A FACTOR ANALYSIS OF TWELVE SELECTED RESISTANCE EXERCISES ON THE UNIVERSAL GYM

THESIS

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This study was to clarify strength factors using 12 selected exercises on the Universal Gym, and to determine what measures present a valid method of assessing strength of college-aged males. Eighty-eight males enrolled in beginning weight-training classes used the Universal Gym for twelve weeks. Subjects were tested for maximum strength on 12 exercises. Alpha and canonical factor analyses were performed on raw scores of all measures, and on scores when body weight and standing height variances were removed. A three-factor structure of upper extremity, lower extremity, and trunk strength was revealed when weight, and weight and height combined were statistically controlled. Results showed that residualized scores of weight can be used to evaluate strength on the Universal Gym.

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Introduction

Strength, one of several fitness components possessed by all people to a certain degree, is necessary for everyday living as well as for maximum performance in athletics. Without adequate strength, the average individual could not perform daily routine tasks such as walking, housework, or a job, without becoming tired or fatigued. Athletes require not only strength for everyday living, but a high strength level, so that they may give their best performance in their sport.

To develop strength, there exist various apparatus, including the conventional free weights and barbells which have been used for many years, and the newer Universal Gym. Due to the time and hazard involved, the free weights and barbells are neither economical nor safe to use in a large group such as in an instructional setting. The Universal Gym, however, is a popular device used by many institutions to develop strength.

The Universal Gym equipment has been in existence for approximately eighteen years. It has been recognized by educational and other foundations as both an economical and effective device for the development of strength. This is evidenced by an average of eight million dollar sales per year by the manufacturer of Universal Gym equipment in Irvine, California. However, its high degree of popularity has not been matched by an equivalent degree of study by researchers.

Numerous studies have been performed on strength development (Berger, 1962A; Berger, 1964; Berger, 1963; Berger, 1962B), but little has been done strictly analyzing the exercises performed on the Universal Gym. No research has been conducted, for example, to determine if each exercise station on the Universal Gym is actually measuring or developing strength that is distinctly different from other related exercise stations. Moreover, there is no evidence in the literature of attempts to develop evaluation strategies for student populations with respect to muscular strength assessments.

The purpose of this study was to clarify the factor structure that exists among the exercises on the Universal Gymnasium. This was accomplished by answering the following research questions:

(1) What underlying structure of strength performances exist using twelve exercises on the Universal Gym?

(2) How are anthropometric measures of height and weight related to the structure, and to what degree?

(3) What strength measures taken on the Universal Gym present the most valid method of assessing an individual's strength level?

Review of Literature

A thorough review of literature revealed a limited number of studies using factor analysis techniques. However, a great deal of strength-related literature was reviewed and served as a source of information concerning strength and its relationships to speed, power, motor performance, and other various factors. The review of literature is divided into the major areas of strength gains, strength and endurance, strength, power and motor performance, and factors related to strength.

Strength Gains

Studies have been numerous concerning different types of strength programs and their effects upon strength. Various studies have been performed utilizing isotonic, isokinetic, and isometric methods of training.

Progressive resistance exercise programs concerning isotonic training were made popular by the work done by

DeLorme and Watkins (1951). They used three sets of ten repetitions for a particular exercise, where the first set was performed with 50 per cent of the 10RM, the second set with 75 per cent of the 10RM and the third and final set with 100 per cent of the 10RM. Numerous studies have confirmed this mode of training as being effective in the development of strength (Barney and Bangerter, 1961; Berger, 1963; Berger, 1962; Berger and Hardage, 1967; O'Shea, 1966).

However, various investigations have suggested that heavier resistance and fewer repetitions will result in optimum strength gains (Berger, 1962; Berger, 1962; Berger and Hardage, 1967; O'Shea, 1966; Withers, 1970). Berger, who is known for his studies concerning strength gains, suggests that between four and eight repetitions should be used for the development of strength (Berger, 1962). In one study Berger trained 180 subjects using nine different weight training programs, including the bench press lift. The subjects trained three times a week for twelve weeks. After nine weeks of training, there was no significant difference between the group that performed three sets of six repetitions and the group that performed three sets of ten repetitions. However, at the end of twelve weeks there was a significant difference between the groups, favoring the three sets of six repetitions.

Capen (1956) performed a study looking at four various heavy resistance exercise programs upon college males, and concluded that three sets of one to three RMs were more effective in the development of strength than one set of eight to fifteen RMs; but there was no difference between the three exercise groups and the exercise group that performed three sets of five to six RMs.

Using the squat exercise, O'Shea (1966) found no significant difference between groups using three sets of ten RMs, three sets of five to six RMs, and three sets of two to three RMs, after six weeks of training. However, O'Shea suggested that the group using three sets of five to six RMs improved in strength more than the other two groups because they had a greater percentage of strength gain, although it was not significant.

Various investigators (Barney and Bangerter, 1961; Berger, 1964; O'Shea, 1966; Withers, 1970) have found no significant differences between strength gains in utilizing high-repetition, low-resistance exercises and low-repetition, high-resistance exercises. However, these studies seldom last more than nine weeks, and it was shown by Berger (1962) that significant differences in strength gains did not occur until after nine weeks of training. This suggests that studies conducted to look at optimum repetitions for the development of strength should last at least twelve weeks.

Hettinger and Mueller were the pioneers in the study of the effects of strength gains from isometric contractions. They found that an increase in strength could be brought on by a muscle contracting to approximately one-third of its maximum, but a maximum training effect occurred with a six-second isometric contraction performed at two-thirds maximum five days a week (deVries, 1974). They found that this brought above a five per cent increase in strength per week. More recent work (deVries, 1974) suggests that the rate of strength may be increased by performing maximum contractions, instead of two-thirds maximum contractions, for five to ten seconds.

Investigators have tried to compare isotonic methods to isometric methods for the development of strength (Berger, 1962; Berger, 1963; Chui, 1964). However, a problem arises when trying to compare the two: what method of strength test should be used, isotonic or isometric? Berger (1963), using a 1RM bench press as the criterion for strength, found that an isometric contraction held in two positions for six to eight seconds three times a week resulted in a more significant strength gain than that made by the dynamically trained group who performed two sets of two RMs three times a week. A third group performed three sets of six RMs three times a week and improved in strength significantly over the other two groups.

In another study by Berger (1962), one group of male students performed isometrically and another group performed isotonically, using the hyperextension exercise. He found strength gains in both groups only when the strength test was the same as the training procedures.

Chui (1964) found no significant differences in strength gains between isotonic and isometric groups when isometric measures were used for the criterion for strength. Rasch and Pierson (1963) had twenty-seven untrained subjects perform three sets of five RMs for the press, curl, supine bench press, and reverse curl. Significant gains in isotonic strength occurred, but no isometric strength gains were recorded.

Isokinetic exercise is a relatively new method of muscular training. It deals with the control of limb speed throughout the range of motion. This type of exercise provides a maximum resistance at every angle of motion, provided the subject is performing maximally (Hislop and Perrine, 1967).

Moffroid and co-workers (1969) divided twelve males and forty-eight females into three groups. Group I performed isometric contractions at two positions for the hamstring and quadricep muscle groups, Group II used DeLorme's technqiue of training, and Group III performed thirty maximum contractions daily, using an isokinetic device. Training lasted for four weeks, with all exercises being performed daily. It was found that the isokinetically trained group increased the work potential of a muscle faster than the isotonically or isometrically trained groups. Moffroid also found that the isokinetically trained group was stronger at every angle of motion than the other two groups.

Wilmore and Pipes (1975) compared the fast isokinetic contractions, and slow isokinetic contractions with isotonic contractions on thirty-six males. It was found that all three movements produced significant strength gains after eight weeks of training, but the fast isokinetic contractions produced the greatest gains.

Clarke (1974) reviewed studies pertaining to the development of strength, and formed the following conclusions:

1. Isotonic training should be used instead of isometric training.

2. For strength development, use heavy weights and lower repetitions.

3. Various resistance workloads during training provide significant strength gains.

4. Muscular strength can be gained by training twice weekly as well as three times weekly.

Strength and Muscular Endurance

It is a well known fact that a muscle contracts in accordance with the "All or None Law;" i.e., a muscle cell or fiber will contract maximally or not at all. It follows that when submaximal contractions take place, the fibers alternate work periods with rest periods (Kusinitz, 1969). It would seem logical that a stronger person would use fewer muscle fibers during a submaximum contraction than would a weaker person, because he would be working at a less intense workload, requiring fewer available muscle fibers to be activated. Thus, it would seem that the greater muscular strength one possesses, the greater his muscular endurance.

Investigations have been conducted to study the relationship between muscular strength and muscular endurance. Shaver (1971) looked at forty college males divided into two groups. Group I was an experimental group who performed low-repetition high-intensity weight training for six weeks. Group II was the control group. Maximum isometric strength of the forearm flexors was measured, along with relative muscular endurance using an arm lever ergometer. A significant relationship existed for the experimental group between maximum isometric strength and relative muscular endurance. However, there was no significant relationship found between relative muscular endurance gains and isometric strength gains.

Howell and co-workers (1962) looked at the effects of isometric and isotonic exercise programs upon muscular endurance. Groups who performed isometrically or isotonically improved significantly on the bicycle ergometer test. Neither group was found superior to the other. Capen (1950) compared a weight training class group with a conditioning class group after eleven weeks of training twice a week and found significant muscular endurance gains among both groups, but no significant differences were found between the groups. Other investigators report similar findings (Coleman, 1977; Hislop and Perrine, 1967; Masley, Hairabedian, and Donaldson, 1953; Shaver, 1971).

Two investigators looked at muscular endurance retention upon the completion of a muscular endurance program. Waldman and Stull (1969) had fifty-four college males train three days a week for eight weeks. They found a significant loss of muscular endurance after eight to twelve weeks of no activity. They also found a significant retention of muscular endurance after the eight- to twelve-week layoff. During the retraining phase, peak performance was achieved in approximately one quarter the number of training sessions required during the initial training term. Sysler and Stull (1970) found no appreciable loss of muscular endurance after one week of detraining. However, after three and five weeks, significant losses in endurance were observed within the group.

Strength, Power, and Motor Performance

Power is composed of two factors: (1) strength and (2) speed. Thus, if someone wants to increase his power, he can do it in three ways: (1) increase his speed, keeping strength constant; (2) increase his strength, keeping speed constant; or (3) increase both strength and speed (deVries, 1974).

Various investigators (Berger, 1963; Capen, 1950; Chui, 1964; Clarke, 1960; and Liba, 1967) have shown relationships between strength, power, and speed. Only one investigator found no increase in power with a resistance training program. Ball, Rich, and Wallis (1964) had an experimental group perform a ten-second maximum isometric contraction in the starting position of a vertical jump three times a week for six weeks. The experimental group improved significantly in strength but not in the vertical jump.

McClements (1966) and Berger (1963) have both found an increase in vertical jumping ability following a resistance training regime. Berger (1963) found that a group that performed squats improved on the vertical jump significantly over the statically trained group. McClements (1966) had eighty-six subjects train the leg flexors and extensors statically for twelve weeks. He found that the groups that trained only the leg extensors improved in the vertical jump equally with the groups that trained only the flexors, and the groups that trained both the flexors and extensors.

Masley and co-workers (1953) trained sixty-nine college males for six weeks. Group I weight-trained, Group II played volleyball, and Group III attended a lecture class. Speed of movement, strength, and coordination were measured. Group I improved significantly on all three of these over the other two groups. Other investigators (Chui,1964; Clarke, 1960; Whitley, 1961; and Zorbas, 1951) have found the same results following weight training programs. However, one investigator (Clarke, 1960) found no relationship between strength mass ratio and speed of arm movement.

Motor performance and strength were investigated by Berger (1967). In two studies, Berger found a significant relationship between strength and performance on the Barrow Motor Ability Test. He also found dynamic strength was more closely related to motor ability than static strength (1967). This was also confirmed by Larson (1940).

The majority of investigations show an increase in the performance of motor ability tests, speed of movement tests, and power tests, following resistance training regimes. However, most studies have failed to show a significant relationship between strength gains and gains in power (Ball, 1964; Berger, 1963; and McClements, 1966).

Factors Concerning Strength

Investigators have conducted various types of studies relating strength to such factors as motivation, physical fitness levels, academic achievement, and anthropometric measures.

Studies have shown that an increase in strength performance can be attained by the use of certain motivational techniques (Ikai and Steinhaus, 1961; Johnson and Nelson, 1967). Johnson and Nelson (1967) pre-tested and post-tested 120 college students. They were divided into four groups that isometrically trained for eight weeks. Group I trained without motivation, Group II trained with knowledge of their scores, Group III trained with knowledge of their scores plus an assigned goal, and Group IV trained as Group III, plus an added placebo that was supposed to give them quick energy and strength. All of the groups significantly increased in strength, but with no differences between the groups. After the post-test, all groups participated in an athletic contest measuring strength, as in the post-test. All groups improved significantly over their post-test scores during the athletic contest.

Ikai and Steinhaus (1961) looked at some factors modifying the strength of right forearm flexors. They found that a gunshot just before a strength measure, or a shout during the strength measure resulted in a greater strength score than when the shout or gunshot were absent. Post-hypnotic suggestion of strength resulted in a significant increase in strength over the group with no hypnosis. The ingestion of alcohol or adrenalin did not improve strength performance (Ikai and Steinhaus, 1961).

Berger (1967) measured fifty-three college students on a 1 repetition maximum performance for sit-ups, curls, bench press, bent-over row, upright row, squat, and standing press. The total of these he termed "dynamic strength." He correlated dynamic strength with the performance on the A.A.H.P.E.R. youth fitness test. He found a correlation of .564, which was significant at the .001 level of confidence. Other investigators (Berger, 1967; Campbell, 1962) have found similar results.

Studies have shown a positive relationship between academic letter grades and strength (Tinkle and Montoye, 1961; Vincent, 1967; Wessel and Nelson, 1961). Marilyn Vincent (1967) measured thirty-seven college females for grades, isometric strength, and efficiency. She found a significant positive relationship between grades and strength. Tinkle and Montoye (1961) found a significant positive relationship between grip strength of 635 college males and their grades in physical education. Wessel and Nelson (1961) found the same results with 200 women.

Studies comparing anthropometric measures and strength have been inconclusive. Clarke (1957) ran multiple correlations between strength measures and ten anthropometric measures. He found that trunk flexion strength and body weight correlated highest (.64). The second highest correlation was .58 between body weight and lateral flexion strength. Rasch and Pierson (1963) found no relationship between flexed upper arm girth, upper arm volume, and strength measures of the upper extremity.

Factor Analysis Studies

Studies measuring strength, using factor analysis, have demonstrated that three general factors occur (Fleishman, 1964; Nicks and Fleishman, 1962). These three factors have been termed "static strength", "dynamic strength", and "explosive strength" (Fleishman, 1964). More recent evidence shows that these general factors may include more specific factors (Fleishman, 1964; Jackson, 1971; Jackson and Frankiewicz, 1975; Liba, 1967). This means that some test items may load on a general factor, such as static strength, but also may load on a smaller, more specific factor, such as static strength of the arm.

Jackson and Frankiewicz (1975) tested fifty male college students on sixteen strength, work, and power tests. They hypothesized that as many as six factors would be found. Factor I was termed static-force-arms;

Factor II, static-force-legs; Factor III, explosive-power-arms; Factor IV, dynamic-work-arms; Factor V, explosive-work-legs; and Factor VI, explosive-power-legs. Factors I, II, III, and IV were confirmed using both the alpha and canonical solutions. These four factors were cited as robust factors. A general alpha factor of work tests of the arms and legs was factored into two factors by the canonical solution. One factor involved work tests of the arms and the second factor was specific to power and work tests for the legs. These findings are generally in accordance with another study by Jackson, except that he found separate robust factors for the arms and legs (1971).

Fleishman (1964), in his study looking at thirty strength and power tests, failed to confirm separate factors for the arms and legs. He did confirm three general factors which he termed static, dynamic, and explosive strength. Dynamic strength was best described as the ability to move the body or parts of the body through a range of motion repeatedly. He found that body weight affected this factor negatively. Thus, the heavier the person, the less likely that he would score well on this factor. A negative relationship between body weight and pull-ups was also found by Dowell and co-workers (1969). The static strength factor was limited to tests that required a maximum effort against a dynamometer or very heavy weight. In contrast to dynamic strength, body weight was positively related to this factor; thus the heavier person would have a better chance of doing well in this factor. The third factor, explosive strength, involved projecting an object or projecting oneself as far as possible. A fourth factor which also loaded on the dynamic strength factor was termed trunk strength. Abdominal exercises loaded on this factor.

Summary

Among the various studies of strength that have been done, some show results that conflict with those of others. Investigations of strength gains from various training regimes, and extending over longer periods of training, still need to be done.

For the majority of investigations, strength performances related positively to motor performance and power tests. This should affect a coach's outlook on involving his athletes in weight training. It was also seen that the old myth that weight training will slow an athlete down is just that--a myth.

The need for more factor analytic studies is justified. Various investigators have delineated between two and nine factors. However, the majority of studies result in the three general factors of static, dynamic, and explosive strength.

Theoretical Model

Jackson (1971) and Liba (1967) found that separate factors exist for upper and lower extremity strength. Fleishman (1964) found that trunk strength represents a separate factor from the strength domain. From these findings, three factors of upper extremity, lower extremity, and trunk strength were hypothesized. Table I lists these factors and the twelve exercises that make up the strength domain.

Jackson (1971) showed that arm extension and flexion and leg extension and flexion movements clustered into two separate factors. Thus, the hypothetical factors of upper extremity and lower extremity strength respectively include movement of the arms and legs.

Fleishman (1964) identified a trunk factor containing sit-ups and leg lifts. The hypothesized factor of trunk strength in this study includes sit-ups and leg lifts (bent knee-ups); however, it also contains a lateral flexion and hyperextension movement of the trunk. Fleishman found that hyperextension movement did not load on his trunk strength factor, suggesting that it could be labeled abdominal strength. However, Fleishman's measures were more of power and muscular endurance; thus, his trunk factor may not deal specifically with strength, but may be more related to trunk power or muscular endurance. In this study, all measures dealt with strength performances. (See Table I, pg 47.)

Selection of Subjects

The subjects were eighty-eight college male freshmen and sophomores enrolled in six weight training classes at North Texas State University during the Fall semester, 1978. The weight training classes selected for the study were all using the Universal Gym exercises for the development of strength, and all subjects had been trained for twelve weeks and developed stable one-repetition maximums (1RM). The mean weight and height of the subjects were 162.2 ± 25.02 pounds (73.5 ± 11.3 Kg) and 68.8 ± 2.77 inches (174.7 ± 7.03 cm), respectively. The weight of the subjects ranged from 113 pounds (51.2 Kg) to 280 pounds (127 Kg), and the height ranged from 60 inches (152.4 cm) to 75 inches (190.5 cm).

Testing Equipment

The equipment used in the study was a previously calibrated Spartacus Model Universal Gym and a standard clinical scale (Health-O-Meter, model 400 DFL). Since previous studies have indicated definite factor loadings for selected measures of strength (Fleishman, 1964; Jackson, 1971), three regional body segments were utilized for testing on the Universal Gym. Moreover, four testing stations were modified to represent each of the body segments. More specifically, the trunk measures were sit-up, bent knee-up, lateral flexion, and hyperextension. The upper extremity measures were bench press, military press, upright row, and lateral pulldown. The lower extremity measures were the upper leg press, lower leg press, leg curl, and leg extension.

During pilot studies (N=12) in minimizing methodological error, the final procedures adopted for the twelve selected exercises revealed stable reliability coefficients ranging from r=.82 to .99. These values compared favorably with those found by Coleman (1977) who reported reliability coefficients of r=.90 to .99 on similar equipment and utilized similar procedures. Furthermore, it was found that two minutes of intertrial rest were required to approximate repeat performances on the equipment and various stations. These findings are consistent with those of Clarke (1954) and O'Shea (1966).

Test Administration

Five days of testing broken by at least one day of rest were utilized for the data collection period. This period of time occurred after twelve consecutive weeks of strength training by the subjects.

The twelve testing exercises were divided into four groups so that each group included one exercise measuring the strength of each body segment; i.e., trunk, upper extremity, and lower extremity. Group I included the upper leg press, bent knee-up, and bench press. Group II included the lower leg press, the lateral flexion exercise, and the upright row exercise. Group III exercises were the leg curl, sit-ups, and military press, and Group IV tested the student's leg extension, hyperextension, and lateral pulldown strength. These groups are listed in Table II. Dividing the exercises into these particular groups allowed for more room, less congestion, and easier test administration, since some of the exercises were tested using the same part of the Universal Gym. (See Table II, pg 48.)

Maximum strength on each of the twelve exercises was determined by the maximum amount of weight that could be lifted one time (1RM). The exercises were performed according to the Universal Gym manufacturer's suggestions, and were strictly adhered to so that no extraneous movement of the subjects occurred. To determine 1RM values, some modifications were made for strength measurement on the hyperextension, sit-up, bent knee-up, and lower and upper leg presses.

Hyperextension strength was measured using the upright row pulley across the subject's chest. He was then instructed to extend his trunk as far as possible, having a position parallel with the floor. The maximum amount of weight the subject could lift one time parallel with the floor was his 1RM strength.

Sit-up strength was also assessed using the upright row pulley. In this exercise, the subject was instructed to assume a bent-knee sit-up position with the knee joint angle around 90^0. He placed the upright row pulley behind his head and performed a sit-up touching his elbows to his knees. The maximum amount of weight the subject correctly lifted one time was his sit-up strength.

The upright row pulley again was used for assessing the subject's bent knee-up strength. The subject assumed a supine position on a bench with his feet facing the pulley. A belt was strapped around the subject's feet connecting them to the pulley. He was then asked to flex his thighs with bent knees to a 90^0 angle with his trunk. The maximum amount of weight the subject correctly lifted one time to 90^{0} was his maximum bent knee-up strength.

The seat for the upper and lower leg press was set in two different positions. The upper leg press was in the 1/2 position and the lower leg press was in the full range of motion position. This gave different leg strength values for the respective seat positions.

Latin square treatments of the exercise groups were administered to the six weight training classes so that no two classes followed the same order of exercises. Table III identifies the exercise groups and the order of test administration. The arrows show the direction in which the exercise order was followed, either ascending or descending. This design served to eliminate order effect on the treatments. (See Table III, pg 49.)

Days one through four were employed for the administration of strength tests. The strength measures were taken following similar procedures used by Berger (1967) in his studies. The subjects warmed up with approximately 50 per cent of their estimated 1RM values for ten repetitions. Next, the subject performed 90 per cent of his estimated maximum for one repetition, and from that point he added ten pounds to each attempt until a failing attempt was observed. The highest successful score was recorded as the subject's 1RM. Rest intervals between trials were at least two minutes, as suggested by Clarke (1954) and O'Shea (1966).

The final test day involved the measurement of body weight and standing height. Body weight and standing height were measured while the subjects were in shorts only. Body weight was measured to the nearest 1/2 pound (.22 Kg) and standing height to the nearest 1/4 inch (.64 cm).

Analysis of Data

Alpha and canonical factor analysis were both used to examine the potential factor structures of the exercises from the Universal Gym. The SPSS program on the North Texas State University computer was used to perform the alpha and canonical factor analysis.

Alpha factor analysis examined the data from the viewpoint that the twelve resistance exercises are a sample from the universe of exercises and the subjects are the population (Johnson and Nelson, 1967). The basic principle is to maximize the correlation of the underlying factors to the universe of exercises.

Canonical factor analysis examines the data from the viewpoint that the subjects are a random sample from a population, and that inferences can be drawn about the population from the results of their performances on the test variables (Johnson and Nelson, 1967). This method maximizes the correlation between the resistance exercises and the factors.

Any agreements among the factors from the alpha and canonical solutions were considered to have been robust factors. These robust factors were further indications that they were not isolated as a result of population variability (Jackson, 1971).

Results

Pearson product moment correlations were performed on the twelve test re-test strength scores. The reliability coefficients ranged from r=.82 to .99.

The means and standard deviations were calculated on all the strength variables, which are presented in Table IV of the appendix. The intercorrelation matrix between the strength variables is presented in Table V of the appendix. Alpha and canonical factor analysis was performed on the twelve strength variables. The varimax solutions for both factor analytic models are presented in Table VI of the appendix. When examining a factor matrix (Tables VI, VIII, and X of the appendix), it is important to identify the variables that have the highest pattern coefficients in the factors. The higher the pattern coefficient, the better that variable represents the factor.

In the rotated canonical solution, two factors accounting for 60.9 per cent of the total variation among the twelve strength tests were isolated. Factor I was labeled lower extremity strength, with upper leg press (.586), lower leg press (.665), leg curl (.592), and leg extension (.850) having the highest pattern coefficients. Factor II was labeled upper extremity strength, with bench press (.867), upright row (.586), military press (.846), and lateral pulldown (.593) being the highest markers.

The rotated alpha solution also isolated two factors. However, Factor I and Factor II were both labeled general strength factors. Factor I was represented by upper leg press (.510), bench press (.531), lower leg press (.644), lateral flexion (.690), upright row (.572), leg curl (.655), military press (.486), leg extension (.751), hyperextension (.564), and lateral pulldown (.514). Factor II's highest markers were upper leg press (.441), bent knee-ups (.538), bench press (.666), lower leg press (.412), upright row (.523), sit-ups (.573), military press (.713), and lateral pulldown (.584).

Of the three hypothesized factors, two were confirmed in the canonical solution--upper and lower extremity strength. However, the alpha solution did not support any of the three hypothesized factors.

Some investigators have shown that the anthropometric measures of standing height and body weight correlate significantly with the performance on strength tasks (Clarke, 1957; Fleishman, 1964; Larson, 1940). Therefore, body weight and standing height may affect the performance on strength tasks. With this in mind, a residual score procedure was used to eliminate the effect of body weight and standing height on the strength scores.

Intercorrelations were calculated on the weight-residualized variables, which are presented in Table III of the appendix. Alpha and canonical factor analysis was performed, and the varimax solutions are presented in Table III of the appendix.

The rotated canonical solution delineated three factors from the weight-residualized variables. Factor I was labeled upper extremity strength. The highest markers on this factor were bench press (.858), upright row (.520), military press (.823), and lateral pulldown (.551). Factor II was a general strength factor.

Lateral flexion (.631), upright row (.457), leg curl (.468), leg extension (.601), and hyperextension (.559) were the highest markers. Factor III, the lower extremity strength factor, had as its primary markers the upper leg press (.837), lower leg press (.833), and leg extension (.363).

The rotated alpha solution also delineated three factors from the weight-residualized variables. Factor I, the upper extremity strength factor, had the bench press (.714), upright row (.516), military press (.730), lateral pulldown (.707), and sit-ups (.578) as its highest markers. The general strength factor, Factor II, included the exercises lateral flexion (.661), leg curl (.512), leg extension (.548), and hyperextension (.563). The primary markers for Factor III, the lower extremity strength factor, were upper leg press (.800), lower leg press (.789), and leg extension (.415). The alpha and canonical solutions both delineated similar three-factor structures, making each factor a robust factor.

The intercorrelation matrix for the combined weight and height residual variables is presented in Table IX of the appendix. The varimax solutions for both the alpha and canonical factor analysis are presented in the appendix under Table X.

The rotated canonical solution delineated a three-factor structure for the weight-height residualized variables. Factor I, the upper extremity strength factor, included the exercises bench press (.806), upright row (.497), military press (.887), and lateral pulldown (.574). Factor II was the lower extremity strength factor, with the upper leg press (.864), lower leg press (.823), and leg extension (.430) having the higher pattern coefficients. Factor III was the general strength factor. Bench press (.428), lateral flexion (.862), upright row (.436) and hyperextension (.445) were the highest markers on this factor.

A similar three-factor structure was delineated by the rotated alpha solution. The upper extremity strength factor, Factor I, had the bench press (.707), upright row (.505), military press (.747), and the lateral pulldown (.700) as its highest markers. Factor II, the lower extremity strength factor, included the upper leg press (.860), lower leg press (.700), leg curl (.424), and leg extension (.520) as the highest markers. Factor III, the general strength factor, was represented by the bench press (.435), lateral flexion (.752), upright row (.396), leg curl (.396), leg extension (.441), and lateral pulldown (.445) exercises.

The weight-residual factor structure and the combined weight-height residual factor structure are very similar. They both include two robust factors. The factor structures all include an upper extremity, lower extremity, and a general trunk strength factor. Each of the isolated factors generally include the same exercises with the highest pattern coefficients. These similarities suggest that no additional clarity exist in the factor structure when the variance of height combined with the variance of weight is residualized from the twelve strength variables. Thus, variance accounted for by weight seems to be the more important of the two when looking at strength performance.

Since weight adversely affects the validity of the strength measures on the Universal Gym, to validly assess strength, weight should be statistically controlled. The use of regression equations is a way to statistically control weight, and they were calculated on the weight-residualized variables with the highest validity (pattern) coefficients. The variables with the highest validity coefficients operationally represent the factors best. The military press (.823) and the bench press (.858) operationally represent the upper extremity strength factor best. The upper (.837) and lower (.833) leg presses represent the lower extremity strength factor, and the trunk-general strength factor was best represented by lateral flexion (.631). The equations for predicting the strength scores on these exercises are listed below:

Upper Leg Press	=	(1.010113)	wt. + 267.2179
Lower Leg Press	=	(1.120067)	wt. + 120.8645
Bench Press	=	(0.7548175)	wt. + 66.51564
Military Press	=	(0.4544819)	wt. + 64.70813
Lateral Flexion	+	(0.5784329)	wt. + 75.06220

In order to provide a muscular strength measure free of weight, the residual score method recommended by DuBois (1965) was used. This method requires the prediction of muscular strength performance from weight. A muscular strength performance free of weight may be calculated by the formula:

$$x - x^1 = x \text{ residual}$$

where x is the actual strength score, x^1 is the strength score predicted from the individual's weight, and x residual is the strength score which is uncorrelated with weight. A positive x residual indicates that an individual performed better than expected for that weight. A negative x residual indicates that an individual performed more poorly than expected for his weight.

Percentile ranks were calculated on the x residual scores for the five most valid exercises for measuring muscular strength. These are presented in Tables XI - XV. The percentile rank shows the percentage of students that scored below the rank. Thus, an instructor could see how his students ranked in relation to the norms from this study.

Discussion

The means of the twelve strength tests are comparable to those found in other studies (Berger, 1967; Berger, 1963). One of Berger's studies (1967) used free weights for the measurement of strength; however, the means were still comparable to those on the Universal Gym. This suggests that comparable strength scores can be attained on both free weights and the Universal Gym equipment. Moreover, the Universal Gym is a more economical and efficient exercise apparatus for teaching institutions; thus it would seem to be the choice of the two for muscular exercise.

The data from this study indicate that when weight, or weight-height in combination are not statistically controlled, then a clearer picture of the components of muscular strength is not delineated.

The findings of this study failed to support a robust three-factor structure for upper and lower extremity strength and trunk strength when weight and height are not statistically controlled. In contrast, Jackson (1971) found robust factors for leg and arm strength. However, Jackson (1971) used isometric contractions to assess muscular strength, and it has been shown that differences exist when comparing maximum isometric strength with maximum isotonic strength (Wilmore, 1976). It is true that some investigators have found separate factors for static (isometric) strength and dynamic strength (Fleishman, 1964; Jackson and Frankiewicz, 1975). However, the assessment of dynamic strength may have really been the assessment of muscular endurance (Wilmore, 1976).

When weight and weight-height are statistically controlled, a robust structure exists. With weight controlled, a three-factor structure is delineated. Separate factors for upper extremity and lower extremity strength exist; however, the hypothesized trunk strength factor is not as clearly delineated. Fleishman (1964) found a trunk strength factor which included the exercises leg lifts, isometric half sit-ups, and isometric leg lifts. However, these exercises may measure muscular endurance, not strength, because they were performed for a maximum amount of time or repetitions, not a maximum amount of force. In this study, trunk extension exercises were the principal markers of the third factor (hypothesized trunk strength factor), with trunk flexion exercises not as related to the factor. In contrast, Fleishman's trunk strength factor included trunk flexion exercises, but did not include trunk extension exercises. These differences in findings may be attributed to the differences in the measurement of strength. Jackson and Frankiewicz (1975) found that separate factors exist for arm work (endurance) and arm strength. Future research may be able to isolate and identify trunk strength and endurance facotrs. Both the alpha and canonical factor solutions isolated three very similar robust factors. This provides evidence that the robust factors were not isolated as a result of population variability (Jackson, 1971).

When weight-height were both statistically controlled, a similar robust three-factor structure exists in both alpha and canonical solutions. The trunk strength factor is not clearly defined, but the trunk extension measure again is the principal marker of the factors.

When weight, and weight-height are controlled, the upper extremity strength factor is clearly isolated. The four measures of bench press (.858), military press (.873), upright row (.520), and lateral pulldown (.550) strength had the highest pattern coefficients. The bench and military presses have the highest pattern coefficients and are pushing exercises, and they represent this factor best. The lateral pulldown and upright row have the lower pattern coefficients, and are pulling exercises. Pulling and pushing strength factors may be delineated for the upper body if more potential operational representatives are made available in a factor analysis study.

The lower extremity strength factor was clearly delineated when weight and weight-height were statistically controlled. The highest markers on this factor were upper leg press (.837), lower leg press (.833), and leg curl (.363). The upper and lower leg press represent this factor best. Leg extension strength failed to mark as high on this factor. Leg extension and leg curl strength were high markers on the hypothesized trunk strength factor. Future study with more potential operational representatives for the lower extremity could delineate more than a general lower extremity strength factor.

Conclusions

(1) There is not a clear factor structure over a muscular strength domain on measures taken on the Universal Gym when the anthropometric variables of body weight and standing height are not statistically controlled.

(2) When body weight alone, and body weight and standing height are statistically controlled, a three-factor structure exists over a muscular strength domain on selected measures of the Universal Gym. These factors are:

a. upper extremity strength, which is best represented by the measures of military and bench press;

b. lower extremity strength, which is best represented by upper and lower leg presses;

c. trunk strength, which is best represented by the hyperextension exercise.

(3) Residualized scores of body weight can be used to equitably evaluate strength performance of college males on the Universal Gym.

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APPENDIX

TABLE I

HYPOTHESIZED STRENGTH FACTORS

Upper Extremities	Lower Extremities	Trunk
Bench Press	Upper Leg Press	Sit up
Military Press	Lower Leg Press	Hyperextension
Upright Row	Leg Extension	Bent Knee-ups
Lateral Pulldown	Leg Curl	Lateral Trunk Flexion

TABLE II

EXERCISE GROUPS

Group I	Group II	Group III	Group IV
1. Upper Leg Press	1. Lower Leg Press	1. Leg Curl	1. Leg Extension
2. Bent Knee-up	2. Lateral Flexion	2. Sit Up	2. Hyperextension
3. Bench Press	3. Upright Row	3. Military Press	3. Lateral Pulldown

TABLE III

Treatment Days

CLASSES	1	2	3	4
1	I ↑	II ↑	III ↑	IV ↑
2	II ↑	III ↑	IV ↑	I ↑
3	III ↑	IV ↑	I ↑	II ↑
4	IV ↑	I ↑	II ↑	III ↑
5	I ↓	II ↓	III ↓	IV ↓
6	II ↓	III ↓	IV ↓	I ↓

TABLE IV

Descriptive Statistics of the Twelve

Universal Gym Station Test Items

VARIABLE	MEAN		STANDARD DEVIATIONS	
	(lbs)	(Kg)	(lbs)	(Kg)
Upper Leg Press (ULP)	431.0	(195.0)	74.0	(33.60)
Bent Kee Ups (BU)	70.1	(31.7)	14.9	(6.76)
Bench Press (BP)	188.9	(85.7)	41.8	(18.90)
Lower Leg Press (LLP)	302.5	(137.0)	45.3	(20.50)
Lateral Flexion (LF)	168.8	(76.6)	31.1	(14.10)
Upright Row (UR)	107.9	(48.9)	18.6	(8.44)
Leg Curl (LC)	101.4	(46.0)	19.5	(8.85)
Sit Ups (S)	31.1	(14.1)	10.3	(4.67)
Military Press (MP)	138.4	(62.8)	23.3	(10.60)
Leg Extension (LX)	164.5	(74.6)	26.2	(11.90)
Hyperextension (HY)	174.5	(79.1)	41.4	(18.80)
Lat Pull down (LP)	153.8	(69.8)	24.3	(11.00)

TABLE V

Correlation Matrix for Twelve Strength Variables

	ULP	BU	BP	LLP	LF	UR	LC	S	MP	LX	HX	LP
Upper Leg Press (ULP)	1.00	.282	.528	.793	.333	.479	.367	.341	.563	.533	.376	.388
Bent Knee Ups (BU)		1.000	.362	.251	.170	.241	.167	.344	.411	.119	.239	.430
Bench Press (BP)			1.000	.581	.605	.698	.450	.439	.872	.413	.434	.664
Lower Leg Press (LLP)				1.000	.431	.551	.480	.290	.614	.606	.382	.521
Lateral Flexion (LF)					1.000	.598	.444	.091	.486	.499	.501	.534
Upright Row (UR)						1.000	.374	.451	.683	.577	.389	.648
Leg Curl (LC)							1.000	.215	.444	.566	.509	.418
Sit Ups (S)								1.000	.409	.289	.232	.359
Military Press (MP)									1.000	.454	.375	.688
Leg Extension (LX)										1.000	.431	.531
Hyperextension (HX)											1.000	.445
Lat Pull down (LP)												1.000

TABLE VI

Factor Matrix Resulting from the Two

Factor Analysis Techniques

	ALPHA (Varimax Rotation)			CANONICAL (Varimax Rotation)		
	FACTOR I	II	η^2	I	II	η^2
Upper Leg Press	.510	.441	.454	.586	.382	.489
Bent Knee Ups	.085	.538	.296	.105	.422	.189
Bench Press	.531	.666	.726	.349	.867	.874
Lower Leg Press	.644	.412	.585	.665	.412	.612
Lateral Flexion	.690	.181	.510	.498	.428	.431
Upright Row	.572	.523	.601	.531	.586	.625
Leg Curl	.655	.170	.458	.592	.258	.417
Sit Ups	.134	.573	.347	.236	.405	.220
Military Press	.486	.713	.745	.373	.846	.856
Leg Extension	.751	.198	.603	.850	.153	.746
Hyperextension	.564	.239	.375	.492	.278	.320
Lat Pulldown	.514	.584	.606	.481	.593	.583

TABLE VII

Correlation Matrix for the Twelve Weight-Residualized Variables

	ULP	BU	BP	LLP	LF	UR	LC	S	MP	LX	HX	LP
Upper Leg Press (ULP)	1.000	.227	.446	.788	.209	.375	.247	.324	.484	.442	.301	.228
Bent Knee Ups (BU)		1.000	.304	.154	.081	.155	.075	.329	.359	.008	.185	.395
Bench Press (BP)			1.000	.430	.500	.608	.299	.438	.836	.233	.345	.545
Lower Leg Press (LLP)				1.000	.206	.342	.268	.282	.455	.424	.252	.180
Lateral Flexion (LF)					1.000	.471	.285	.045	.335	.339	.422	.337
Upright Row (UR)						1.000	.168	.463	.576	.421	.278	.474
Leg Curl (LC)							1.0000	.185	.275	.423	.430	.150
Sit Ups (S)								1.000	.409	.272	.209	.386
Military Press (MP)									1.000	.268	.267	.557
Leg Extension (LX)										1.000	.330	.287
Hyperextension (HX)											1.000	.334
Lat Pull down (LP)												1.000

TABLE VIII

Factor Matrix of the Weight Residualized Variables

	ALPHA (Varimax Rotation)				CANONICAL (Varimax Rotation)			
	I	II	III	η^2	I	II	III	η^2
Upper Leg Press	.283	.185	.800	.754	.271	.221	.837	.824
Bent Knee Ups	.484	-.011	.076	.240	.371	.011	.109	.150
Bench Press	.714	.387	.200	.700	.858	.319	.170	.868
Lower Leg Press	.204	.200	.789	.704	.246	.203	.833	.796
Lateral Flexion	.224	.661	-.019	.487	.298	.631	-.014	.487
Upright Row	.516	.386	.215	.462	.520	.457	.156	.504
Leg Curl	.068	.512	.225	.317	.137	.468	.159	.263
Sit Ups	.538	.082	.270	.369	.403	.188	.201	.238
Military Press	.730	.258	.282	.679	.873	.179	.251	.857
Leg Extension	.072	.548	.415	.477	.036	.601	.363	.494
Hyperextension	.216	.563	.132	.381	.165	.559	.134	.359
Lat Pull Down	.707	.281	-.008	.578	.551	.338	-.001	.418

TABLE IX

Correlation Matrix for the Weight and Height Combined Residualized Variables

	ULP	BU	BP	LLP	LF	UR	LC	S	MP	LX	HX	LP
Upper Leg Press (ULP)	1.000	.240	.456	.795	.282	.411	.352	.373	.439	.451	.382	.325
Bent Knee Ups (BU)		1.000	.303	.151	.084	.154	.080	.330	.362	.005	.189	.402
Bench Press (BP)			1.000	.422	.512	.608	.315	.441	.841	.226	.355	.564
Lower Leg Press (LLP)				1.000	.231	.345	.307	.292	.428	.415	.276	.214
Lateral Flexion (LF)					1.000	.475	.277	.044	.366	.351	.419	.331
Upright Row (UR)						1.000	.173	.463	.587	.421	.281	.481
Leg Curl (LC)							1.000	.185	.317	.441	.425	.136
Sit Ups (S)								1.000	.424	.275	.209	.388
Military Press (MP)									1.000	.254	.293	.606
Leg Extension (LX)										1.000	.340	.303
Hyperextension (HX)											1.000	.327
Lat Pull down (LP)												1.000

TABLE X

Factor Matrix of the Height-Weight Residualized Variables

	ALPHA (Varimax Rotation)				CANONICAL (Varimax Rotation)			
	I	II	III	η^2	I	II	III	η^2
Upper Leg Press	.329	.816	.123	.789	.274	.864	.201	.864
Bent Knee Ups	.485	.084	-.027	.244	.385	.117	.002	.162
Bench Press	.707	.189	.435	.725	.806	.170	.428	.861
Lower Leg Press	.240	.700	.119	.562	.269	.823	.132	.767
Lateral Flexion	.187	.075	.752	.606	.154	.078	.862	.774
Upright Row	.505	.231	.396	.466	.497	.213	.436	.483
Leg Curl	.054	.424	.396	.340	.182	.293	.295	.206
Sit Ups	.559	.308	.004	.408	.468	.266	.014	.290
Military Press	.747	.214	.321	.707	.887	.175	.250	.881
Leg Extension	.064	.520	.441	.470	.074	.430	.372	.329
Hyperextension	.202	.316	.445	.340	.159	.271	.445	.297
Lat Pull down	.700	.079	.277	.573	.574	.104	.278	.418

TABLE XI

PERCENTILE RANKS OF X RESIDUALS

FROM THE UPPER LEG PRESS

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
1	-162,14	26	-44,94
2	-107,26	27	-44,17
3	-105,33	28	-43.40
4	-90,61	29	-33.73
5	-89,32	30	-32.76
6	-88,03	31	-31.80
7	-86,80	32	-30.83
8	-85,84	33	-29.82
9	-84,87	34	-27.89
10	-83,91	35	-25.96
11	-82,94	36	-24.03
12	-80,13	37	-22.10
13	-76,27	38	-20.16
14	-73,34	39	-18.23
15	-72,05	40	-16.30
16	-70,77	41	-14.37
17	-69,48	42	-12.44
18	-56,95	43	-11.12
19	-55,20	44	-9.83
20	-53,91	45	-8.55
21	-52,62	46	-7.54
22	-50,28	47	-6.77
23	-47,26	48	-5.99
24	-46,49	49	-5.22
25	-45,71	50	-4.45

TABLE XI--Continued

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
51	-3.68	76	35.41
52	-2.74	77	37.04
53	-1.77	78	38.34
54	-0.80	79	39.63
55	0.16	80	45.60
56	1.23	81	47.53
57	2.52	82	49.46
58	3.81	83	51.39
59	5.09	84	53.32
60	6.38	85	61.40
61	7.67	86	69.66
62	8.96	87	84.84
63	10.08	88	85.81
64	11.05	89	86.78
65	12.01	90	87.74
66	12.98	91	88.80
67	13.95	92	90.73
68	17.68	93	92.66
69	18.91	94	120.40
70	19.55	95	121.69
71	20.19	96	122.98
72	20.84	97	138.49
73	21.48	98	216.98
74	22.13	99	269.14
75	22.77	100	273.00

TABLE XII

PERCENTILE RANKS OF X RESIDUALS

FROM THE LOWER LEG PRESS

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
1	-92.40	26	-21.42
2	-68.96	27	-20.51
3	-63.72	28	-19.71
4	-58.47	29	-18.91
5	-56.87	30	-18.11
6	-51.63	31	-17.05
7	-50.03	32	-15.45
8	-46.61	33	-13.88
9	-45.01	34	-13.08
10	-43.40	35	-12.28
11	-40.60	36	-10.86
12	-39.80	37	-9.77
13	-38.60	38	-8.97
14	-37.29	39	-8.31
15	-36.49	40	-7.91
16	-33.87	41	-7.51
17	-33.07	42	-7.11
18	-32.27	43	-6.71
19	-30.81	44	-5.33
20	-30.03	45	-4.27
21	-29.63	46	-3.47
22	-29.23	47	-2.87
23	-28.83	48	-2.55
24	-24.62	49	-2.23
25	-23.02	50	-1.91

TABLE XII--*Continued*

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
51	-1.59	76	25.44
52	-1.27	77	25.97
53	-0.02	78	27.28
54	0.96	79	28.41
55	1.49	80	29.21
56	2.02	81	30.01
57	2.56	82	30.82
58	3.09	83	31.60
59	3.62	84	32.14
60	4.16	85	32.67
61	5.52	86	33.21
62	8.43	87	38.06
63	9.23	88	42.77
64	9.93	89	43.30
65	10.47	90	43.83
66	11.00	91	44.47
67	11.54	92	46.07
68	14.91	93	53.13
69	15.86	94	65.65
70	16.66	95	72.71
71	17.46	96	75.70
72	18.26	97	76.50
73	21.10	98	77.52
74	24.37	99	86.40
75	24.91	100	88.00

TABLE XIII

PERCENTILE RANKS OF X RESIDUALS

FROM THE BENCH PRESS

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
1	-80.33	26	-29.86
2	-74.86	27	-29.03
3	-60.69	28	-25.68
4	-60.14	29	-24.01
5	-59.58	30	-22.85
6	-55.13	31	-22.29
7	-54.30	32	-21.73
8	-49.62	33	-21.12
9	-47.95	34	-19.45
10	-43.24	35	-18.79
11	-42.40	36	-18.24
12	-39.67	37	-17.68
13	-38.83	38	-11.28
14	-37.69	39	-10.45
15	-36.21	40	-9.42
16	-35.37	41	-7.75
17	-34.54	42	-6.08
18	-34.10	43	-5.68
19	-33.68	44	-5.35
20	-33.27	45	-5.01
21	-32.85	46	-4.68
22	-32.37	47	-4.34
23	-31.81	48	-3.87
24	-31.26	49	-3.04
25	-30.70	50	-2.20

TABLE XIII--Continued

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
51	-1.36	76	29.87
52	-0.53	77	30.58
53	0.92	78	31.14
54	2.09	79	31.70
55	2.93	80	35.99
56	3.77	81	36.41
57	4.60	82	36.83
58	5.48	83	37.24
59	7.15	84	37.66
60	8.82	85	39.90
61	10.49	86	40.24
62	13.53	87	40.57
63	14.37	88	40.91
64	15.10	89	41.24
65	15.66	90	41.88
66	16.22	91	43.48
67	16.77	92	44.31
68	19.50	93	45.15
69	20.33	94	45.76
70	21.74	95	46.31
71	22.96	96	46.87
72	23.79	97	93.14
73	24.86	98	93.98
74	26.53	99	106.33
75	28.20	100	108.00

TABLE XIV

PERCENTILE RANKS OF X RESIDUALS

FROM THE MILITARY PRESS

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
1	-47.08	26	-14.46
2	-45.10	27	-13.60
3	-36.83	28	-12.68
4	-34.85	29	-10.70
5	-33.93	30	-9.78
6	-30.91	31	-8.86
7	-28.93	32	-7.93
8	-28.01	33	-7.03
9	-27.08	34	-6.57
10	-25.53	35	-6.11
11	-25.07	36	-5.29
12	-24.70	37	-4.66
13	-24.40	38	-4.19
14	-24.09	39	-3.83
15	-23.64	40	-3.65
16	-21.67	41	-3.46
17	-20.74	42	-3.28
18	-18.38	43	-3.09
19	-18.15	44	-2.91
20	-17.92	45	-2.22
21	-17.69	46	-1.30
22	-17.17	47	-0.62
23	-16.25	48	-0.32
24	-15.39	49	-0.01
25	-14.93	50	0.30

TABLE XIV--*Continued*

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
51	0.61	76	13.91
52	0.92	77	14.75
53	1.22	78	15.34
54	1.62	79	15.80
55	2.08	80	16.26
56	2.69	81	16.72
57	3.49	82	17.18
58	3.72	83	17.65
59	3.95	84	18.11
60	4.18	85	18.99
61	4.42	86	19.91
62	5.09	87	21.89
63	6.75	88	23.86
64	7.06	89	24.79
65	7.37	90	26.76
66	7.73	91	27.64
67	8.66	92	28.10
68	8.99	93	28.57
69	9.30	94	31.51
70	9.61	95	32.43
71	10.25	96	35.45
72	12.23	97	41.63
73	12.98	98	43.60
74	13.29	99	56.08
75	13.60	100	57.00

TABLE XV

PERCENTILE RANKS OF X RESIDUALS

FROM LATERAL FLEXION

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
1	-47.94	26	-18.65
2	-46.89	27	-18.30
3	-44.63	28	-17.94
4	-42.69	29	-15.98
5	-42.16	30	-15.16
6	-41.63	31	-14.63
7	-41.10	32	-12.95
8	-40.55	33	-12.69
9	-39.50	34	-12.42
10	-36.04	35	-12.16
11	-33.78	36	-11.90
12	-30.33	37	-11.46
13	-29.54	38	-10.94
14	-29.01	39	-10.22
15	-28.48	40	-9.16
16	-27.95	41	-6.90
17	-27.42	42	-5.85
18	-26.90	43	-5.30
19	-26.37	44	-4.77
20	-25.48	45	-4.36
21	-23.22	46	-4.01
22	-22.38	47	-3.66
23	-21.86	48	-3.11
24	-21.26	49	-2.06
25	-20.20	50	-1.00

TABLE XV--Continued

PERCENTILE	X RESIDUAL	PERCENTILE	X RESIDUAL
51	-0.65	76	16.86
52	-0.30	77	17.46
53	0.60	78	17.98
54	0.82	79	18.82
55	1.64	80	19.88
56	2.17	81	22.14
57	2.63	82	23.10
58	2.81	83	23.62
59	2.98	84	24.15
60	3.16	85	26.36
61	3.34	86	34.21
62	3.51	87	34.74
63	3.69	88	36.46
64	6.58	89	36.99
65	7.52	90	37.64
66	8.05	91	39.90
67	8.58	92	40.95
68	11.34	93	42.01
69	11.69	94	49.06
70	12.04	95	54.92
71	12.78	96	60.78
72	13.83	97	61.83
73	14.74	98	62.89
74	15.27	99	69.94
75	15.80	100	71.00