THERAPEUTIC EXERCISE

for Body Alignment and Function

MARIAN WILLIAMS
CATHERINE WORTHINGHAM

W. B. SAUNDERS COMPANY

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MARIAN WILLIAMS, Ph.D.
Assistant Professor of Physical Therapy,
Department of Allied Medical Sciences,
School of Medicine, Stanford University

CATHERINE WORTHINGHAM, Ph.D.
Director of Professional Education,
The National Foundation for Infantile Paralysis, Inc.

EXERCISE ILLUSTRATIONS BY HAROLD BLACK

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Contents

Chapter I

INTRODUCTION: STANDING POSTURE.............. 1

STANDING POSTURE.................... 2

BIBLIOGRAPHY 7

Chapter II

ANALYSIS OF BODY ALIGNMENT.. 9

PROCEDURES USED IN EVALUATION.......... 16

TESTS FOR MUSCLE SHORTENING.......... 28

ADDITIONAL DATA FOR THE RECORD.... 31

BIBLIOGRAPHY 32

Chapter III

THE THERAPEUTIC EXERCISE PROGRAM............ 33

SPECIFIC OBJECTIVES OF EXERCISE THERAPY................... 33

PLANNING THE EXERCISE PROGRAM.......... 33

POINTS IN THE TEACHING OF EXERCISES. 36

FUNDAMENTAL POSITIONS FOR ALL TYPES OF EXERCISES................. 37

BIBLIOGRAPHY 39

Chapter IV

PRINCIPLES OF TREATMENT AND EXERCISES FOR THE VARIOUS AREAS.......... 41

LOW BACK AREA......................... 41

I. Exercises for Alignment and Control of the Lumbar Spine and Pelvic Segment.......... 44

II. Exercises for Stretching Muscle Groups Which Limit Correction of Low Back and Pelvic Alignment.......... 46

Exercises for the Abdominal Musculature.................. 49

A. Exercises for Strengthening Anterior Abdominal Muscles 49

B. Exercises for Strengthening Lateral Abdominal Muscles. 52

Chapter IV (CONTINUED)

UPPER TRUNK AND NECK AREA 55

Thoracic and Cervical Spine 55

I. Exercises for Stretching Intercostal and Pectoralis Major and Minor Muscles 57

II. Exercises for Alignment of Thoracic and Cervical Spine. 59

Shoulder Girdle 61

III. Exercises for Shoulder Girdle Alignment 62

Thoracic Area: Breathing Exercises 65

IV. Breathing Exercises 67

Mobilization of Upper Spine and Shoulder Girdle Area 69

V. Exercises for Mobilization of the Upper Spine and Shoulder Girdle Area 70

EXERCISES FOR THE LOWER EXTREMITIES 71

Thigh and Leg Alignment 71

I. Stretching of Muscles Limiting Correction of Lower Extremity Alignment: Hip Adductors, Internal Rotators, Hamstrings 72

II. Training of Muscles for Improved Alignment of Lower Extremity 74

Foot Alignment and Function 77

III. Stretching of Muscles Limiting Correction of Foot Alignment: Gastrocnemius and Soleus, and Peroneal Group. 79

IV. Exercises for Correction of Foot Alignment.......... 80

BIBLIOGRAPHY 85

Chapter V

POSITIONS OF THE BODY IN ACTIVITY AND REST 87

BIBLIOGRAPHY 104

APPENDIX 105

INDEX 123

Chapter I

Introduction: Standing Posture

THE CASE for good body alignment and function has been stated by many persons over the years. The subject has been approached from several aspects, including the psychologic as well as the purely physiologic and mechanical. General interest in this field is not surprising, as it concerns all of us regardless of our activities and environment. We are constantly subject to the force of gravity in whatever postural position we may assume. This force is utilized in equilibrium and movement, for instance, to provide the necessary friction for locomotion and to stabilize the lower extremity in standing. At the same time the force of gravity places considerable stress on the structures of the body which are responsible for maintaining the upright position. Consequently so-called postural faults are common, and acute distress and disability afflict large numbers of persons as a result of strain and injury to antigravity structures.

An area of the body which is particularly subject to difficulty is the lower back. In a study of 5,353 patients referred for physical therapy in eleven hospitals in the San Francisco Bay region over a period of one year, Semans found that 30 per cent of diagnoses included various types of back disabilities. Of these 70 per cent were in the category of "low back strain" or similar diagnoses. The economic loss from back strain and injury among workers is well recognized. Undoubtedly, a vast number of persons have various degrees of difficulty which are not on the record either in terms of work days lost or clinical treatments given.

Good posture in children is most important, as during the period of growth the body tissues and organs are particularly responsive to stresses placed upon them.

The best defense against these problems is for each individual to learn as much as possible about the postural mechanisms of the body and to apply this knowledge in the most effective manner. Training in the prevention of injury is essential as well as treatment following injury. The approach to improved alignment and function by means of specific exercises is based on the concept that postural adjustment is a homeostatic mechanism which may be voluntarily controlled to a large degree.[1] Repeated conscious correction of faulty alignment and maintenance of good position lead to improved habits. A person with a mild spinal curvature may feel comfortable although he sees in a mirror that his trunk is deviated. When his position is corrected, he feels strange at first even though his eyes tell him that he is now straight. He must constantly correct and overcorrect his faulty position until he can recognize by proprioceptive means that he is in a good position and that the former unbalanced alignment makes him feel uncomfortable. Training of the patient's kinesthetic sense is a fundamental factor in posture correction. In the case of the "low back" patients, positions and movements in which strain is minimized should be practiced until they become habitual.

In order to plan effective treatment it is first necessary to evaluate the subject's condition. The basic criterion used in the grading of body alignment is the standing posture. It has been pointed out by some persons that this has limitations in that standing is a static position and is only one of many postures which the individual may assume in the course of the day. However, it provides a useful means of judging numerous points quickly and accurately, and this approach is supplemented by tests for limitation of joint range, muscle weakness, and so on. As a background for the appraisal of standing posture, some basic elements to be considered are reviewed in the next section.

STANDING POSTURE

The concept of the center of gravity of the body is basic to an analysis of standing posture. It is likewise basic to an analysis of any position of movement or rest, and therefore a concept fundamental to all considerations of body alignment and function. The center of gravity is a point at the exact center of mass of the body. Its location varies among individuals according to their build, and also in a given subject it moves upward, downward, or sideward in accordance with changes in the position of the body segments during activity. The important thing to remember is that an object behaves as though its entire mass were centered at this point. Actually the human body is made up of a number of movable segments, each of which has its own center of gravity. However, in a consideration of standing posture the entire body may be visualized as a whole, with a single center of gravity located in the region of the second sacral vertebra.

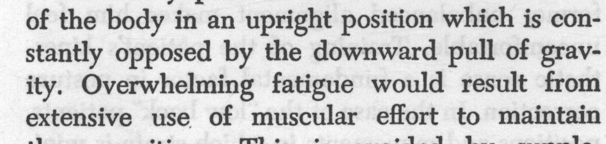

Fig. 1. Early method for determining the height of the center of gravity of the body.

Most daily postures involve the maintenance of the body in an upright position which is constantly opposed by the downward pull of gravity. Overwhelming fatigue would result from extensive use of muscular effort to maintain these positions. This is avoided by supplementary "passive" supporting structures such as ligaments and fascia which assist with the job and save energy. When a person is standing, the suprafemoral mass is supported on the segmented lower extremities in such a fashion that gravity itself is utilized to promote stability.

The importance of two of these subjects mentioned, (1) the location of the body's center of gravity, and (2) stabilizing mechanisms of the lower extremity in the standing position, is reflected in the vast amount of attention they have received in the literature. As early as the seventeenth century Borelli originated the time-honored method of using a plank balanced over a wedge to determine the position of the center of gravity. The subject was placed supine on the plank and moved back and forth until balance was again obtained (Fig. 1). Some years later, the Weber brothers determined by a similar method that the center of gravity lay 56.8 per cent of the distance from the soles of the feet to the top of the head. DuBois-Reymond was apparently the first to use a board supported at one end on a scale to locate the subject's center of gravity, although this was originally suggested by Borelli.[29] Variations in center of gravity height have been reported: 57.99 per cent (Harless) and 54.8 per cent (Braune and Fischer). Recently Hellebrandt and Franseen, using women subjects, found the mean to be 55 per cent. Meyer,[27] Scheidt and Palmer were among those who stressed variability in the location of the center of gravity according to age and sex. The scale method, which has been widely used, provides a convenient means of determining not only the height of the center of gravity but also the position of the so-called gravity line or weight line. This is the vertical projection of the center of gravity with the subject upright (Fig. 2). It may be visualized as an imaginary plumb line passing through the center of gravity of the body.

In order for the standing position to be stable, the line of gravity must fall well within the base of support. The placement of the feet, whether parallel or in a toe-out position, close together or far apart, will influence the stability of the standing posture by providing a base of variable size (Fig. 3). (Foot placement is discussed further on page 71.)

Another factor in standing posture is the constant slight swaying of the body over the feet. Hesser reported the magnitude of these oscillations to be from 0.9 cm. to 2.7 cm. (7 subjects). In his observations the vertical projection of the

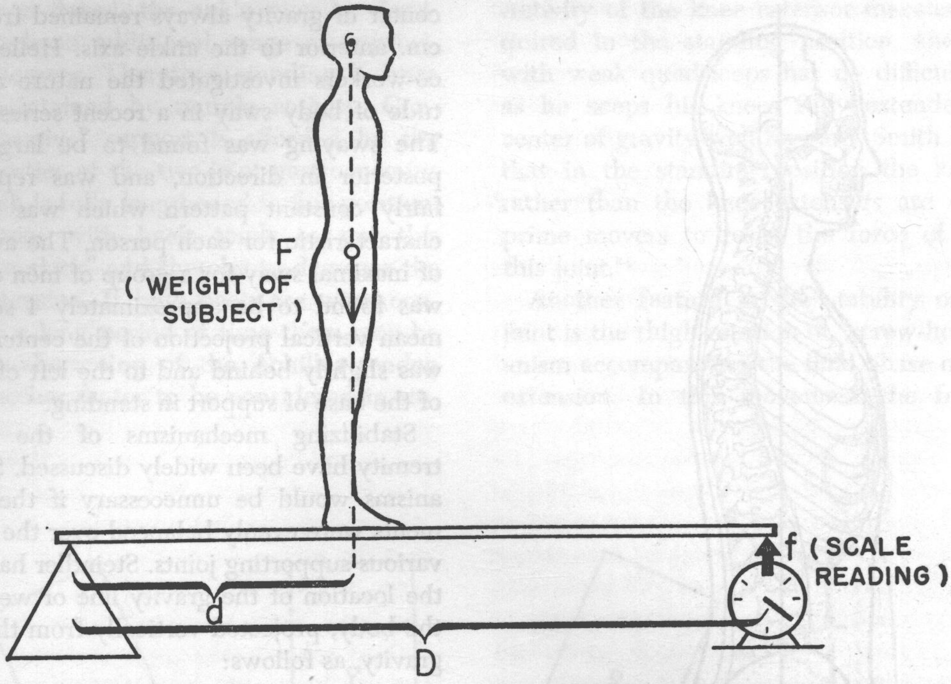

Fig. 2. A convenient method for determining the position of the gravity line of the body (vertical projection from the center of gravity). The length of d can be computed by the formula $d \times F = D \times f$. F, f, and D can be measured; thus $d = \frac{D \times f}{F}$. This gives an accurate picture of anteroposterior balance. To find the gravity line in relation to lateral balance, the subject faces forward on the board.

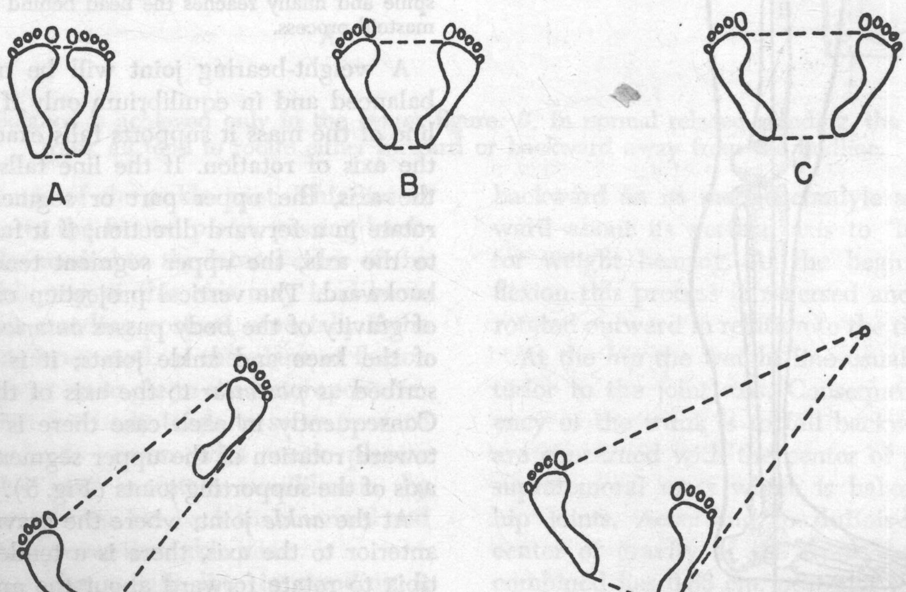

Fig. 3. Various foot positions in standing which provide varying areas of support. The base increases in size from *A* to *D*. *E* illustrates the large area of support made possible by the use of a cane. Crutches would increase the base considerably more.

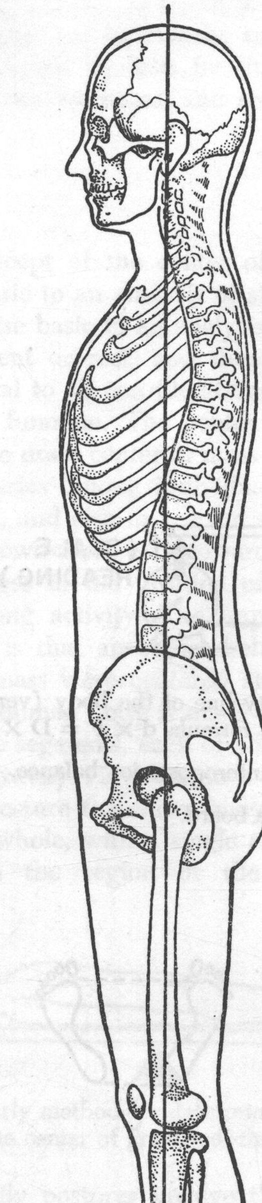

Fig. 4. The vertical gravity line of the body.

center of gravity always remained from 1 to 4.8 cm. anterior to the ankle axis. Hellebrandt and co-workers investigated the nature and magnitude of body sway in a recent series of studies. The swaying was found to be largely anteroposterior in direction, and was repeated in a fairly constant pattern which was remarkably characteristic for each person. The average area of maximal sway for a group of men and women was found to be approximately 4 sq. cm. The mean vertical projection of the center of gravity was slightly behind and to the left of the center of the base of support in standing.[14]

Stabilizing mechanisms of the lower extremity have been widely discussed. Such mechanisms would be unnecessary if the body segments were evenly balanced over the axes of the various supporting joints. Steindler has described the location of the gravity line or weight line of the body, projected vertically from the center of gravity, as follows:

> It arises from the supporting surface between ball and heel in front of the ankle joint; it runs slightly in front of the knee joint axis: in relaxed posture, through or directly behind the center of the hip joint; then it ascends to cut the upper end of the sacroiliac junction. It then runs upward behind the center of the bodies of the lumbar spine and intersects with the spine at the lumbo-dorsal junction; it continues in front of the dorsal spine and intersects with the spine again at the cervico-dorsal junction. It then runs slightly behind the cervical spine and finally reaches the head behind the ear at the mastoid process.

A weight-bearing joint will be mechanically balanced and in equilibrium only if the gravity line of the mass it supports falls exactly through the axis of rotation. If the line falls anterior to the axis, the upper part or segment tends to rotate in a forward direction; if it falls posterior to the axis, the upper segment tends to rotate backward. The vertical projection of the center of gravity of the body passes *anterior* to the axis of the knee and ankle joints; it is usually described as *posterior* to the axis of the hip joint. Consequently in each case there is a tendency toward rotation of the upper segment about the axis of the supporting joints (Fig. 5).

At the *ankle* joint, where the gravity line falls anterior to the axis, there is a tendency for the tibia to rotate forward about the ankle. This is prevented by the guy-wire action of the plantar flexor muscles which are anchored on the calcaneus and pull the tibia backward. Ligaments are not an element in support here because the limit of the joint range has not been reached.

If the knee is flexed, the ankle may be dorsiflexed through an additional range of approximately 30 degrees. Therefore, standing balance must be maintained by muscle activity. Considerable "passive" support is afforded by the elastic properties of the two-joint gastrocnemius muscle which is fully lengthened in this position. Wearing shoes with heels tends to put this muscle "on a slack" and thereby to decrease the supportive tension. If high heels are worn constantly over a long period of time there may be an adaptive shortening of the Achilles tendon muscles. Another factor to be considered in stability is the axis of the ankle joint. This lies at a slight angle to the frontal plane, passing backward from the medial to the lateral sides of the joint. The obliquity of this axis may lend some stability to the standing posture, especially if the feet are pointed outward, as the plane of flexion at the joints is at an angle to the anteroposterior plane in which the body tends to sway forward and backward. A person with weak plantar flexor muscles may maintain equilibrium by keeping his weight farther back than normal and balanced directly over the ankle joints.

At the *knee* the weight line in standing is again anterior to the axis. Here, however, forward rotation of the femur on the tibia is prevented by the strong posterior, collateral and cruciate ligaments, as well as by the muscles passing over the posterior aspect of the joint. Activity of the knee extensor muscles is not required in the standing position, and a person with weak quadriceps has no difficulty as long as he keeps his knees fully extended and his center of gravity well forward. Smith has argued that in the standing position the knee flexors rather than the knee extensors are situated as prime movers to resist the force of gravity at this joint.[34]

Another feature in the stability of the knee joint is the thigh rotation or "screw-home" mechanism accompanying the final phase of complete extension. In this movement the femur rides backward on its medial condyle and rotates inward about its vertical axis to "lock" the joint for weight bearing. At the beginning of knee flexion this process is reversed and the femur is rotated outward in relation to the tibia.

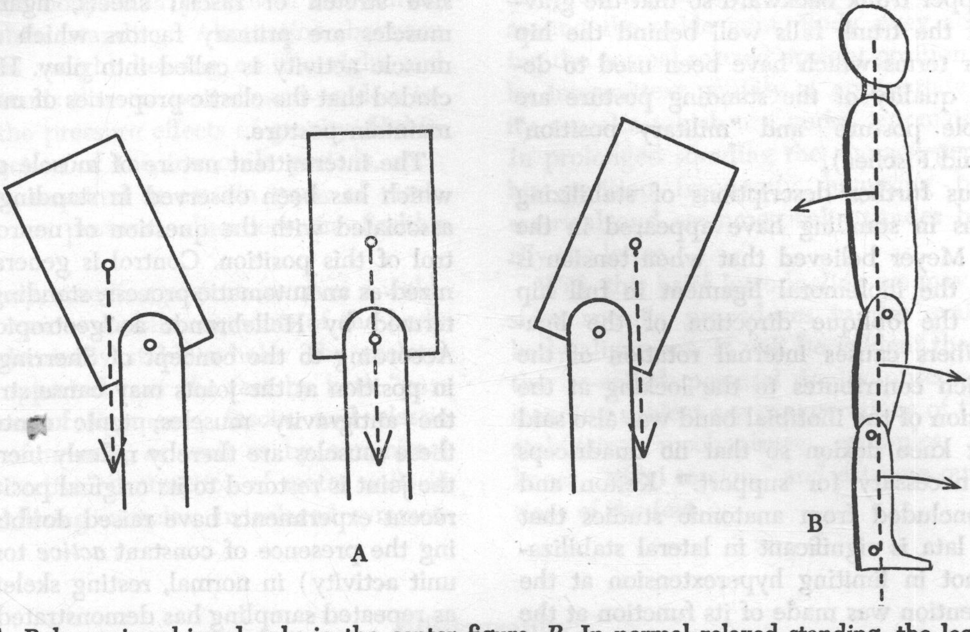

Fig. 5. A, Balance is achieved only in the center figure. *B,* In normal relaxed standing, the leg, thigh, and trunk all tend to rotate either forward or backward away from the midline.

At the *hip* the weight line usually passes posterior to the joint axis. Consequently the tendency of the trunk is to fall backward. Here we are concerned with the center of gravity of the suprafemoral mass which is balanced over the hip joints. According to duBois-Reymond the center of gravity of the trunk, head and arms combined lies 0.86 cm. posterior to the hip axis. On the other hand, Meyer placed it 5 cm. behind the hip axis.[26] It is probable that this distance varies considerably from person to person according to body build and habitual posture. Posterior rotation of the trunk is prevented by the structures which cross the anterior aspect of the hip joint, principally the iliofemoral ligament (see illustration on p. 43), and the hip flexor muscles (p. 113).

Among others, Mommsen has differentiated between "alert" and "relaxed" standing positions. When a person is under tension in standing, for example, when he tries to appear as erect as possible, the trunk weight may be exactly balanced over the hip joints in the sagittal plane. However, in ordinary "relaxed" standing, particularly over a long period of time, it is more common for the pelvis to shift slightly forward and the upper trunk backward so that the gravity line of the trunk falls well behind the hip axis. Other terms which have been used to describe the quality of the standing posture are "comfortable posture" and "military position" (Braune and Fischer).

Numerous further descriptions of stabilizing mechanisms in standing have appeared in the literature. Meyer believed that when tension is placed on the iliofemoral ligament in full hip extension, the oblique direction of the ligamentous fibers causes internal rotation of the femur which contributes to the locking at the knee. Tension of the iliotibial band was also said to prevent knee flexion so that no quadriceps action is necessary for support.[29] Kelton and Wright concluded from anatomic studies that the fascia lata is significant in lateral stabilization but not in limiting hyperextension at the hip. No mention was made of its function at the knee. These authors described a so-called easy standing position in which stability is brought about by osseous and ligamentous arrangements rather than by muscle action. The feet are separated by approximately the interacetabular distance and are turned outward about 25 degrees.

With the subject in this position, Kelton and Wright recorded muscle action potentials from a number of lower extremity muscles. They found that all the thigh and leg muscles tested were electrically silent for long periods of time with the exception of the soleus and anterior tibial muscles. These were sometimes simultaneously inactive for periods of from one to five seconds, although there were also periods of constant activity in the soleus of from five seconds to three minutes and in the tibialis anterior of from two to forty seconds.

Other investigators utilizing the electromyograph have likewise demonstrated that surprisingly little active muscle contraction is used to maintain the standing position. Joseph and Nightingale found activity in the calf muscles, particularly the soleus, but electrical silence in the anterior tibial. Hoefer found very little activity in either the gastrocnemius or anterior tibial muscle in seven standing subjects. After reviewing electromyographic evidence Ralston and Libet ask, "What does maintain a sitting or standing posture if not relatively continuous active muscle contractions serving to lock the joints in position?" They agree that balancing of the body parts and tension resulting from passive stretch of fascial sheets, ligaments and muscles are primary factors which act before muscle activity is called into play. Hoefer concluded that the elastic properties of muscles may maintain posture.

The intermittent nature of muscle contraction which has been observed in standing is closely associated with the question of neurologic control of this position. Control is generally recognized as an automatic process; standing has been termed by Hellebrandt a "geotropic reflex."[13] According to the concept of Sherrington, shifts in position at the joints may cause stretching of the antigravity muscles; tonic contraction of these muscles are thereby reflexly increased and the joint is restored to its original position. More recent experiments have raised doubts concerning the presence of constant *active* tone (motor unit activity) in normal, resting skeletal muscle as repeated sampling has demonstrated electrical silence. Also, there is a question whether the stretch reflex as originally described can be the mechanism responsible for maintaining the upright position when such extremely slight adjustments in joint position are involved. A detailed review of this material is perhaps outside the scope of the present discussion, but interested readers may wish to pursue the subject further. At any rate, during easy standing there appears to be a constant slight swaying of the body, accompanied by intermittent periods of activity in the appropriate antigravity muscles which restore the upright position. This process takes place automatically but is subject to voluntary alteration and control.

Smith has investigated the attitudes of standing assumed during prolonged stance. Two hundred and fifty subjects were observed for at least two minutes, none knowing he was under observation. This author differentiated between "dynamic standing" which reflects a readiness to move in the immediate future, and "static standing" which is characteristic of periods of prolonged immobilization. In the latter, two basic positions were observed: (1) symmetrical stance, with the weight distributed equally on both feet, and (2) asymmetrical, in which nearly all the weight rests on one foot. The asymmetrical attitudes occurred about four times as often as the symmetrical. The mean duration of all positions was about thirty seconds, and 93 per cent were maintained for less than one minute. Frequent shifting of position allows the supporting tissues of the body brief periods of rest during long immobile standing. Alternation between asymmetrical weight bearing on the right and left foot extends the rest periods and renders intermittent the pressure effects of gravity. Habitual prolongation of the immobile periods, such as might be required in certain types of work, may lead to postural disorders in Smith's opinion.[35]

In summary, standing posture involves a welding of the various mobile segments of the body into a mechanically stable whole. The skeletal parts are supported over the feet by both "passive" tension of ligaments, fascia, and elastic properties of muscle, as well as by a minimal amount of "active" contraction of motor units in certain stabilizing muscles. In relaxed symmetrical standing both the hip and knee joints assume a position of full extension as they support the superincumbent weight. The knee joint has an additional stabilizing element in its "screw home" mechanism; here rotation is superimposed on full extension to lock the joint more firmly. At the ankle there is no bony or ligamentous limit to motion. However, passive tension of the two-joint gastrocnemius muscle is a factor in stability since the knee is extended and the body leans slightly forward from the ankles. This stabilizing force is decreased by the wearing of heels. It is not surprising that in standing, action potentials are present primarily in those muscles which act around the ankle joint. Body sway accompanying the normal relaxed upright position is limited by intermittent activity of appropriate antigravity muscles which are under automatic control. In prolonged standing the average person shifts his position frequently, assuming both symmetrical and asymmetrical attitudes but primarily the latter.

With this brief introduction we may next consider specific procedures in the evaluation of body alignment. It will be evident that many of the so-called postural faults observed in the standing subject are exaggerations of the normal stabilizing mechanisms; examples are back knees, "tibial torsion," and extreme out-toe positions of the feet.

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Chapter II

Analysis of Body Alignment

An appraisal of body alignment serves a dual purpose: First, it acquaints the examiner with the postural deviations of the subject and thereby serves as a guide for the exercise program; and second, it provides a record for future reference from which to evaluate progress. In order to judge alignment as accurately as possible, a number of methods have been described in which specific grading is based on reasonably definite criteria. Among others, Cureton and Clarke have summarized the currently available methods.

Many workers investigating body alignment have made use of mechanical aids in an attempt to increase the objectivity of measurement. However, there is a danger that the beginner may become so preoccupied with slight deviations of the various segments that he misses the more basic picture of overall body balance. For this reason it is advised that the student first master the method of sighting total alignment and then estimating deviations with a grade of "mild," "moderate," or "severe" degree. After he has grasped the fundamental concept of "good" and "poor" alignment of the body segments and has gained proficiency in judging posture by inspection, he may then wish to investigate the use of such apparatus as goniometers, metal pointers, and spirit levels in a further refinement of his techniques.

Appraisal of postural malalignment, like that of any specific deformity of the body, rests on the concept of a so-called "normal" standard. It should be remembered that individuals with different types of body build may be expected to have variations in alignment which lie well within acceptable limits.

The first step in evaluating standing posture is to sight the overall balance of the body. The body weight should be evenly supported in an

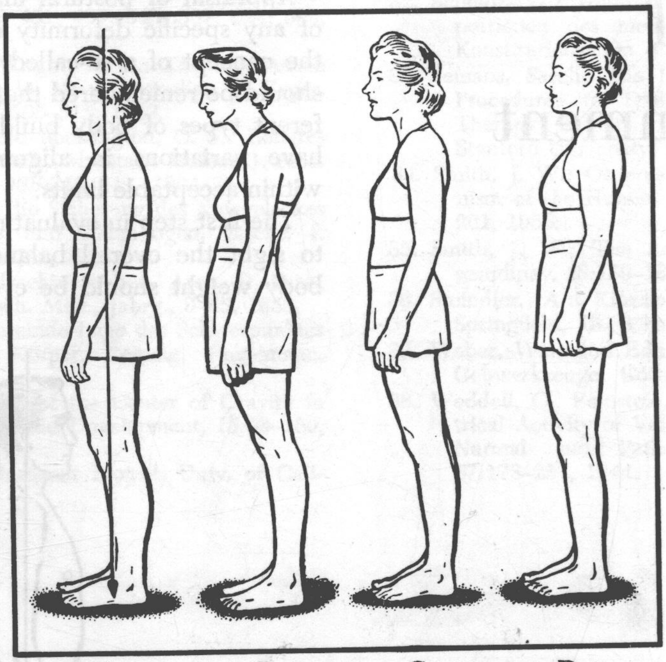
Fig. 6. External landmarks associated with the vertical gravity line.

anteroposterior direction and not shifted abnormally far forward over the balls of the feet, or backward over the heels (anteroposterior balance). Likewise, the subject's weight should be borne evenly on both feet and not shifted to either the right or left sides predominantly (lateral balance). The alignment of the individual segments above the feet is considered next.

Deviations in the sagittal plane, or in an anteroposterior direction from the vertical gravity line, are viewed from the side. They must be judged for the posture record from external bony landmarks. For this purpose the examiner may visualize a hypothetical vertical gravity line starting from the floor which should pass upward anterior to the outer malleolus, just posterior to the patella, through the greater trochanter of the femur, the middle of the tip of the shoulder, and the lobe of the ear[9] (Fig. 6). The line is described from the stable point, or contact of the feet with the floor, to emphasize the concept that posture involves a series of superincumbent segments, all of which are balanced over the feet.

Flexible individuals with an abnormal degree of mobility tend to have exaggerated anteroposterior spinal curves and to stand with the hip and knee joints hyperextended. The pelvis is shifted forward, the thorax backward, and the head forward. Here the distance from the hip and knee axes to the vertical gravity line is greater than normal, and abnormal strain is put upon the supporting joint structures.

Deviations in the frontal plane, or laterally from the midline, may be judged from the anterior or posterior view. The gravity line ideally bisects the body into two symmetrical halves. Although slight deviations are common, irregularities in symmetry beyond a minor degree



A B C D

Four types of anteroposterior body alignment commonly seen.

A. The segmental alignment in this subject is close to the so-called "normal" concept. A vertical line visualized by the examiner or a plumb line suspended at the side of the subject would pass midway between the heel and ball of the foot, behind the patella, over the trochanter, the acromion, and the lobe of the ear. The spinal curves are not exaggerated.

B. "Relaxed" posture is demonstrated in this subject, who has a forward head, kypholordosis, anterior tilt of the pelvis, and back knees. The pelvis, upper trunk, and head are shifted away from the vertical gravity line. The abdominal muscle, thoracic spine extensors, and adductor muscles of the scapulae are relaxed.

C. Here the body weight is shifted forward over the balls of the feet. The subject has a forward head, lordosis, anterior pelvic tilt and back knees.

D. In this subject the upper trunk and head are carried back over the heels. There is a mild kypholordosis and the scapulae are abducted so that the acromion has shifted slightly forward.

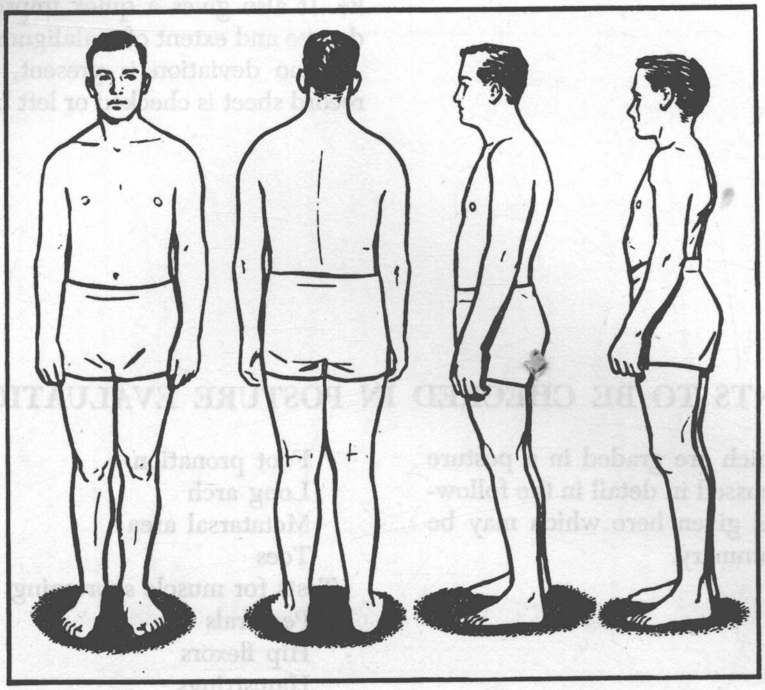
should be carefully noted, as they may indicate a short leg, muscle weakness in the trunk or hip area, or incipient spinal curvature (scoliosis).

Occasionally, certain lateral displacements are more apparent from the front than from the posterior view. It is a good idea to check alignment from both aspects; however, sometimes subjects tend to align themselves in relation to the examiner when he stands in front where he can be seen.

In judging alignment it may be helpful to have the subject stand at an angle to a mirror over which a long plumb line is hung, or to suspend a plumb line by hand to serve as a guide. In this way, not only total balance but gross deviations in the position of the pelvis, thorax and head may be noted at the outset. Segmental deviations are often graded according to their relation to neighboring segments. This procedure is valid only if the segment used for a point of reference is in a good position, which is often not the case.

If the subject is tense during a posture examination and holds himself in a rigid and unnatural position, try to put him at ease and, if necessary, tell him to stand in a more relaxed fashion. Also, he may tend to correct his specific faults momentarily even though he is unaware of doing so. It is a good precaution to glance back from time to time over points already recorded in order to make sure the position has not changed significantly.

The various points to be recorded in the posture examination are indicated on the record form on page 14. This information may be kept conveniently on printed sheets or large



A B C D

Examples of lateral and anteroposterior balance.

A, *B*, and *C* are views of the same subject. An analysis of his posture is entered on the record sheet on page 14 to illustrate the use of the symbols in grading.

A. The body weight is shifted slightly toward the left side as seen in the anterior view. The left shoulder is high and rotated forward so that the left arm is carried farther anteriorly than the right arm. The subject has mild bilateral knock knees.

B. The posterior view shows a left total curvature of the spine, a high left shoulder, asymmetrical trunk contours, knock knees and pronated feet.

C. The anteroposterior balance is "relaxed" with increase in the physiologic spinal curves. The pelvis is shifted forward, the upper trunk backward, and the subject is "leaning" on his iliofemoral ligaments to help support the trunk. The head is forward.

D. The lateral view of a subject with abdominal muscle weakness shows marked lordosis, anterior pelvic tilt, and flaring of the lower ribs.

cards and filed with the patient's history. There should always be sufficient space provided in such a record for additional data or comments as the symbols alone are not always fully descriptive. A special form should be used for scoliosis cases.

Materials needed for a posture examination of the type suggested include:

Record sheet
Pen
Plumb line
Skin pencil, for marking spinous processes and other landmarks
Flexible steel measuring tape, for chest and leg measurements

A colored pencil may be used to record deviations of moderate or severe degree. This makes it easy to see in a quick survey of the record sheet the areas in which the subject's problems lie. It also gives a quick impression of the total degree and extent of malalignment.

If no deviation is present, the space on the record sheet is checked or left blank.

POINTS TO BE CHECKED IN POSTURE EVALUATION

Specific points which are graded in a posture examination are discussed in detail in the following section. A list is given here which may be used as a guide or summary.

- Body type
- Body balance:
  - Anteroposterior
  - Lateral
- Alignment of segments:
  - Head
  - Chest
  - Shoulder level
  - Scapulae
  - Hip level
  - Abdomen
  - Spine
  - Legs
  - Foot pronation
  - Long arch
  - Metatarsal area
  - Toes
- Tests for muscle shortening:
  - Pectorals
  - Hip flexors
  - Hamstrings
  - Lumbar extensors
  - Tensor fascia latae
  - Gastrocnemius-soleus
- Chest expansion measurements
- Leg length measurements

The examiner should also look for signs and symptoms of malnutrition, fatigue, hypertonicity and the like. He may test for specific muscle weakness whenever such tests appear to be indicated. Space is available in this section for notes, alternate procedures, or additional tests the examiner may wish to add. The beginner is often puzzled by whether or not a slight deviation should be noted in the record, and to what extent malalignment must be present to be classified as first, second or third degree. He will arrive at the answers for himself after he has checked many persons of various ages and body types. Consistent judgment comes only with experience.