A COMPARATIVE STUDY OF BODY SWAY IN THE ANTERIOR-POSTERIOR PLANE WITH REFERENCE TO THE EXTERNAL MALLEOLUS IN FEMALES AGES THREE THROUGH TWENTY-TWO

by

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This study was conducted to determine if any similarity existed in the anterior-posterior body sway of different age groups of females in relation to the base of support as measured from the posterior border of the external malleolus. Subjects ranging from three to twenty-two years of age were divided into pre-school, late childhood, pre-adolescent, and adult age groups. A total of one hundred eighteen subjects were administered four one-minute tests, the first two one-minute tests were administered during one week and the last two one-minute tests were administered a week later.

During the testing sessions, the subject's total weight was recorded first, then the subject stepped upon a balance board where a measurement was taken from the posterior border of the external malleolus to the anterior angle iron. While the subject stood quietly on the balance board, scale readings were taken at 15, 30, 45, and 60 seconds.

The Reynolds-Lovett technique was used to determine the body sway.

There was a statistically significant difference between the mean line of gravity readings of the pre-adolescent and adult groups. This difference was believed to be due to the marked differences in morphological characteristics in each of the groups.

In this study, the administration of the Reynolds-Lovett technique was executed by two people. This produced a statistically unreliable measure of body sway. The reliability could be improved by using photography to obtain the scale readings.

There was no statistically significant differences among scores within any of the age groups.

Measurements regarding the foot position were found to be reliable.

No generalizations can be made concerning the location of line of gravity in different age groups. The fact that a definite pattern of sway exists within all individuals was evident.

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CHAPTER I

INTRODUCTION

> We cannot run till we have learnt [sic] to walk, and we cannot walk till we are able to stand; therefore the first step towards the transition into a land-living animal from a fish was taken when the animal was able to stand--to balance its body against the pull of gravity. (14:59)

Throughout the ages man continually has been confronted with the problem of opposing gravity in his upright stance. Static posture has been examined and analyzed in terms of such factors as center of gravity, line of gravity, and body sway and their effects on erect standing.

Attempts have been made to describe the ideal erect posture of man in terms of aesthetics, mechanics, physiologic processes and psychic interpretations. However, as the ideal posture description was established the fact that man's structure changes throughout the growth process was often overlooked. It is quite possible that the young child's ideal posture may differ from that of the adult. It has been assumed that postural alignment is only partially related to chronological age.

Although studies have been conducted measuring line of gravity and body sway in standing anterior-posterior posture, no attempt has been made to compare body sway in different age groups.

Hellebrandt (49) found that a definite and constant pattern of sway was displayed by each individual. This study was an attempt to generalize Hellebrandt's observation to see if specific age groups demonstrated a definite and constant pattern of sway. No attempt was made to define good and poor anterior-posterior posture, nor to investigate the muscular involvement in body sway in this study.

There is an implied need to know if any relationship exists between pre-school, late childhood, pre-adolescent, adolescent, and adult age groups in relation to their body sway, and what implications this relationship would have on posture education at the different levels.

Most authors have agreed that posture is an individual matter, yet students receive posture education as a group in many school situations. Often students are evaluated and corrected as a group. The methods of evaluation are subjective, and many more times the instructor has no objective point from which to begin evaluation or from which to make comparisons. Some institutions use posture pictures for posture evaluation, but when this is done the student's "habitual" posture is difficult to capture.

It has been observed that generalizations regarding body sway all have different anatomical references. The body must sway in erect standing to provide circulation for the lower extremities. Some writers have attempted to explain body sway by considering the actions of the anti-gravity muscles of the lower extremity. But more recent work with electromyography has questioned the importance of certain anti-gravity muscles in body sway.

According to Broer (6) when one body segment moves out of line, another segment must be displaced in the opposite direction to bring the center of gravity back over the base of support. This base of support was described by Broer as falling somewhere near the ankle joint. Studies which have examined the line of gravity in the standing anterior-posterior position differ in describing where the line of gravity falls in relation to the ankle, and also the point from which measurements were made at the ankle. Fox and Young (44) did their measuring from the anterior border of the tibia at the ankle. Steindler (30) described his measurement from the ankle joint. Hellebrandt, and others (50) indicated the distance from the external malleolus. Brown (37) took her measurements from the posterior aspects of the heels. Kelton and Wright (56) measured from the center of rotation at the ankle joint.

Hellebrandt, and others (50) observed that the line of gravity of the body as a whole shifts incessantly during relaxed and effortless standing. They found a relative consistency in the patterns formed by the trajectory of the shifting center of weight and the mean position of vertical projection of the theoretical point. Drew and Kinzley (10) attributed variations in the line of gravity to the individual skeletal build and comparative length of the curves of the body.

The normal child's physical form changes as he matures. With each physical growth development, his posture must be altered to maintain an erect position. The pre-school child is normally described as having a prominent abdomen and an increased lumbar curvature. Because of these normal growth patterns and resulting morphological characteristics, the pre-school child cannot be expected to have a posture resembling that of an adult. Posture education has occasionally been based on the adult posture as the "ideal" posture for all age groups, with no consideration for growth changes. It would seem plausible that the child's line of gravity could alter with each growth change.

As Broer (6) suggested, the body tends to protect itself, so when one body segment is out of alignment, another segment will compensate to keep the body parts safely over the base of support.

This study was done with five age groups. These groups were the pre-school, 3-5 years; late childhood, 6-9 years; pre-adolescent, 10-13 years; adolescent, 14-19 years; and adult, 20-22 years. The subjects were tested while standing in the anterior-posterior plane since this is the position most often used in posture evaluation. According to Hellebrandt (49), sway is always greater in the anterior-posterior plane than in the transverse vertical plane.

Watson and Lowrey (32) named the two important factors in posture as the variations in the curve of the vertebral column and the shifting line of gravity.

This study was an attempt to examine the shifting line of gravity in terms of various age groups.

CHAPTER II

STATEMENT OF THE PROBLEM

The problem was to see if any similarity existed in body sway of different age groups of females in relation to the location of the line of gravity at the posterior border of the external malleolus during erect anterior-posterior posture. The age groups compared were pre-school, ages 3-5 years; late childhood, ages 6-9 years; pre-adolescent, ages 10-13 years; adolescent, ages 14-19 years; and adult, ages 20-22 years.

Body sway was measured by the Reynolds-Lovett technique using one scale and a stationary block. The subject stood on a board supported on the edges of two angle irons resting on the scale and block.

The Reynolds-Lovett technique was used to determine a line of gravity for the individual for each scale reading. By taking scale readings at 15, 30, 45, and 60 seconds, the four lines of gravity were established and from these lines of gravity an individual's body sway (the difference between extreme lines of gravity readings) was determined. Each subject was administered two one-minute trials one week and two one-minute trials a week later.

In addition to the scale readings, a reading of the distance from the posterior border of the external malleolus to the straight edge of the anterior angle iron was taken.

CHAPTER III

REVIEW OF LITERATURE

I. DEFINITIONS

Posture

Posture is an encompassing term used to describe the position of man. The term may be used in a narrow or general context depending upon the individual's connotation.

Using posture in its most general terms Martha Graham (34:188) said, "Posture--the perpendicular line connecting heaven and earth." Perrott (22:178), Daniels (9:312) and Lowman and Young (17:86) agreed that posture is a natural, poised, balanced position of the body. Scott (27:396) stated that good posture is more than the ability to stand erect, it includes the ability to handle the body easily, gracefully and efficiently under all circumstances.

Another general definition was given by Anthony (2:162) who said,

> Posture means simply position or alignment of body parts. "Good posture" means body alignment which most favors function; it means position which requires the least muscular work to maintain, which puts least strain on muscles, ligaments and bones; it means keeping the body's center of gravity over its base.

Miller (63:89) gave an historical picture of posture from 1900 to the present. According to Miller, there are three basic differences of opinion with regard to posture. One opinion concerns the argument regarding whether one particular posture is more physiologically advantageous than any other. Another opinion concerns whether prescribed physical activity can actually modify posture. Thirdly, Miller wondered whether it is possible to agree upon a method of accurately measuring posture. He believed that the study of posture has advanced and become increasingly bewildering and inconsistent.

More specific definitions of posture were given by Bartels (68:66) and Willgoose (34:188) who said that posture is not a static thing but involves the body segments at any given time. Willgoose indicated that,

> Individual body build and its influence on behavior, together with anthropometric measurements in general, are related to posture. Structure precedes function; and the function of the whole organism is related to the sum effects of its separate parts.

More recent literature on posture stressed the importance of the individual differences in defining posture automatically or descriptively. Metheny (20:193) expressed this individual concept in her definition:

> There is no single best posture for all individuals. Each person must take the body he has and make the best of it. For each person the best posture is that in which the body segments are balanced in the position of least strain and maximum support. This is an individual matter.

Mathews (18:235) agreed with Metheny that the uniqueness of body structure makes it not only difficult but perhaps against the best interest of the individual to establish definite posture standards. Goldthwaite, and others (12:115) similarly believed in the importance of individual differences in posture. Rasch and Burke (24:329) joined this school of thought when they said, "Whatever the values of a prescribed posture, expecting everyone to meet any given standard is to ignore the fact that posture is largely an individual matter."

Other writers who have described posture in individual terms are McCloy (62:235), Massey (61:3,4), and Phelps, Kiphuth and Goff (23:59).

Scott (27:8) explained why posture must be individual when she stated that,

> 'Good posture' is more than an aesthetic ideal, a common mold for all individuals. It is a mechanical problem--a problem related to gravity, stress and strain on body parts, and muscular strength and tonus.

Basmajian (4:84) said posture must be examined in terms of the constant battle between human beings and gravitational forces, thus the study of posture in essence is made up of the counteraction of gravity by the body's mechanisms.

Obviously there is no one definition for posture, but Clarke and Clarke (7:192) seemed to sum up the latest concepts of posture when they stated that,

> Posture is not just related to the standing position, as was generally the case in the past. It encompasses many aspects of a person's stance, involving the correlation of the skeletal, muscular and nervous systems.

Line of Gravity

An important concept in posture is the line of gravity which is often used synonymously with center of gravity, center of weight or gravitational line. This term needs description because some authors tend to use the above terms interchangeably within their writings. Perrott (22:184) defined the line of gravity as,

> ... the vertical line passing through the center of gravity. It represents the position of the coronal plane (divides body top to bottom at right angles to median plane) dividing the body into unequal anterior and posterior segments. The plane forms the 'plane of balance' of the body for movements in the antero-posterior directions,...

Perrott then explained that the line of gravity can be marked on the surface by going through specific anatomical landmarks.

Broer (6:89) said the line of gravity of each body segment is an extension of the line of gravity of the segments above and below and thus gravity helps maintain the position by pulling down evenly from one section to the one below. When the body is properly aligned, the line of gravity passes downward through the body. This imaginary line passing through the body was discussed by Wells (33:8,341) in relation to the base of support. She acknowledged the automatic adjustment of body segments to maintain equilibrium, and thus demonstrated there is no one constant point where gravity falls consistently.

Steindler (30:106) agreed that the line of gravity is not constant, but continually shifting forward and backward as viewed in the frontal plane. Brown (37), Fox and Young (44) and Scott (27) referred to the gravital line instead of the line of gravity. Scott defined the gravital line as the intersection of two vertical planes which determines the object's center of weight.

Center of gravity may be defined as a specific point within the body, called the center of mass, in the transverse plane (1:26), or as a point from which a vertical line may be dropped (25:88). The center of gravity was defined by Wells (33:8) as

> ... an imaginary point representing the weight center of an object...that point in the body about which all the body parts exactly balance each other...the point at which the entire weight of the body may be considered as concentrated.

Rasch and Burke (24:138,139) agreed with the latter definition and added that it is the point where all three planes intersect. Scott (27:158) called the center of gravity the "... weight center of the object, the point around which it balances in every direction."

Hellebrandt, and others (50:466) spoke of the center of weight as the point through which the coronal and sagittal planes pass.

In summarizing the definitions of line of gravity it would appear that the line of gravity (gravital line) has its origin at the center of gravity (center of mass) of the body segments.

Body Sway

Body sway is another important component of posture. Body sway appears to be the result of anti-gravity muscular action.

A vast amount of work with body sway was done by Hellebrandt, and others (50:472,473) who defined body sway as the involuntary center of gravity which shifts during a natural vertical stance. She reminded the reader that it has long been known that sway is inseparable from upright stance. Standing is a dynamic phenomenon which Hellebrandt, and others called "... movement upon a stationary base."

Scott (27:202) explained that, "Even the most erect standing position requires muscular action,..." She said there is always a slight amount of body sway in the antero-posterior direction and it is greater in some individuals than in others.

According to Hutchins (69:120) the instability (body sway) in posture is caused by the continual downward pull of gravity which tends to flex the body joints and to stimulate extensor muscles reflexly.

Basmajian's (4:89) definition of body sway was similar to Hellebrandt's when he said it is any shift forward or backward producing compensatory activities in muscles to prevent complete imbalance.

These definitions for the most part have been concerned with body sway in the anterior-posterior standing posture, but sway is also observed from side to side. (56:511)

II. STUDIES CONCERNING BODY SWAY

With the use of electromyography some light has been shed on the facts regarding body sway.

In electrical studies by Kelton and Wright (56:508-511), they found all muscles except the tibialis anterior and soleus silent for long periods of time. These results would indicate the absence of muscular tone as observed in previous studies. Kelton and Wright observed these results by connecting an Offner amplifier to seven pairs of muscles of the lower extremity. When anterior-posterior sway began, the tibialis anterior and soleus moved well ahead of the gastrocnemius. They used electromyographic and gavimetric means to determine the angle of sway at the ankle joint. During this examination the subject stood on a board and electrodes were inserted in the suspected muscles and the results projected through an oscilloscope.

In opposition to Kelton and Wright's findings Joseph, Nightingale and Williams (55:620,624), using surface electrodes, found activity present in the gastrocnemius in the majority of subjects but little activity in the tibialis anterior and the front and back thigh muscles.

Hellebrandt (49:471,472) studied body sway and found that the center of gravity of the body as a whole shifts incessantly during relaxed and effortless standing. She found the maximal sway approximately 4.09 square centimeters for men and women when standing for three minutes in a natural comfortable stance with eyes on a fixed point. For this study her subjects were placed in a position of greatest stability with the toes turned out 30-40 degrees. Her subjects were placed on a board supported by two knife edges and connected to a kymograph which recorded movements. She declared the effort to explain the peripheral mechanism of tonus largely hypothetical.

Cooper and Glassow (8:113) related that since sway is much greater in the anterior-posterior vertical plane, the feet should be placed at a 45 degree angle to equalize the coronal and sagittal diameters for better balance. When the feet are together, stance is unsettled.

Fox and Young (44) reported that Hellebrandt found body sway greatly affected the reliability of the line of gravity when posture pictures in a series were compared.

Scott (27:202) reported a study by Skaggs concerning body sway with a small group of subjects. The purpose of Skaggs' study was to compare body sway when the leg muscles were in normal tension and when in hypertension. Skaggs found that hypertension of the leg muscles tended to cause a greater body sway and greater variability as compared with the leg muscles in normal tension, but the differences were not statistically significant. Skaggs believed that there was considerable individual variation in sway and that it increased with eyes closed.

Miles (11) made use of an ataxiameter to test static equilibrium. The ataxiameter consisted of a wooden frame, scales and head gear. The subject was asked to stand as quietly as possible for two minutes in his own shoes and with eyes closed. Any movement of the subject's head caused the adders at each corner of the wooden frame to operate. The adders were adjusted so they could be read directly in millimeters.

Miles found that respiration, heartbeat, position of the feet, height, weight, age and psychic factors influenced static equilibrium.

Joseph, Nightingale and Williams (55:16) reported the results of a study by Bowman and Jalvavisto in 1953 who measured the extent of body sway by movements of a light strapped to the forehead and shining upwards on to a camera. The anterior-posterior sway in 43 subjects, age 18 to 30 years was 41.7 $\pm$ 16 millimeters. It was found that the amount of sway was significantly greater in persons over 30 years.

Basmajian (4:88) using needle electrodes demonstrated with respect to sway that there is actually a wide range of findings for each of the muscles of the leg. His results compare with those of Joseph, Nightingale, and Williams for he found the posterior calf muscles generally much more active than the tibialis anterior. Basmajian maintains that the slightest shift is reacted to through the nervous system by reflex postural adjustments; often so fine they can only be detected by electromyography.

According to Scott (27:202) there is always a slight amount of body sway in the anterior-posterior direction and it is greater in some individuals than others. A person is ordinarily unaware of sway unless he tries to stop it for some reason as for example in standing for posture pictures. Hesser (38:112) stated that sway varies not only in different persons, but also in different tests of the same person. Using thirty-one subjects Hesser found minimum sway to be nine millimeters, maximum sway twenty-seven millimeters.

Morehouse and Miller (21:33), Rathbone (25:80,81) and Hutchins (69:120) attempted to explain body sway in terms of the stretch reflex.

III. PREVIOUS POSTURE EVALUATIONS

Posture evaluation methods, techniques and studies have been numerous.

The most recent posture evaluation techniques have used photographs to take individual pictures for motivational and evaluative purposes. The Polaroid camera has provided a practical means for posture evaluation (42:72) although not objective enough to use without subjective analysis.

A more objective photographic method was devised by Blesh, Meyers and Kiphuth (36) who used a series of mirrors to view the body from four angles at once. Poley (70:124) used photography in her study to correlate posture and body build.

Goff (46) employed posture orthograms (body types) to determine good posture. Hubbard (52) made use of a shadow-silhouettograph in his studies. Christenson (40) also used a silhouettograph. Buhl and Morrill (39) used a device called a posturemeter for correcting posture. A predetermined shape (comparagraph) was used by Korb (57) to evaluate excellent posture.

Massey (61:5) listed the following subjective methods of posture evaluation: Bancroft Vertical Line test, Lowman's Method of Examination, Iowa Posture test, Crampton's Wall tests and a semi-objective method by Rowe and Crampton. Massey also described some tests to arouse pupil interest in posture, such as the schematograph, panograph and lithograph.

Only the photographic method is being used as an objective measure of posture at present, and better techniques are being devised with photography.

IV. SOME POSTURAL MISCONCEPTIONS

Misconceptions in the posture area are numerous. Wells (33:31) stated that

> ... we need to accept the evidence we already have, and not continue to teach outmoded, unproven concepts such as the one that says the lobe of the ear, tip of the acromion process, middle of the trochanter and head of the fibula should be aligned vertically.

This statement by Wells attempted to correct a misconception of physical educators teaching posture. She continued that teachers must make allowances for variations in body build.

Leonard (58) goes into detail to describe the system she developed to have a stationary plumb line in all posture pictures. This plumb line was designed to drop just in front of the ankle bone so any deviations from normal could quickly be seen. Leonard failed to conceive the importance of an individual gravity line for each subject.

Hewes (51), an anthropologist, described different types and positions of posture in four hundred cultures. He gave illustrations of different standing body positions for man and why these positions were important in terms of the cultural connotation.

A posture analysis by Kimber, and others (16:134) described the line of gravity passing through the balls of the feet. He gives no facts or studies to support this erroneous assumption.

According to Stafford and Kelly (29:90) there is no validity in the criticism often offered physical educators for concentrating almost exclusively on improvement in the stationary standing posture because few people stand in one position for long intervals. Stafford and Kelly said that there is marked evidence available that one's habitual stationary standing posture bears a marked resemblance to carriage in daily activities.

Willgoose (34:188) indicated that some physical educators disregard posture training on the basis that many defects are temporary and represent a feeling or attitude of the moment. He stated that evidence indicates that the assumption is not altogether true.

Mathews, Kruse and Shaw (19:152) stated that in a search through the literature relative to the relationship between posture and health, they found no writer who disclaimed the health values of posture in their entirety.

Irwin (53:471) disclosed the fact that children are expected to conform to a single pattern to be considered as having excellent postures, but this concept is erroneous. He showed that children vary greatly in body type and anatomical structure and that dynamic posture is of greater importance than static posture, as far as the school child is concerned.

V. METHOD OF DETERMINING LINE OF GRAVITY

All studies available to date have used the Reynolds-Lovett (64:287) technique or a variation of that technique for determining the line of gravity. Fox and Young (44), Grace (47), Brown (37), Johnston and Crawley (66), and Flint (43) used the original Reynolds-Lovett formula which is:

$$\frac{\text{Total Body Weight}}{\text{Weight registered on scale}} = \frac{\text{Length of board (angle to angle)}}{X}$$

Wells (67:348) used the formula:

$$d = \frac{(\text{PWS\&B}) \quad - \quad (\text{Pt.Wt. of B})}{\text{Total wt. of subj.}} \quad X \quad (\text{Length of board})$$

where:

d = distance from rear knife edge to frontal plane
PWS&B = partial weight of subject and board
Pt.Wt. of B = partial weight of board

Williams and Worthingham (35:4) used the following formula for determining line of gravity:

$$d \times F = D \times f \qquad \text{or} \qquad d = \frac{D \times f}{F}$$

where:

d = unknown distance from angle edge to posterior malleolus
F = total weight of subject (in pounds)
f = scale reading (in pounds)
D = angle to angle edge

The Cureton and Wickens' (41:3) Antero-Posterior Center of Gravity Test used two balance type scales which were balanced by an examiner while the subject stood on the board between the scales. The internal malleoli were lined up evenly with a vertical pin in the exact center of the board. The boards in these studies rested on knife edges (angle irons). The boards varied in size in each study.

VI. POSTURAL GROWTH CHARACTERISTICS

Growth characteristics which may effect posture differences and especially body sway within specific age groups should be considered in any analysis of posture.

With regard to children's posture, Watson and Lawrey (32:80) said, "A child typically adopts that posture which keeps the parts of his body in proper balance." Both Loewendahl (59) and Sellwood (65) indicated that children do not conform to one pattern of growth. Each child develops individually at a different rate. Sellwood (65:190) pointed out two laws determining structure:

> Wolff's law--the internal conformation and external shape of bone changes with any constant change in stress.
> Jansen's law--the part of bone in which pressure exceeds normal develops a more rapid growth. The tissues are more easily injured during the period of their most rapid growth.

Different developmental characteristics are seen in different age groups. The velocity of growth is relatively even for the pre-school child (3-5 years). During this age the cervical inclination gradually decreases and the scapular tilt is at a maximum. The body tilts from very erect in little children to an increasing backward tilt as the child grows older. (60) Bayer and Bayley (5:23) described the 3-4 year old as having a protruding abdomen and lordosis. Phelps, Kiphuth and Goff (23:37) said the structures of the pre-school child may show pronation, have short or long heel cords and contracted toes and other lesser abnormalities.

Sellwood (65:191) stated that due to poor development of the trunk stabilizers or abdominal muscles there is usually a prominent abdomen, lumbar lordosis, straight upper back, prominent scapula and feet are in slight pronation.

Children in the late childhood group (6-9 years) usually have rounded shoulders which are little influenced by exercise. (32:79) These children are often slender and long-legged, (5:23) with a marked cervical inclination. (60) A female contour is assumed at the pelvis and fat deposits begin to accumulate. (13:272)

The pre-adolescent group (10-13 years) in females begin to have hypertrophy of the breasts with increased enlargement continuing.

(13:272) There is only slight muscle increase, the pelvis rounds out and enlarges, fat is deposited in characteristic patterns and the child can become quite plump. (5:23) A marked decrease is shown in the sacral angle. (60) Phelps, Kiphuth, and Goff (23) maintained the neck and upper back should be nearly vertical. Positions of the lower back and abdomen are quite different from that of the adult. There is frequently a rather marked lordosis with a moderately prominent abdomen.

The adolescent (14-19 years) has attained histologic maturity. (13:272) During this period leg growth slows down but body growth continues undiminished for 1-2 years, thus contributing to a laterality of body build. (5:23) Bayer and Bayley (5) also say the adolescent is slightly knock-kneed, with thighs closely approximated from a broadening of the pelvis, the head held high, shoulders back and chest equal with plane of abdomen. (32:79)

According to Clarke and Clarke (7:195) a mature girl with large busts will tend to lean backward from the hips.

Phelps, Kiphuth and Goff (23:51) reminded his readers that at adolescence a classification of posture must be arbitrary for no classification of posture during such a formative period can include all aspects. The more muscle power developed with the body out of line, the worse posture may become.

The young adult (20-25 years) tends to lose some weight in the growth process which may affect her posture. (5:23)

Frost (45:31-33) did a study to discover any existing relationship between age and posture. He found age to be an indispensable factor in considering posture; which may indicate there should be a standard of posture for each age group.

Jorgensen and Hatlestad (54) and Hall (48) compared thirty-three different indexes and concluded that the ponderal index ($\sqrt[3]{\text{weight}}$/height) was most satisfactory for determining body build in women.

Goldthwait, and others (12) and Clarke and Clarke (7) agreed that posture depends much on body build.

VII. STUDIES CONCERNING LINE OF GRAVITY

A study by Fox and Young (44:284) showed the line of gravity to lie a mean distance of 0.95 centimeters in front of the anterior border of the tibia at the ankle. They found that in 84% of the cases the line of gravity was anterior to the anterior border of the tibia but averaged less than a centimeter from it.

A study by Cureton and Wickens (41:97) used a variation of the Reynolds and Lovett technique with two scales. They obtained a reliability of .928 $\pm$ .015. Johnston (66:92) obtained a reliability of .562 to .910 when measurements were taken in quick succession. However, the readings taken a month apart were not reliable (.221 to .406).

Cureton and Wickens observed that men with strong muscles seemed to stand with greater forward lean while those in poor condition seemed to stand with their center of gravity balanced more over the malleoli. This test correlated relatively high with Rogers' strength test. Massey (61) criticized the Cureton and Wickens study because of the probability that poor alignment of body segments might exist without noticeable displacement of the center of weight as measured at the feet.

Steindler (30:106) placed the line of gravity at four centimeters in front of the ankle joint.

An extensive study using 357 college freshmen, and 88 graduate and undergraduate professional students to determine the center of gravity in the transverse plane was done by Hellebrandt, and others (50:466). They indicated the location of the weight line from the malleolus. The average for the "best posture" group was 4.928 ± .073 centimeters anterior to the external malleolus with a standard deviation of 1.95 ± .0519. This mean difference was fourteen per cent greater when a natural stance was assumed.

Brown (37:30,31) used an alignometer developed by Howland to evaluate alignment based on the mechanics of balance. Brown used the Reynolds and Lovett technique for determining gravital line at the base of support. Brown found the point of the center of balance to be between 6.03 centimeters and 13.1 centimeters from the posterior aspects of the heels. She found no significant relationship between center of balance and body type nor between foot length and center of balance in body alignment.

Brunnstrom (38:114) indicated the fallacy in the assumption that in ordinary erect stance, when a subject is viewed from the side, the plumb line must necessarily fall through the ankle joint. He stated that investigations have shown that the center of gravity falls anteriorly to the ankle joint. Brunnstrom cited a study by Hesser which showed the center of gravity falling 10 to 48 millimeters anterior to the axis of the ankle joint. He also cited Basler (38:113) who found in persons with a foot length 24 to 26.5 centimeters the center of gravity lies 3.6 to 6.7 centimeters anteriorly to the axis of the ankle joint.

Johnston (66:92) found the gravital line of 130 freshmen and sophomores at Wellesley College. Their line of gravity was 7.7 centimeters in front of internal malleolus in "habitual" posture. Average deviations of measurements taken in a series of four were 0.4 centimeters with an average of 4.35 centimeters. The position of line of gravity was found to vary as much as 2.79 centimeters during the day for a single individual. This difference was probably due to body sway.

Scott (27:162) placed the line of gravity generally midway in the weight bearing part of the foot, which is from the calcaneal tuberosity to the distal end of the metatarsals.

Other writers concerned with the line of gravity include Steindler (30:235) who said the line of gravity drops to the base of support at the feet directly in front of the ankle joint. Broer (6:90) stated that the line of gravity falls in front of the ankle joint. Kelton and Wright (56:510) placed the line of gravity just in front of the center of rotation at the ankle joint.

This variety of results in studies of the line of gravity in the anterior-posterior position may be caused by the examiners using different points from which to measure the constant shift resulting from body sway.

VIII. SUMMARY OF REVIEW

Posture has been defined in different terms by different people. Most persons who have defined posture agree that it cannot be an aesthetic concept alone for posture (body position) is directly influenced by an individual's body build, strength and psychic state, not to mention the mechanical problems related to outside forces such as gravity.

Because the postural concept is effected by gravity, it is necessary to examine the line of gravity which is a theoretical line of stress going from the top of the head to the plantar section of the feet and falling through all body segments as it drops through the body. This line of gravity has its origin at the center of mass of each body segment.

Persons who have examined the shifting line of gravity (body sway) have attempted to describe the sway in terms of deviations forward and backward from a completely upright position.

Electromyographic studies have helped explain some questions concerning why a body sways as it does by examining the anti-gravity muscles.

The position of the feet seems to be a factor in examining body sway. Hellebrandt (49) recommended placing the feet with the toes turned out 30-40 degrees for the most stable position. Cooper and Glassow (8) said the most stable position was with the feet at a 45 degree angle. Those persons examining body sway agree that the body was more stable with the eyes focused at a fixed point.

Numerous methods of posture evaluation have been developed, most of which have been found subjective and insufficient as a reliable technique. The most recent and objective techniques have been those using photography as an evaluative procedure.

Some previous postural misconceptions have been recognized by various authors and the truth expressed about those misconceptions. A few of these misconceptions include the postural landmarks for good posture, the evaluation of posture using a stationary plumb line, the criticism against posture improvement in a static standing position, and the ideal posture which all ages are expected to attain.

Methods used for determining line of gravity have stemmed from the Reynolds-Lovett technique with some variations.

Because each child develops at a different rate, it was necessary to examine some general postural growth characteristics of each age group. The pre-school child was described as having an even growth rate and usually a protruding abdomen, lordosis, and straight upper back.

The late childhood group was described as having rounded shoulders with marked cervical inclination.

The pre-adolescent frequently displays a marked lordosis with a moderately prominent abdomen. Also at this time in females hypertrophy of the breasts and enlarging of the pelvis begin to appear.

No single classification for the adolescent was sufficient, for during such a formative period this age group included all aspects of posture characteristics. Age was found by Frost (45) to be an indispensable factor in considering posture.

A variety of results were shown in studies to determine the single line of gravity for persons in the anterior-posterior position. These variations probably prevail because of the different points from which the measurements were taken.

CHAPTER IV

PROCEDURES

The first problem of this study was to find a measuring device which was accurate and reliable to use to determine an individual's body sway.

After reading studies concerning line of gravity and measuring devices used, it was decided that the Reynolds-Lovett technique (64) using one scale was the most practical.

Equipment

A board, 122 centimeters long and 45.5 centimeters wide was made from a bleacher seat of hardwood (to eliminate any bend when the subject stood in the center of the board) and painted black. The length and width of the board were determined to facilitate the board's use in another study.

An adjustable heel device was made to attach on top of the board to assure a consistent, comfortable and natural stance for each subject. See Appendix A for diagram of this device. The adjustable heel device was designed to be easily and quickly removed from the board and to adjust to any width (to take into account the different stances for females 3-22 years of age).

The device consisted of a strip of wood, three-fourths by one-fourth inch square by sixteen inches long, placed twenty-six inches back from the front of the board and parallel to the ends of the board and bolted down to the board at each end. This wooden strip, which served as a guide for the heel blocks, was painted black with white stripes every one-half inch and numbers from 1-30 painted in the black spaces.

The heel blocks consisted of two wooden blocks, four and one-half by five and one-half by one and three-fourths inches, with a U shape cut three and one-fourth inches and tapering to one and three-fourths inches wide by two and one-fourth inches long in the anterior end of the block. A groove one and one-eighth inches wide was cut three-fourth inch deep through the posterior end of the heel block and one and one-half inches back of the center of the U and parallel to the ends of the block. (This channel fitted immediately over the wooden guide strip.) A screw sixteen inches long extended the width of the board and ran through the heel blocks just above the wooden guide strip.

The heel blocks could be moved apart or together with the tightening and loosening of a nut on either side of the heel blocks.

Two and one-half inches anterior to the heel blocks was a section (eight inches by thirteen and one-half inches) painted in black and white stripes one-fourth inch apart with even numbers 1-67 on the white stripes upon which the subject placed the toes and ball section of the foot. This section was patterned after that used by Reynolds and Lovett (64:291) in 1909.

The board rested on the straight edge of two, three-fourth inch angle irons which were kept in a constant position in regard to the board by wooden strips (three-fourth inch) tacked to the board on the medial and lateral side of the angle iron.

These angle irons rested upon a cement block (six and one-half inches high) at one end, and a Chatillion scale with temperature compensated springs calibrated in pounds with a capacity of three hundred pounds on a one-half inch thick plywood board (which provided a level base for the board) at the other end.

A wooden caliper calibrated in tenths of an inch was used to obtain the reading from the posterior border of the external malleolus to the anterior angle iron. To aid the accuracy of this reading, a nail was embedded in the board exactly above the anterior angle irons' straight edge.

A picture was taped to the wall facing the subjects as a target to minimize erratic body sway and to duplicate the head position for each testing session.

All equipment was portable to facilitate moving from one school to another at various times during the testing sessions.

Selection of Subjects

A stratified sample of 118 subjects ranging in age from 3 to 22 years was selected as being unbiased as far as line of gravity and body sway were concerned.

Because of the range of ages needed in the female subjects used in this study, it was necessary to obtain subjects from various situations.

For the pre-school group, Miss Helen Canaday, Director of the Nursery School at the University of North Carolina at Greensboro, was contacted. She approved two dates, a week apart, as a time for testing the twelve Nursery School girls. Due to illness, only seven girls were able to participate in the study.

The examiner agreed to write a letter of information to the parents concerning the study to be done with the children and to report the results of this study to the parents upon completion. A copy of the letter to the parents may be found in Appendix C.

The Nursery School Director also recommended the examiner visit the children and tell them what they would do for the study; therefore, one hour of the week prior to the testing was spent visiting with the Nursery School children.

The next person contacted was the Principal of Curry Demonstration School, Mr. Herbert E. Vaughan, Jr., who consented to the use of 75 female students ranging in age from 5-18. Most of the Curry School subjects were tested during part of their regular physical education program with the cooperation of Mrs. Delores J. Watson, Girls' Physical Education Director.

To complete the adolescent group, it was necessary to use thirteen members of a college Archery class of freshmen and sophomore women at the University of North Carolina at Greensboro.

The adult group was comprised of twenty-three volunteers (non-physical education majors) who lived in Reynolds Hall on the University of North Carolina at Greensboro campus. These women volunteered to be in the dormitory at 10 P.M. two nights, a week apart, to participate in the study.

Since it was not practical to ask all subjects to dress alike, they were asked to wear clothes similar to that worn for the first test on the following test.

Score cards (see Appendix D) were prepared ahead of testing time with the subject's name and age in years already recorded.

Test Administration

Two assistants were trained to help with the testing. One assistant took a measurement of the whole foot and the distance from the great toe to the posterior border of the external malleolus to the anterior angle iron (nail) with the wooden caliper described under equipment above. This assistant did all the measurements throughout the test and re-test sessions.

Another assistant was used to take the subjects three at a time to and from the testing area. This assistant also checked the score cards to see that each subject's age and month of birth were properly recorded. Following each one minute reading, this assistant recorded the date and time of that testing. See score card in Appendix D.

Three subjects came to the testing area at one time and were asked to remove their shoes and socks. Each subject was given an individual score card and asked to step upon the Chatillion scale where the total weight was read and recorded on the card. Following the weight reading for each subject, the board was placed on the angle irons and the Chatillion scale was adjusted to zero with a screw driver.

The first subject's total foot length was measured and she was asked to step on the board placing her heels as far back as possible in the heel blocks in a natural stance. If the heel blocks were too near or far apart to be comfortable, they were adjusted and these heel positions were recorded on the score card. The position of the most medial aspect of the head of the first metatarsus of each foot was also recorded.

Next the measurement from the posterior border of the external malleolus to the anterior angle iron edge (nail) was taken and recorded on the score card. Because some subjects failed to have a prominent posterior border at the external malleolus, the assistant measuring from the malleolus placed her index finger firmly against the posterior edge of the external malleolus on each subject. The assistant then placed the end of the wooden caliper against her index finger in order to have a more uniform technique for this measure.

The subjects were not told the purpose of the testing to avoid an attempt to help or hinder their body sway. They were told to look straight ahead at the picture and stand as quietly as possible with arms at the sides. A stopwatch was started by the weight recorder who stooped exactly in front of the scale face where weight readings were taken at 15, 30, 45, and 60 seconds to the nearest one-half pound.

The subjects stepped down from the board and sat down to wait for the second trial following the first trial of the two other subjects.

For the second trial the subject stepped on the board where her feet were placed in exactly the same position as on previous trial. Again she was asked to look straight ahead at the target and stand as quietly as possible with arms at the sides. Again weight readings were taken at 15, 30, 45, and 60 seconds. Then the subject stepped down, replaced the shoes and socks and left the testing area.

A re-test following the above procedures was given exactly one week following the first test at approximately the same time of day (within fifteen minutes).

Treatment of Data

After the four one-minute trials (test and re-test) were finished, the score cards were arranged by age and numbered consecutively 1-118.

Next each scale reading was put into the Reynolds-Lovett formula: (64:287)

$$\frac{\dfrac{\text{total weight of subject (in pounds)}}{\text{partial weight of subject (in pounds)}}}{} = \frac{\text{distance from angle to angle}}{X}$$

The partial weight was the scale reading and the distance from angle iron to angle iron edge was a constant ninety centimeters. The value of X found in the above formula was then subtracted from the distance of the posterior border of the external malleolus from the anterior angle iron. This distance reading was obtained by converting the reading in the nearest one-tenth of an inch to centimeters.

The sum obtained when X was subtracted from the distance gave the point in centimeters anterior to the posterior border of the external malleolus where the line of gravity fell for each scale reading.

To obtain the average range of body sway for each one-minute trial, the lower reading was subtracted from the higher reading. The sum obtained from the first and second reading (taken the same day) were then added and divided by two to get the average for the one test. The same procedure was followed for the re-test readings. Raw scores may be found in the Appendix.

CHAPTER V

ANALYSIS OF DATA

Tests and re-tests were administered to seven girls at the University of North Carolina at Greensboro Nursery School, seventy-five girls in Kindergarten through twelfth grades at Curry Demonstration School in Greensboro, North Carolina, thirteen female students in an Archery class and twenty-three volunteers from a woman's dormitory at the University of North Carolina at Greensboro. The total group consisted of one hundred eighteen subjects.

The Reynolds-Lovett technique of determining line of gravity was the test administered to the subjects. The Reynolds-Lovett technique (64) was accepted at face validity for determining lines of gravity and therefore a sway pattern in relation to the base of support. The Reynolds-Lovett technique had been accepted at face validity when used in studies by Fox and Young (44), Massey (61), and Brown (37).

For all measures the Pearson Product-Moment method of correlation was used to determine reliability.

As evidenced in Table I, the correlation between the first minute of the test and the first minute of the re-test (given one week later) was significant when all scores were combined. There was an r of .21 for 118 subjects. However when the scores for individual groups were tested for reliability between the first minute of test one and the re-test, the following r's were attained: pre-school .40, late

TABLE I

CORRELATIONS AMONGST GROUPS AND
VARIOUS SCALE READINGS

Group	1st min. of T. 1st min. of R.	1st & 2nd min. First test	1st & 2nd min. Re-test	A. D. T & R	No. Subs.
Pre-school	.40	.38	-.37	.66*	12
Late childhood	.11	.39*	.46**	.11	31
Pre-adolescent	.04	-.14	.40	-.01	22
Adolescent	.08	.23	.32	-.06	27
Adult	.10	-.26	.32	.38	26
All Groups Combined	.21*	.06	.24*	.18	118

* Significant at five per cent level of confidence
** Significant at one per cent level of confidence

Key:

T = test
R = re-test
A. D. = average difference
Subs. = number of subjects

childhood .11, pre-adolescent .04, adolescent .08, and adult .10. This low reliability for the individual groups was probably due to the small number of cases in each age group. These low reliabilities also indicate that there is no consistent pattern of sway from a measure taken one week and a second measure taken one week later. Although the subject's feet were placed exactly in the same position as the first time she assumed a comfortable stance each time a one-minute reading was taken, she could easily lean forward or backward slightly which would change the scale readings significantly. No attempt was made to have the subject stand in the same position with regards to her upper body each time a reading was taken. The subject was asked to stand in the comfortable position with hands at sides and looking directly at the target. It should be noted that with the increased number of cases for all groups combined, an r significant at the five per cent level of confidence was attained, however, in spite of the statistical significance the r has a low reliability.

Table I shows that only the late childhood group had a significant r of .39 for thirty-one subjects between the first minute and the second minute of the first test. There seemed to be both statistical and empirical justification to average the first and second minute readings to obtain a more complete picture of the sway in that age group. This averaging was done because the writer observed the amount of sway usually varied in each one-minute reading, and the subject's sway tended to lessen more quickly during the second minute, therefore, she felt an average of that sway should be used for comparisons.

When correlating the difference on reading one and two of the re-test (second session a week later) for the entire group an r of .24 for

118 subjects was found of significance at better than the five per cent level of confidence.

It was believed that this significance resulted from the subject's familiarity with the testing procedures during the re-test--they were more at ease than during the first test and standing in a similar stance for the first and second minute of the re-test.

A reliability coefficient of .98 was obtained when comparing the foot measurement taken during the first test and that taken during the re-test. This foot measurement was the distance from the posterior border of the external malleolus to the anterior angle iron (a nail placed exactly above the angle iron edge).

The total foot measure taken for each subject and the measurement from the posterior border of the external malleolus to the anterior end of the great toe were not used in this study. These measurements were found to exhibit a very low reliability which can possibly be explained by the positioning of the toes. The foot measurement taken from the posterior border of the external malleolus to the anterior angle iron edge (nail) was used to obtain the points at the base of support where lines of gravity fell. The latter measurement was more reliable because the positioning of the toes did not affect this measure.

Although statistically significant r's of .21 (correlating the first minute of the test and the first minute of the re-test) and .24 (correlating the first and second minute of the re-test) were obtained with 118 subjects, these are considered low reliabilities.

Two examiners measuring the distance from the posterior border of the external malleolus to the anterior angle iron edge had an objectivity coefficient of .93 for nine sample subjects.

Objectivity for the scale reading may be found in Table II. A coefficient of correlation of .52 for nine subjects selected at random was found. This coefficient of correlation was not statistically significant at the level of confidence of five per cent or above.

TABLE II

OBJECTIVITY

Reading	n	r
Foot Measurement	9	.93**
Scale Readings	9	.52

** Significant at the one per cent level of confidence

This resulting coefficient was probably due to the impossibility of both examiners to focus their eyes level with the scale pointer. Other factors to consider were that a stopwatch was used to time the one-minute test and the two examiners did not look up from the stopwatch to the scale at exactly the same time; since the body was shifting, the reading could easily vary from one-half to two pounds.

The sixteen scale readings taken at 15, 30, 45, and 60 seconds during the four one-minute tests and the two foot measurements taken during the testing period are located in the Appendix and listed under Raw Data.

Since this study was interested in differences which might exist among the five age groups, it was determined that Fisher's "t" formula for correlated means should be used in evaluating the difference between means within each group.

Means and standard deviations were calculated in order to compare each individual within the group with regard to age and average body sway. From the calculations mentioned above it was possible to examine the data to see if there was any significant difference between individuals within the five age groups. The hypothesis was that no differences existed within the groups.

The data listed in Table III suggests that the null hypothesis was found tenable and that any difference within the groups existed through chance.

The five groups were then compared with each other to determine if any significant differences existed between the groups. To test the hypothesis of no difference among the five groups, each subject's average line of gravity score was determined from the four, one-minute tests and the sum of these scores for the group was computed and used in the hypothesis testing. No values of "t" but the one between the pre-adolescent and adult were found to be statistically significant, and therefore the null hypotheses were found tenable. The hypothesis that there was no difference between the pre-adolescent and adult group was found not to be tenable at the five per cent level of confidence. Table IV reports these findings.

This difference between the pre-adolescent and adult age groups possibly may be explained by the morphological differences between the age groups. According to Phelps, Kiphuth and Goff (23), the neck and upper back of the pre-adolescent should be nearly vertical. Phelps, Kiphuth and Goff also stated that the position of the lower back and

TABLE III

FISHER'S "t" TEST FOR CORRELATED MEANS

Group	Number	Mean	df	Fisher's t
Pre-school	12	.10	10	.51
Late childhood	31	.12	29	.92
Pre-adolescent	22	.19	20	.12
Adolescent	27	.22	25	1.34
Adult	26	.09	24	1.18

TABLE IV

FISHER'S "t" TEST FOR DIFFERENCE BETWEEN UNCORRELATED MEANS

Group	M_1	M_2	SD_1	SD_2	Fisher's t
Pre-school-Late child.	1.16	1.01	.55	.65	.70
Pre-school-Pre-adol.	1.16	1.16	.55	.50	-.01
Pre-school-Adolescent	1.16	1.00	.55	.55	.85
Pre-school-Adult	1.16	.89	.55	.36	1.75
Late child.-Pre-adol.	1.01	1.16	.65	.50	-.92
Late child.-Adolescent	1.01	1.00	.65	.55	.10
Late child.-Adult	1.01	.89	.65	.36	.83
Pre-adol.-Adolescent	1.16	1.00	.50	.55	1.10
Pre-adol.-Adult	1.16	.89	.50	.36	2.16*
Adolescent-Adult	1.00	.89	.55	.36	.80

* Differences significant at the five per cent level of confidence

abdomen are quite different from that of the adult. The pre-adolescent frequently has a marked lordosis with a moderately prominent abdomen. Maple (60) describes children from 10-14 years of age as having a most striking body contour with scapula in a position flat against the back, but with the head markedly more forward than in the case of smaller children. Maple supports Phelps, Kiphuth and Goff's observation concerning the marked lordosis. Maple adds that a marked body tilt may be evidenced in the pre-adolescent.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This study was conducted to determine if any similarity existed in the anterior-posterior body sway of different age groups of females in relation to the base of support as measured from the posterior border of the external malleolus. Subjects ranging from three to twenty-two years of age were divided into pre-school, late childhood, pre-adolescent, and adult age groups. A total of one hundred eighteen subjects were administered four one-minute tests, the first two one-minute tests were administered during one week and the last two one-minute tests were administered a week later.

During the testing sessions, the subject's total weight was recorded first, then the subject stepped upon a balance board where a measurement was taken from the posterior border of the external malleolus to the anterior angle iron. An illustration of these sites may be found in the Appendix. While the subject stood quietly on the balance board, scale reading were taken at 15, 30, 45, and 60 seconds.

The Reynolds-Lovett technique was used to determine the body sway.

There was a statistically significant reliability score between reading one of the Reynolds-Lovett test and reading one of the re-test.

The foot measurement data yielded a reliability of .98 for 118 subjects.

There was a statistically significant difference between the mean line of gravity readings of the pre-adolescent and adult groups. This difference was believed to be due to the marked differences in morphological characteristics in each of the groups.

On the basis of this study the following conclusions can be drawn:

1. There was no statistically significant difference among scores within any of the age groups.

2. There was a statistically significant difference between the pre-adolescent and adult groups with respect to line of gravity. This can probably be explained by marked morphological differences between the two age groups.

3. In this study, the administration of the Reynolds-Lovett technique was executed by two people. This produced a statistically unreliable measure of body sway. The reliability could be improved by using photography to obtain the scale readings.

4. Measurements regarding the foot position were found to be reliable.

5. No generalization can be made concerning the location of line of gravity in different age groups. The fact that a definite pattern of sway exists within all individuals was evident.

CHAPTER VII

CRITIQUE AND SUGGESTIONS FOR FURTHER STUDY

The writer feels the strongest factors in this study were the organization of the testing procedures, the foot position apparatus, and the reliable foot measure.

The factors which contributed to the study's weaknesses were variations in body sway, the inconvenience of moving the equipment from one testing station to another, and absenteeism among the students.

A number of subjects were observed who swayed a great amount one way or the other, but this deviation often was not recorded because it was not time for a reading to be taken.

Many subjects complained of their legs hurting following the quiet standing for one minute, but most of those were observed as standing with hyperextended knees. Some subjects complained of a dizzy feeling from staring at a multi-colored circle on the wall. Consequently the target was changed to a picture to reduce visually associated dizziness.

The students' attitude in general was good towards the testing. They felt it was a challenge to stand quietly for one minute. The young age group subjects were exceptionally cooperative on the tests.

It is suggested that future tests concerned with body sway should have the subjects stand for less than one minute at each testing and record the scale reading every five seconds.

Since when two persons took the scale readings the correlation between their readings was low, it is suggested that photography be used to obtain the various scale readings.

It is also suggested that future studies of this type arrange the testing so it can be done at a central location, even though the factor of unfamiliar surroundings may have an effect on the younger subjects.

A study concerning line of gravity and adult morphology might be an interesting research study.

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APPENDIX

APPENDIX A

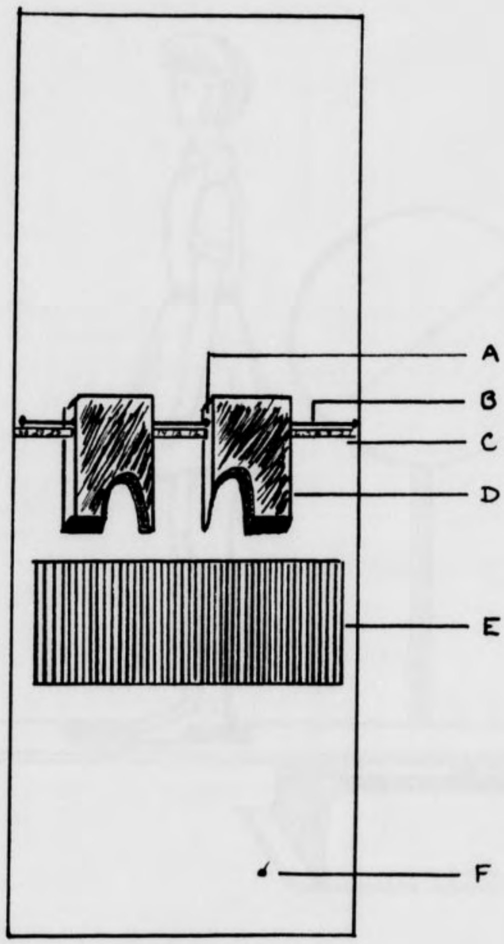

FIGURE 1

DIAGRAM OF FOOT DEVICE

A = Adjusting nut
B = Adjusting screw
C = Heel position scale and guide for heel blocks
D = Heel blocks
E = Metatarsal placement section
F = Nail at anterior angle iron

APPENDIX B

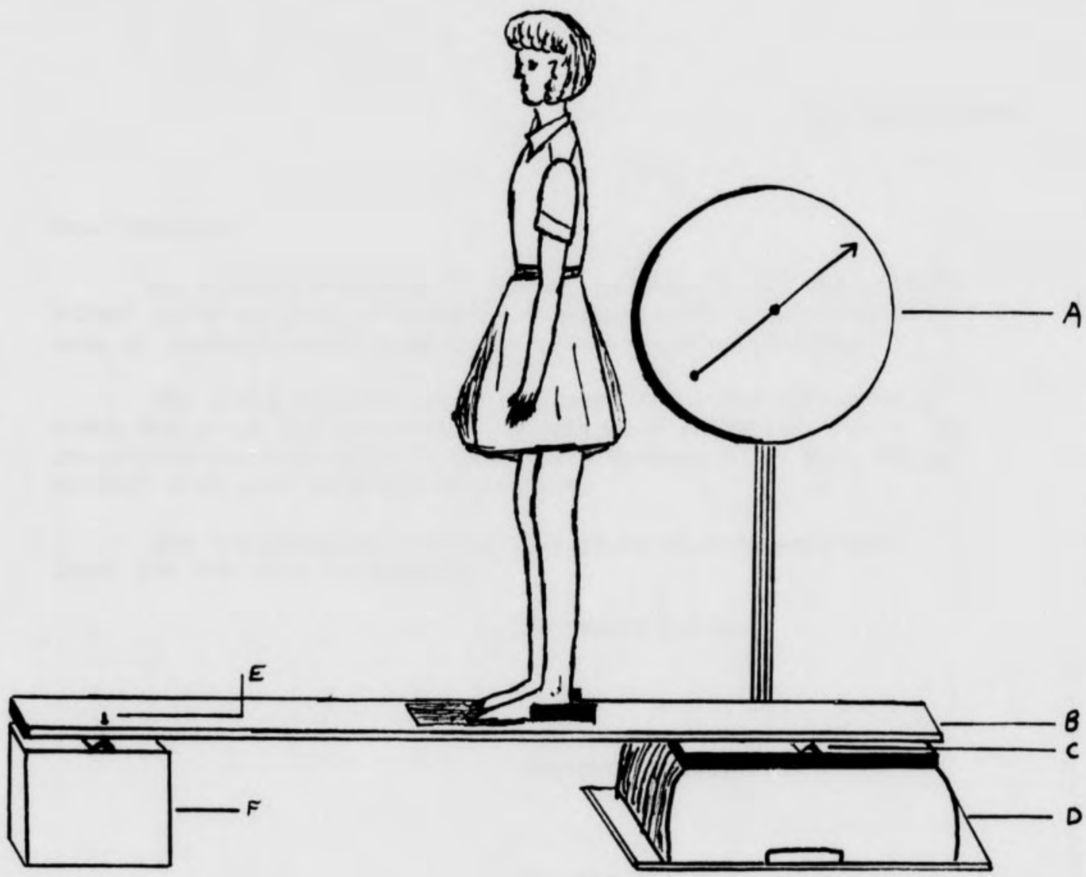

FIGURE 2

DIAGRAM OF EQUIPMENT

A = Chatillion scale
B = Balance board
C = Angle iron
D = Plywood board
E = Nail above anterior angle edge
F = Block

APPENDIX C

February 2, 1965

Dear Parents:

On Monday, February 15 and 22, we plan to use the nursery school girls as part of a Master's thesis study concerning body sway of females (ages 3-20) in an erect standing position.

The girls will be asked to stand on a board supported by a scale and block for one minute to determine their body sway. Two one-minute readings will be taken each Monday, so it will be important that your daughter be present.

Any inquiries concerning this study will be welcomed. Thank you for your cooperation.

Sincerely yours,

Carol Swim
Graduate Fellow

Celeste Ulrich
Thesis Advisor

APPENDIX D

Menses
J F M A M J
J A S O N D

#________ NAME____________________________________ AGE________

WEIGHT:
1st________
2nd________

FOOT LENGTH:
1st total________
t to m________
2nd total________
t to m________
1st m to nail________
2nd m to nail________

FOOT POSITION:

1st
Heels________
R.F.______ L.F.______

Heels________
R.F.______ L.F.______

2nd
Heels________
R.F.______ L.F.______

Heels________
R.F.______ L.F.______

SCALE READINGS:

1st	2nd	3rd	4th
15________	15________	15________	15________
30________	30________	30________	30________
45________	45________	45________	45________
60________	60________	60________	60________
Date: /	Date: /	Date: /	Date: /

SCORE CARD

APPENDIX E

PRE-SCHOOL RAW DATA

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
1	3	32½	33	17.3	17.3	14½	15	14	14½	15	15	15	15½	15	14½	15	15	15	15½	15	15
2	3	39½	40	17.1	17.1	18	18	18½	19	18	18	18½	18	18	18	18	18½	18	18	18½	18½
3	3	30	30	17.3	17.3	14	14	14	13½	14	13½	14	14	12½	12½	13	13	13	13	13	13
4	3	38½	39	17.2	17.2	18½	17	17½	17½	17	17	16½	17	16½	17	16	16	17	17	17½	17
5	4	30	30½	17.4	17.3	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14½	14
6	4	38	38	17	17	17	17½	17½	17½	17	17	17	17	17½	18	17½	18	18	18	17½	18
7	4	38	38	17	17	17½	18	18	17	18	18	17	18	17½	17½	17	17½	17½	17	17½	17½
8	5	32½	32	17.3	17.3	15	15	15	15	15	14½	14½	15	14½	14½	14½	15	14½	15	15	15
9	5	50½	51	17.3	17.3	22	21½	22½	22	22½	22½	22	22½	23	23	23	22½	22½	22½	23	23
10	5	50	49½	17.3	17.2	23	23	23	22½	23	22	22	22½	22	22	22½	21½	22	21	22	21½
11	5	35	34	17.3	17.3	15	15	15½	15	15½	15½	16	16	16	15½	15	15½	15	15	15	15
12	5	50	50	17	17	23	23	22½	22½	23	23	23	23	22	22	22	22½	21½	22	22	22

KEY:

S = Subject number
A = Age (in years)
T. Wt. = Total weight of subject (in pounds)

Ft. M. = Foot measure from malleolus to angle edge (in inches)
1st Min. = Minute and readings taken during that minute (in pounds)

LATE CHILDHOOD RAW DATA

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
13	6	44	43	17.1	17.1	19	18½	19	19	19	19	19	19	18½	18	19	18½	19	18	19	19
14	6	42	43	17.1	17.1	18	18	18	19	18	18½	18½	18	19	19	19	19½	18½	19	18½	18
15	6	53	52½	17	17	23½	23	23	23	23	23	22½	23	23	23½	23½	23	23½	23	23½	24
16	6	45	45	17.2	17.2	20½	20½	20	21	20	20	20	20½	20½	20	20	20	20½	20½	20	20
17	6	44½	44½	17.2	17.1	20	20	20	20	19½	20	20	19	20	20	19½	20	19½	19½	20	20
18	6	48½	47	17.2	17.2	21½	22	22½	22	22	22	22	22	21½	22	22	21½	21	22	21	21
19	6	57½	58	17	17	25½	25½	25½	26	25½	25	26	25½	25	26	25	26	25	25½	26	26
20	6	51	52	17.1	17.1	23	23½	23	23	23	22½	23	22½	23½	23½	23	23½	22½	23	23	23½
21	6	47½	47½	17.3	17.3	21	21½	21	21½	21½	21½	21½	21½	21	21	21½	21	21½	22	21½	21½
22	7	52	52	17.2	17.2	22½	23½	23½	23	23½	23	23	22½	22½	22½	23	23	22½	22	23	22½
23	7	55½	56	17.4	17.4	24	24	24½	24½	24	24	24½	24½	24	24	24	24	24	24	24	24½
24	7	57	56½	16.9	16.9	25	25	24½	25	25	25½	25	25	24½	25	25	24½	24½	24½	24	24½

KEY:

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Ft. M. = Foot measure from malleolus to angle edge (in inches)
1st Min. = Minute and readings taken during that minute (in pounds)

LATE CHILDHOOD RAW DATA (CHART 2)

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
25	7	56	57	17.2	17.2	25	24	25	25½	25½	25½	25½	26	25½	26	25½	26	26½	26	26	26½
26	7	52	53	17.1	17	21	22	22	22	22	21½	21½	22	22½	22	22	22½	22	22½	22½	22
27	7	69	69	17	16.9	30	30	29½	29½	30½	31	30½	30½	29½	31	30	30½	30½	30	30½	31
28	8	58	59	16.9	16.9	26	26	26	26	26	26	26	25½	26	25½	27	26	26	25½	27	27
29	8	59½	59½	17	17.1	26	26	26	26	26	26	26	26	25½	25½	25½	26	26	26	26	26
30	8	44½	44½	17	16.95	20	20½	20½	20	20	20	20	20	19½	19½	20	19½	20	20½	20	20
31	8	67½	68	17	17	30	29	29	29	28½	28½	28	29	29	28½	28½	29	28½	29	28½	28½
32	8	55	53½	17	17	24	24½	24	24½	25	25	25	25	24	24	24	23½	24½	24	24	24
33	8	76	76	16.8	16.8	33	33	33½	33	33	33½	34	33	34	33½	34	33½	34	34	34	33½
34	8	65½	66	15.9	16.9	29	28½	28½	28	29	29	29	29	30	30	29½	30	29½	29	29½	29½
35	9	68	70	16.7	16.7	30	30	30	30	30	30	30	30	30½	30	30	30	30	30	29½	29½
36	9	51	51½	16.9	17	22	22½	22	22½	22½	22½	23	22½	21	21	21	21	22	21	21	21

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Ft. M. = Foot measure from malleolus to angle edge (in inches)
1st Min. = Minute and readings taken during that minute (in pounds)

LATE CHILDHOOD RAW DATA (CHART 3)

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
37	9	55	54½	16.7	16.7	23½	24	24	24	23½	23	23	23	23	23	23	23½	23½	23½	23½	23½
38	9	59	60	17	17	27	27	27½	27	27	27	26½	27	28	28	28	27	27½	27	27½	27
39	9	57	57	16.8	16.8	23½	24	23	23½	23	22½	22½	23	23	23	23	22½	23	22	22	21½
40	9	63	63½	17.2	17.1	26	28½	28	28	27	26	27½	28	28	27	28	28	27½	28	28	28
41	9	71	72	16.9	16.9	31½	31	31½	31	32	32	32	31½	32	31	32½	32½	32	32	32	32½
42	9	59½	59½	17	17	25	25	25	25	25	24½	25	24½	24	24	24	24	23½	24	24	24
43	9	75½	75	16.8	16.8	30	31	31½	30	30	30½	31½	31½	31½	30½	30½	30½	30	30	31	30

KEY:

S = Subject number
A = Age (In years)
T. Wt. = Total weight of subject (In pounds)

Ft. M. = Foot measure from malleolus to angle edge (In inches)
1st Min. = Minute and readings taken that minute (In pounds)

PRE-ADOLESCENT RAW DATA

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
44	10	78	78	17	17	33½	31	31½	31½	33	33	33½	33½	33	33	32½	33	33	33	33	33
45	10	62½	63½	16.9	16.9	28½	28	28	28	28	28	28	28	28½	29½	28½	29	28½	28	28½	28
46	10	55	54	17.1	17.1	23	22½	23	23½	23	23	23	22½	23½	23	23	23	23½	23	23	23½
47	10	126	125½	16.5	16.5	52	52	51½	50½	55	54½	55	54½	56½	55	53½	52½	55½	55½	55½	53
48	10	59½	58½	16.8	16.9	25½	26	25½	26	26	25½	25	25½	25	25½	26	25½	25½	26	26	25½
49	10	85	84½	16.5	16.5	34	33	34	34	34½	34½	35	34½	35	35	35	34½	34	34	34	34
50	10	68	68	16.9	16.8	26	27	26	26	28	27½	27	27	28½	29	29½	30	28½	28	28	27½
51	10	61	62	16.8	16.8	26	26½	26½	26½	26	27	27½	26½	27	26	26	26	25½	25½	26	26
52	11	71	72½	16.9	16.9	31	30	31	30	30	30	30½	30½	20½	30½	31	30½	31	31½	31	31
53	11	74½	75½	16.9	16.9	30½	31	30½	31½	31	31½	31	31½	31½	31½	31½	32	30	30½	31	31
54	12	120½	120½	16.7	16.7	45	46	46½	47	44	44	42½	43	43	44½	45½	45	41½	43½	44½	43½
55	12	95	95	16.5	16.5	38	37	37½	37	38	38	39	39	40	39	38½	39	37	37	38	37½

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Ft. M. = Foot measure from malleolus to angle edge (in inches)
1st Min. = Minute and readings taken during that minute (in pounds)

PRE-ADOLESCENT RAW DATA (CHART 2)

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
56	12	107½	108	16.7	16.7	43½	44½	45	45	43	43½	44	44	45	45	44½	44	44	44½	43½	44
57	12	89	88½	17.2	17.2	36	35½	36	36	35	36	36½	36	34½	34½	35½	35½	35	36	35½	35½
58	12	122	122	16.5	16.5	52½	51½	52	52	52½	53	51	53	52	53	53	53	53	52	52	51
59	12	102½	102	16.6	16.6	41½	41½	40½	40½	42	40½	41½	42	41	40½	40½	40½	40½	40½	40	40½
60	12	104½	105	16.8	16.8	42	43	44	45	41½	42	44½	42	44	43½	43½	43	42	42½	43	42½
61	12	110	110	16.8	16.8	41	41	40½	41	43	42	43½	44	41½	42	42	42½	43	43	43½	44½
62	13	102½	101	16.6	16.6	43½	44	42½	42	44½	44½	44	45	45	44½	44	43	44½	44	44½	46
63	13	77	77	17	16.9	31	32	32½	32½	31	32	33	32	32	31	31½	32	30	31	32	31½
64	13	111	112½	16.8	16.8	47½	47	47	46½	46½	48	47½	48	48	48	48½	49	48½	48½	48	49
65	13	95	96	17.2	17.1	40	40	40	39½	40½	40	40	40	40½	40½	41	40½	41	40½	40½	40

KEY:

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Ft. M. = Foot measure from malleolus to angle edge (in inches)
1st Min. = Minute and readings taken during minute (in pounds)

ADOLESCENT RAW DATA

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
66	15	111	111	16.7	16.7	44½	44½	45½	46	45	46	46½	46½	49	48½	49½	50	45½	49	49	48½
67	15	173	172	16.5	16.5	68	69	67	66½	68½	68½	69	68	69	69½	69½	69½	69	69	69½	72½
68	15	136	134	16.7	16.7	52	53	54	53	53	54	53½	54	56	55½	55	55	55	55	55½	55
69	15	111	110	16.5	16.5	43	42½	44	45	43½	42	42	43	42	43½	45	45½	44	44	43½	44
70	15	93	93	16.5	16.5	38	39	39	39	37	37½	37½	37½	37	38½	38	36½	37	37	36½	36
71	15	108	107½	16.8	16.8	45	45	45	45½	46	46	44½	45	44	44½	44	44½	45½	45	45	44½
72	15	100½	101	16.8	16.9	39	38½	39	39½	38	39	38½	38	39	39½	39	38½	39½	40	40	40½
73	15	115	115	16.4	16.4	45½	44½	44	44	44	44½	44½	44½	47	46½	47½	47	49	49	49	48½
74	15	138½	141	16.5	16.6	59	57	59	58	58½	59	59½	61	58	60½	60	59	56½	58	58	60
75	15	116	115	16.9	16.8	48	47	46½	46½	48	47½	48	48½	48	47	48	47	47½	48	48	47½
76	15	117	117	17	17	51	52	51½	50	49	49½	50	51	50	50	51	51½	50½	51	52	52
77	16	112	112	16.7	16.7	49	48½	47½	48	48	48½	47	47	47	47	47	47	48	48	48½	48½

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A = Age (in years)
T. Wt. = Total weight of subject (in pounds)
Ft. M. = Foot measure from malleolus to angle edge (in inches)
1st Min. = Minute and readings taken during that minute (in pounds)

ADOLESCENT RAW DATA (CHART 2)

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
78	17	132	133	16.6	16.6	51	50½	52	51½	51	50½	51½	51½	50½	51½	51	52	50	50½	50½	51
79	17	123½	122	16.7	16.7	53½	53	54½	55	54½	55	55	53	53	52	52	53	52½	53	52	52½
80	17	145½	145½	16.6	16.6	62½	63	62	63	60	60	61	61	59½	63	62	62	57½	60	61	59
81	17	110	110	16.7	16.6	41½	42	42½	43	42	43½	42½	44	44½	44½	44½	44½	45½	45½	45½	45½
82	18	136½	136½	16.8	16.7	58½	59	59	59	60	60	59½	60½	58	57½	57	57	57½	58	58	57½
83	18	103½	103	17.2	17.1	42	43	44	44½	44½	44½	45	44	45	44½	45	44	46	45½	45½	45½
84	18	128	129	16.7	16.8	51	51½	52	52	53	53	53	53	53	52½	53	53	53	52½	53	53
85	18	159½	162½	16.5	16.5	62½	63½	63	62½	63	62½	65½	65	65	65½	66	65	65	65½	65	64
86	18	93½	94	16.7	16.7	37	36	36	39	38	37½	37	37½	38	38	38½	38	38	38	38	38
87	19	112	111½	16.8	16.8	48	47½	48	48½	48	47	47	47½	48	48	48	48	48	48	48	48
88	19	118	120	16.5	16.5	48	47	48	48½	47½	48½	48	47	48½	49	49½	49	47	47½	48	48
89	19	123½	123	16.4	16.5	52	51	51½	50	52½	51½	51	50½	54	52	53	51½	55½	55½	54	53

KEY:

S = Subject number

A = Age (in years)

T. Wt. = Total weight of subject (in pounds)

Ft. M. = Foot measure from malleolus to angle edge (in inches)

1st Min. = Minute and readings taken during that minute (in pounds)

ADOLESCENT RAW DATA (CHART 3)

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
90	19	115	116	16.8	16.8	51	50	50	48½	49	50	50	49	50	50	50	50	50½	50½	50	51
91	19	147½	148	16.3	16.3	60	61	60	59	60	60½	60	61	61	61	61	62	62	61½	60½	61½
92	19	144	143	16.6	16.6	58	57½	58	57	60	61	60½	61	62½	61	62	62	62	62	61½	60½

KEY:

S = Subject number
A = Age (in years)
T. Wt. = Total weight of subject (in pounds)
Ft. M. = Foot measure from malleolus to angle edge (in inches)
1st Min. = Minute and readings taken during that minute (in pounds)

ADULT RAW DATA

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
93	20	131	132	16.9	17.0	55	54½	55	55	55	55	55½	56	56½	57	56	56	57	57½	58	57½
94	20	117	119	17	16.8	50	50½	50	50	51	52	50½	50½	50	40½	50½	49½	51½	52	52	50
95	20	116	115	17	16.9	49	49	49	50	51	51½	50½	51	50	52	51	51	50	50	50	50
96	20	107½	107½	16.6	16.7	43½	43½	44	44	44	44½	45	45	44½	44½	44	43½	44	43½	45	44½
97	20	119½	119	16.7	16.6	48	47½	48	48½	48	49	48½	48	45	45½	46	47½	48	46	48	47
98	20	115	116½	17	17	49	49	49	49	49	48	49	49	48½	47½	48	48	49	48	47½	47
99	20	117	116	16.8	16.8	50	49	50	50	50	48½	50	50	48	47½	48	48	48	49	49	49
100	20	109	107½	16.5	16.4	44	43½	44	44	46	45	44½	45	45	44½	45	44½	46	45½	45	45
101	20	99	99	17	17	41	40½	40	40½	43	42	42	42½	44	43	43	43	43	42	42½	43
102	20	123½	123	16.7	16.7	52	53	52	51	52	52	52½	54	53½	53	53½	52	53	54	54½	54
103	20	119	118½	16.7	16.7	47	48½	47½	49½	48	48½	48	49	49	48½	49	47	46	49	46	46½
104	20	115	113½	16.3	16.3	48	47	47	47	46½	47	46½	47	47½	47	48	47½	48	48	47½	47
105	20	129	129	16.8	16.8	52½	52	52	52½	53½	53	54	53½	52½	53	53	53½	53½	53	54	54

KEY:

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ADULT RAW DATA (CHART 2)

S.	A.	T. Wt.		Ft. M.		1st Min.				2nd Min.				3rd Min.				4th Min.			
		1	2	1	2	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
106	20	132	131½	16.5	16.5	56	55	55½	55	54½	54½	56	56	55	56	56	56	55½	55½	56	57
107	21	201	200½	16.5	16.5	80½	81	81	81½	80	80	80	82½	82½	84	85	83½	82	84	84	83½
108	21	134	134	16.7	16.5	55	55½	55	55½	57	57	57½	57	57	57	57½	58	57	57½	57	56½
109	21	116	117	16.8	16.8	48	47½	48	47	48	49	48	48½	48	48	48	48	48½	48	48	48½
110	21	120	120½	16.7	16.7	46	46	45½	45	46½	48	48	48	46	46	48	47	48	49	47	47½
111	21	129	128	16.8	16.8	51	53	54	54	53½	54	53½	54	54	54½	53½	54½	53½	53½	54	53
112	21	118	118	16.7	16.7	46	48	48	46½	50½	49½	49	49	49	48½	47	46½	48	48	47	46½
113	21	122½	124	16.4	16.4	51	51½	52	53	50	52	52	52½	52	53	53	52½	52	53	54	53
114	21	130½	128½	16.3	16.3	54	55	55	54½	55½	56	56	56½	54	55	55½	55	54½	54½	54½	55
115	21	130½	129	16.5	16.5	51½	52	52½	52½	52½	53½	53	53½	51½	52	51½	52	51	51	51	52
116	21	104½	106	16.7	16.7	42½	43½	44	43	45	44½	45	45½	43	43	43½	44	44	43½	44	45
117	22	137	140	16.6	16.5	57	58	57	57	56	57	56½	57	62	62	62	62	60	58	59	59½
118	22	130	132	16.7	16.7	54	54½	54	54	54	52½	53½	54	55	54½	55	56	55	55	54½	55½

KEY:

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