Duser (1984), $r = -.48$.

Finally, the speed-power relationship with body weight held constant ($r = -.46$) was found to be significant ($p < .01$). However, because of the lack of research concerning the relationships between these variables, comparisons could not be made.

The results of the strength-speed, strength-power and speed-power partial correlations, when controlling for body weight, were all found to be statistically significant excluding the ratio partial r values. Moreover, when the first order values with body weight held constant were compared with the corresponding zero order values, the speed and power values were found to be numerically and systematically higher; however the differences were not significant.

In Hypothesis 2, it was stated that the interrelationships between strength-power, strength-speed and speed-power increase when body weight and body composition are held constant. The results relative to the body composition and the performance variables are presented in Table IV.

In comparing the strength-power relationship with fat weight held constant, it was discovered that most of the investigations were comprised of male subjects and the effects of fat weight were rarely statistically controlled (i.e., first order), thus direct comparisons could not be made. However, the positive correlations obtained in the study, r = .12 to .54, are consistent with the zero order values of Carpenter (1938) r = .21 and other investigators (Berger & Henderson, 1965; McClements, 1964).

The correlational data for the strength-speed relationship while controlling for fat weight ranged from r = -.50

to -.60, which is comparable with the findings of Jackson and Van Duser (1984) r = -.36 to -.44. Speed and power were found to be inversely related (r = -.46) which is consistent with the findings of McArdle, Katch and Katch (1981) and Cureton (1939).

All partial correlations with body fat held constant were found to be statistically significant ($p < .01$) excluding the ratio values. It was found that when the partial r values were compared with the respective zero order data, a systematic and numeric increase in the magnitude of the relationship emerged, however the differences were not significant.

In summary, controlling for body weight and fat weight does not significantly increase the relationship between strength, speed and power. However, a numeric and systematic increase did occur between the performance measures when the anthropometric variables were held constant, however the results were not significant. It was determined that the relationship would probably have been meaningful if the sample size were increased three-fold. Finally, a subsample of 30 randomly selected subjects was used to perform a cross validation, and comparable values were obtained. In light of the findings cited, the null hypothesis was accepted and Hypothesis 2 was rejected.

Conclusions

Within the parameters of this study, the following conclusions may be made.

1. There is a moderate positive relationship between strength and power.

2. There is a moderate inverse relationship between strength and speed.

3. There is a moderate positive relationship between power and speed.

4. The interrelationship of strength-power, strength-speed and speed-power are not increased significantly when body weight and fat are statistically held constant.

5. The correlational values obtained for females are similar to the values obtained for males by previous investigators.

Recommendations

The following recommendations are made based on the results of the data.

1. A three-fold increase in sample size is recommended in order to increase the statistical power of the test.

2. A more valid and accurate power test, preferably the Margaria-Kalaman, is recommended in order to increase accuracy.

APPENDIX A

INFORMED CONSENT

The purpose of this investigation is to study the interrelationships of strength, speed, power, body fat and body weight. As a subject you will be asked to demonstrate: (1) maximal leg and arm strength on the Universal Gym Spartacus machine, (2) maximal running speed in a 40 yard dash, (3) maximal jumping power in the vertical jump and (4) allow for the measurement of body weight and body fat by way of a scale and skinfold calipers respectively.

Risks

In performing the tests, you may experience temporary physical discomfort which may include: localized muscular soreness, fatigue and in rare instances--muscular strains or pulls. Every effort will be made to minimize the risk of injury and insure your safety. You may withdraw from the study at any point without fear of offending the parties involved and/or affecting the outcome of the investigation.

Benefits

By participating in the study, you will gain valuable information which may be used to comprise part of your overall motor fitness profile. Furthermore, you will be given information explaining how you may modify or maintain your present level of fitness.

The information obtained will be treated as privileged and confidential and will not be released without your express written consent, however it may be used for statistical or scientific purposes with your right of privacy retained.

I hereby consent to voluntary engage in tests which measure these parameters. I have read and understand the information above. Furthermore, any questions concerning the study and my role as a subject have been answered to my satisfaction.

SIGNED ______________________ DATE SIGNED ____________________
(subject)

WITNESS ______________________

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