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BILATERAL ASYMMETRY IN THE ALIGNMENT OF THE SKELETAL FRAMEWORK OF THE HUMAN BODY

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requirements for the degree of Doctor of
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PREFACE

From 1928 to 1931 the investigator took surface measurements of the relation of various parts of the body of students in her classes. These measurements, which were taken three different times both before and after a period of instruction in posture and body mechanics, included: standing height, sitting height, and anteroposterior and diagonal relationships of various bony landmarks of the body. The anteroposterior measurements were taken with the Posturimeter,* an instrument designed and constructed by the American Child Health Association and used by the Association to measure the posture of many school children.**

The fundamental assumptions on which the teaching procedure used in the experimental study was based were formulated by the investigator after attending a series of challenging lectures on posture by Mabel Elsworth Todd at Teachers College, Columbia University. These assumptions were, briefly: (a) posture is an expression of habits of body mechanics,

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* See Appendix for photographs of the Posturimeter, page 171

** The School Health Study by the American Child Health Association was searching for answers to such questions as the following: (1) What types of measurement of posture can be devised which will have objectivity and reliability? (2) What is the relation of thelumbar region to the abdominal region of the body, and what is the relation of these two regions to the position of the head and the shoulders? In the attempt to answer these questions anteroposterior posture was measured in relation to two axes, one through the xiphoid process and the center of the ankle, the other through the center of the neck and the center of the ankle. The results of this study are unpublished.

(b) balance and movement of the body take place by means of conditioned neuromuscular reflex action without so-called voluntary control of the individual, (c) the human body functions as an organismic whole through the integrative action of the nervous systems, (d) principles of mechanics apply to the human body as to inanimate structures, (e) thinking influences muscle action, and (f) changing habits of neuromuscular responses to stimuli is basically an educational procedure, not an exercise procedure.

In the study, many of the changes which took place in the relationships of parts of the body were found to be inconsistent with existing theory on posture and body mechanics. Reports of the subjects on health values, however, were very favorable, particularly with regard to sleep, rest, greater ease in everyday activities, less "nervousness" and strain, and greater ability to relax in the midst of tense situations.

The experimentation indicated the need of objective data, particularly on the alignment of the skeletal structure as the supporting framework of the weight of the body. Until such objective data was obtained and further study related the contour of the body to the alignment of the skeletal framework, interpretations of body alignment would of necessity continue to be largely subjective.

It seemed to the investigator that there was an urgent need of a basic study in posture which would not only produce reliable data on the alignment of the skeletal structure, but would point to other research needed either to substantiate or to redirect present procedure in the alleviation of postural difficulties.

It is generally granted that in most people there are lateral differences in the height of the shoulders and the hips, and that lateral curvature of the spinal column tends to occur to some degree. However, the relationship, if any, among these and other lateral deviations in skeletal alignment is still subject to opinion. The present study was conducted with the purpose of attempting to discover (1) some of the bilateral asymmetries in the alignment of the skeletal framework and (2) the extent to which these asymmetries tend to occur together.

This study would have been impossible without the aid of many co-workers and without the encouragement of those friends and colleagues interested in its outcomes. Though individual acknowledgement of the generous help of these friends cannot be made here, for lack of space, the stimulation of their interest is nonetheless appreciated by the author.

To Mabel Elsworth Todd, the author owes a debt of gratitude for having disturbed her complacency in regard to posture and body mechanics, thereby giving her the incentive to undertake an investigation in an unexplored area.

The author extends her sincere thanks to Professor Jay B. Nash for giving her the opportunity to carry out the research on her problem at New York University.

The interest of H. O. Mahoney, of the Educational Division of General Electric X-Ray Corporation, has been invaluable. His vision of the possible outcomes of such a study led him to secure the support of the General Electric X-Ray Corporation, which kindly furnished the x-ray apparatus and the help of one of their specialists in radiography, J. B. Thomas. Thanks are due Mr. Thomas for his untiring help during the period when the radiographs were taken. Thanks also are due the many members of the General Electric Corporation both in Chicago and in New York City who gave their time and services freely for the success of the project.

For assisting with the important task of taking and developing the radiographs, the author wishes to thank Elwood Glassford, Edna Muhlfeld, and George Freisinger. The cooperation of fellow staff members of the Department of Physical Education during the taking of the radiographs is also greatly appreciated.

To all those students who were subjects for the study, most of whom have been in the posture and body mechanics classes of the author since their radiographs were taken, and who have made many challenging inquiries, thanks are given.

For their wise counselling and constructive criticisms, the author's sincere thanks are extended to Professors Harvey W. Zorbaugh, Charles J. Pieper, and, particularly, Frank S. Lloyd, Chairman, who gave valuable assistance in shaping the problem under consideration and in helping her to see the problem as a whole.

Mayhew Derryberry, Senior Public Health Statistician of the National Institute of Health, Washington, D. C., and formerly of the Department of Physical Education and Health of the School of Education of New York University, has given statistical guidance and encouragement since the beginning of the study and in doing this has given most generously of his time. The author is more than happy to acknowledge her debt of gratitude to him.

Sincere appreciation is extended to Shailer Upton Lawton, M.D., for guidance on anatomical data and for his spirit of cooperation and encouragement which helped to dispel the more quickly the inevitable discouragements encountered in the study.

The author is indebted to Clay-Adams Company of New York City for their cooperation in securing the photographs of the skeleton used in the thesis.

Finally, the author is deeply grateful to her friend, Anna D. Cordts, for encouragement and for constructive criticism of the manuscript, which have been of inestimable value. It is hoped that the completed study will justify the interest, encouragement, and the assistance of the many individuals who have contributed so willingly of their time and energy.

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CHAPTER I

INTRODUCTION

The contour of the human body has been, heretofore, the main criterion of its posture. The interpretation of lateral and anteroposterior deviations of the skeletal structure from a so-called normal alignment has been predicated almost invariably upon observation and/or measurement of the surface aspect of the body, rather than upon measurement of the skeletal structure itself. Such deviations have been designated as "postural defects" and these in turn have generally been treated as if they were separate or independent entities apart from and uninfluenced by the functioning of the body as a whole. Poor posture, then, was believed to be the sum total of postural defects each of which could be "corrected" by exercises designed specifically for that purpose. In accord with this point of view a large number of exercises came into use for such postural deviations as round shoulders, kyphosis, lordosis, visceroptosis, scoliosis, forward head, and pronated feet, not to exhaust the list. When individual treatment of various postural difficulties through specific exercises, each with little or no reference to the functioning of the whole, is not found in current posture literature, it is an exception to the general rule.

The problem which motivated this investigation grew out of a conflict arising between the traditional theory of posture as above stated and certain generally accepted principles* such as the following:

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* These principles are synthesized from various fields of knowledge, particularly anatomy, neurology, physiology, and psychology.

1. The mind and body interrelate and interact in their functioning.
2. Through the agency of the nervous systems the human being is an integrated individual, an organismic whole.
3. No two individuals are alike, particularly in neuromuscular habits and in psychological reactions.
4. It is doubtful whether there is any direct voluntary control of the intricate, conditioned reflex action occurring in the neuromuscular mechanisms to produce balance and movement of the body.

PURPOSE OF THE STUDY

This investigation holds that posture education can make a definite contribution to the reduction of mental, emotional, and physical strain. Therefore, the basic purpose of this study is to present pertinent data on bilateral asymmetry in the alignment of the skeletal structure that will lead, first, toward a reorientation of point of view on the subject of posture and body mechanics; and second, toward a teaching procedure which will be more fully in accord with principles of general education. To this end data were collected on the difference in position of identical lateral parts of the skeletal framework as the supporting mechanism of body weight. In treating these data a definite attempt has been made to take some of the phenomena of functional skeletal asymmetry out of the realm of opinion into a demonstrable, verifiable status. It is hoped that these data may be used in further research to determine what, if any, relationship exists between the contour of the body and the alignment of the skeletal structure.

THE PROBLEM

This study proposes to discover by means of anteroposterior radiographs some of the deviations from bilateral symmetry which occur in the alignment of the skeletal framework of the human body when it is in the standing position, and to determine their interrelationship.

Amplification of the Problem

In the analysis of deviations from bilateral symmetry in skeletal alignment, this study will attempt to answer the following questions:

1. Which part of the skeletal framework maintains its position most consistently over a period of time? What is the consistency of position of other parts distal to this most stable part?
2. Do any bilateral asymmetries occur together often enough that they may be grouped into specific patterns of bilateral asymmetry? Is there evidence that one type of movement, or that a blending of types of movement produces a pattern or patterns of asymmetry?
3. Do specific patterns of bilateral asymmetry occur together often enough to indicate a general pattern of bilateral asymmetry? What units of the skeletal structure are involved in the general pattern?
4. Do any bilateral skeletal asymmetries occur more frequently on one side of the structure than on the other?
5. Which asymmetry occurs most frequently with other asymmetries in each pattern? Which asymmetry shows the highest correlation with other asymmetries in the general pattern?

6. Is age, sex, or handedness related to bilateral skeletal asymmetry? If so, to what extent?

<u>Fundamental Assumptions</u>

The fundamental assumptions on which this study is based are as follows:

1. The skeletal structure is the framework supporting the weight of the body. Its component parts serve as levers on which the muscles act to maintain the equilibrium of the body weight as a whole.
2. Bilateral asymmetry tends to occur in the skeletal alignment of so-called normal individuals.
3. The alignment of the skeletal structure which occurs consistently in the standing position, when the weight is considered by the individual to be evenly distributed between the feet, is the individual's pattern of posture, that is, the pattern of alignment which he habitually assumes.
4. The human body functions as an organismic whole and in accordance with Newton's Third Law of Motion. Hence, when asymmetry occurs in the position of any identical lateral parts at one level of the skeletal structure, it is apt to be accompanied by asymmetry in position of identical lateral parts at other levels of the skeletal structure.
5. When the skeletal structure is maintained in equilibrium in the upright position, its alignment and accompanying muscle action are interrelated and interdependent.
6. The best point of reference for the location of a vertical line to divide the skeletal structure into lateral halves is the

center of the top of the sacrum where there is a division of the weight of the spinal column and its appended structures into the right and left sides of the pelvis.

7. The conformation of the lateral halves of the skeletal structure is sufficiently similar to allow comparison of position of its lateral identical parts through measurement.

Definitions

Various terms used in this study are defined as follows:

A skeletal radiograph is a shadow of the skeletal structure recorded on a photographic plate by passing x-rays through the tissues of the body.

The anteroposterior position of a subject being radiographed is the position in which the anterior part of the subject is nearest the x-ray tube, and the posterior part is nearest the x-ray film.

The plumb line used in this study was a weighted brass wire which was hung in front of the Potter-Bucky diaphragm. It was radiographed simultaneously with the skeletal structure of each subject.

The central vertical axis is the path of a plumb line drawn on the radiographs through the center of the top of the sacrum.

A point of reference is a spot on the central vertical axis or on the skeletal structure from which the distance of a skeletal part is measured.

Alignment of the skeletal framework is the relationship of its parts to each other and to a central vertical axis which occurs consistently each time the subject assumes a specified position.

Posture is considered synonymous with alignment.

Bilateral symmetry in the alignment of the skeletal framework occurs when the design of skeletal relationships is the same on the right and left sides of the structure.

A deviation from bilateral symmetry is considered in this study as movement* which has taken place at one or more joints to produce a consistent difference in the location of identical lateral skeletal structures.

The types of deviation are classified in this study as follows: lateral angulation or rotation in the coronal plane,** horizontal rotation in a transverse plane, anteroposterior rotation in a sagittal plane, and lateral deviation in a coronal plane. It is recognized that probably no one type of movement occurs singly, or purely in one of the anatomical planes.

An asymmetry in the alignment of the skeletal structure is a measurable difference in the location of lateral identical structures.

Type of asymmetry is designated according to the type or kind of measurement used to determine the difference in location of lateral identical parts, as follows: angulation, horizontal distance, diagonal distance, vertical distance.

A pattern of asymmetry in the alignment of the skeletal structure is a configuration of asymmetries which consistently occur together each time the subject assumes the same specified position.

The general pattern of asymmetry in skeletal alignment is the basic configuration of skeletal relationships which tends to occur

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* See page 8 for kinds of movement.

** See page 7 for planes of the body.

consistently in the function of maintaining the balance of the body in a standing position.

Compensatory. Asymmetries in skeletal alignment are considered compensatory when they consistently occur together, but on opposite sides of the structure.

The units of the skeletal structure which enter into this study are the pelvis, the thighs, the spinal column, the upper thorax, and the shoulder girdle.

The spinal column refers to the presacral or movable vertebrae of the vertebral column.

The gluteal fold is the horizontal crease on the surface of the body separating the buttock from the thigh.[1]

Newton's Third Law of Motion. "To every action there is an equal and opposite reaction."[2]

Planes of the body. "For descriptive purpose the body is supposed to be in the erect posture, with the arms hanging by the sides and the palms of the hands directed forward. The median plane is the vertical anteroposterior plane, passing through the center of the trunk. This plane will pass approximately through the sagittal suture of the skull, and hence any plane parallel to it is termed as sagittal plane. A vertical plane at right angles to the median plane passes, roughly speaking, through the central part of the coronal suture or through a line parallel to it; such a plane is known as a frontal plane or sometimes as a coronal plane. A plane at right angles to both the median and the

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1. Henry Gray, Anatomy of the Human Body. 22nd edition, page 1335.

2. Millikan and Gale, Elements of Physics, page 93.

frontal planes is termed a transverse plane."[1]

Kinds of movement. "The movements admissible in joints may be divided into four kinds: gliding and angular movements, circumduction, and rotation. These movements are often, however, more or less combined in various joints, so as to produce an infinite variety, and it is seldom that only one kind of motion is found in any particular joint."[2]

"Body mechanics is the work of muscles exerting power in the bones as levers, to produce motion and maintain the body's equilibrium in relation to both internal and external forces."[3]

Limitations of the Study

Since the radiographs and questionnaires used in this study were a source of more data than could be considered in one investigation, the following limitations were put upon the study:

1. The study was limited to an investigation of the bilateral alignment of the skeletal structure when the subject assumed an easy standing position with the feet parallel and two inches apart, and with the weight, according to the subject's judgment, evenly distributed between the feet.
2. Measurements of asymmetry were limited to the shoulder girdle, the upper thorax, and to the following weight-supporting parts of the skeletal structure: the proximal part of the femora, the pelvis, and the lumbar and thoracic regions of the spinal column and as much of the cervical region as appeared on

1. Gray, op. cit., page 34.

2. Ibid., page 282.

3. Lulu E. Sweigard, Symposium on Posture, page 18.

each radiograph. The extent of the cervical region included on each radiograph varied with the height of the subject.

3. No attempt was made to relate bilateral asymmetry to such factors as height, weight, anomalies of the skeletal structure, intelligence, accident, operation, pathology, health, fatigue, economic status, occupation, race, or skill in sport.
4. The study excluded measurement of rotation of vertebrae, therefore no attempt was made to determine the relationship between lateral deviation and rotation in the spinal column.
5. No attempt was made to determine whether lateral deviations in the spinal column were scolioses of a functional, transitional, or structural type.
6. The study does not ascribe a grade or rating to the varying degrees of bilateral asymmetry.
7. The purpose of the study was neither to support nor to deny any theory or procedure in posture and body mechanics.

NEED FOR THE STUDY

Brownell's study says: "One cannot state with any certainty that experts in physical education are better qualified to rank posture silhouettes than those individuals who have not had special training in this field."[1] There may be several reasons why this may be true, for example: (a) the silhouette may not provide an adequate record of information needed by the "expert" to judge posture with a satisfactory degree of accuracy; (b) "experts" may differ in their standards of good posture; (c) the sub-

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1. Clifford Lee Brownell, A Scale for Measuring the Antero-posterior Posture of Ninth Grade Boys, page 37.

jective judgment of both the "expert" and the untrained person may be unreliable; (d) scientific information regarding the interpretation of the alignment of the body as shown by its contour outline may not be available. Whatever the reason or reasons, it will undoubtedly be granted that the specialist in any field of work should be able to observe more, and to interpret that which he observes, with a greater degree of accuracy than the untrained person.

The unique tool in physical education procedure is activity. All activity involves neuromuscular function, and habits of muscular function are registered in posture. For this reason it is of vital importance that the physical educator should be able to interpret posture -- its advantages and disadvantages to ease and rhythm in movement -- with a greater degree of accuracy than the untrained person. Otherwise, it might truly be said that the individual tends to become skillful in spite of the teaching he receives, not because of it.

In all structures that support and move weight, the reduction of strain in the framework is of fundamental importance to the efficiency and the lasting powers of the entire structure. This general principle is equally applicable to the human being if efficiency and duration are to be achieved in skills and in every day activities. Studies in posture thus far have been concerned with the contour of the body. There has been no study of the relationship of contour to the alignment of the supporting skeletal framework. Before such a study can be made, information must be obtained concerning the asymmetry of the skeletal structure itself. The investigator's study is an attempt to meet this need.

HISTORICAL AND CONTEMPORARY STATUS

Various studies in the alignment of the human body have been made of photographic and silhouetteographic records of the contour of the body. Most of these studies have dealt with anteroposterior alignment, and from their results have been drawn theories concerning the alignment of the supporting skeleton. These interpretations have, however, of necessity thus far been largely subjective. Until the present study, no investigation of relationships in the major portions of the skeletal structure itself has been made by means of radiography.

Radiography has, for the most part, been used in studies of anatomic variations, of deformity, or of pathology in bones and joints.* Radiographs of the skeletal structure as a whole have seldom been made, and never has a study employing them with a large number of subjects been undertaken. The chief reasons why this is true -- why radiography has not been used in postural studies -- are that the procedure is so expensive as to be practically prohibitive for the research of an individual, that areas of the body are different in density, and that the necessary apparatus for securing a clear radiograph of human size is not commercially available.

A study of the anatomic relationships in the trunk of the body has been made by H. O. Mahoney, of the Educational Division of General Electric X-Ray Corporation, by means of radiography,[1] the purpose of which

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* Many studies of pathomechanics of parts of the body, particularly of the spinal column, have been made. These studies are not considered applicable to a study of the so-called normal structure, nor are the results of the studies of the skeletal structure as independent parts considered applicable to the integrated relation which maintains in the skeletal structure as a whole.

1. H. O. Mahoney, Unpublished research.

was to procure anatomical information and to produce some form of records of anatomical relationships which would meet the needs of both instructors of anatomy and of those engaged in radiographic work. "No form of anatomy could be found in the textbooks nor in the dissecting room which would give the necessary information. The main points of interest regarding anatomy from the technician's standpoint are the location of the parts to be radiographed and the relation of these parts to other parts of the body."[1]

Mahoney's study used a large number of radiographs of sagittal, of coronal, and of transverse sections of the body in which very fine detail was shown in the mosaic of all parts of the trunk including the nervous system. No means has been found so far of photographing these radiographs without loss of much of the fine detail of structural design.

In the Department of Child Hygiene, of the School of Public Health of Harvard University, a study of children during the early years is now in progress. William T. Green, M.D., makes the following statement regarding this study:

> We have been interested in determining the skeletal relationships of the standing position with relation to the center of balance.
>
> Since posture is an evolutionary thing, we have studied this in children of various ages and are particularly interested in the evolution of particular children over the period of years. Our x-ray studies are carried out with the individual standing on a spring balance in such fashion as to determine the actual center of weight bearing.
>
> These studies have been going on for four years. The x-ray film has included the skeleton from below the knees through the complete spine.

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1. Mahoney, op.cit.

> We have been interested not only in the relationship of parts of the body to the center of weight bearing, but also in various angles that may be factors in classifying postural relationships. Our adult studies have been rather brief, but enough to get some idea of the normal standards.[1]

Another contemporary study is that of Du Bois[2] which will no doubt evolve an objective means of interpreting bilateral asymmetry in skeletal alignment from bilateral asymmetry in body contour. The present statement of the purpose of this study is as follows:

> This study seeks to determine two things: first, the relationships existing between the posterior view contour of the human body and the alignment of its supporting skeletal framework and second, on the basis of the discovered relationships, the significance of contour measurements for predicting how the opposite sides of the skeleton will differ in pattern of alignment.

Literature on bilateral asymmetry is confined generally to the spinal column, with some discussion of the accompanying asymmetry in the pelvis and the shoulder girdle, but with little or no discussion of asymmetry in the supporting femora. It places a greater emphasis on the patho-mechanics of parts of the structure than it does on the mechanics in the coordinated function of the body as a whole in the so-called normal individual.

Since emphasis is being increasingly placed on the functioning of the body as a whole, rather than in parts unrelated to the whole, the need of studies of the body as a unit and the need of relating the results of studies of parts of the body to the body as a unit is of paramount importance.

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1. William T. Green, M.D. Unpublished statement.

2. Goddard Du Bois, The Relationship Between the Posterior View Contour of the Human Body and the Bilateral Alignment of its Skeletal Framework. Uncompleted research.

CHAPTER II

PROCEDURE

In recent years advancement in the science of radiography has made it possible to secure shadow pictures of the internal organic structures of the living human body. In general these radiographs have been used in two ways, namely, to increase knowledge of living tissues and to aid, or to confirm, diagnosis made by the medical profession.

To fulfill the purpose of this study data on lateral differences in the alignment of the skeletal framework were needed, and such data could best be procured from radiographs. Since the radiograph presents a two-dimensional picture of a three-dimensional structure, clarity of outline of the conformation of all skeletal parts was essential to clarity of outline of bony landmarks which might be used as points of reference for measurement. In addition to adequate x-ray apparatus, expert work in taking radiographs of the skeletal structure and in developing them was of fundamental importance to the reliability of the source of data.

THE SUBJECTS

The subjects of this study were 497 graduate and undergraduate men and women students of the Department of Physical Education and Health*

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* 516 subjects were radiographed, but the number of subjects entering the study was reduced to 497 for reasons given on page 58.

in the School of Education of New York University.

All the students in the investigator's classes and all freshmen in the department of physical education served as subjects. Other students who became interested in the proposed research volunteered to serve as subjects and were accepted in order of appointment for their radiographs until 516 subjects had been radiographed.

METHOD OF SECURING THE DATA

Measurements on the right and left sides of the skeletal structure constitute the main data for the study. These data were secured from the radiographs of the subjects.

Taking the Radiographs

The procedure used in radiography was planned and conducted with the advice and assistance of specialists in the field of radiography. Through the cooperation of Mr. H. O. Mahoney and Mr. J. B. Thomas of the Educational Department of General Electric X-Ray Corporation, radiographs of the subjects of this study were taken in Room 682, Education Building of New York University during the month of February, 1934.

In order to obtain a radiograph of the area of the skeletal structure needed in the study it was necessary to take two fourteen by seventeen inch radiographs of each subject.* The first radiograph was taken to show the proximal parts of the femora, the pelvis, and as much of

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* The Potter-Bucky diaphragm was used to insure good diagnostic quality in the radiographs. Since this diaphragm was not available in a size sufficiently large for radiographing the complete portion of the subject's body needed in the study, two radiographs were necessary.

A

B

C

Figure 1. Equipment for taking the radiographs. C shows a subject in position for a thoracic radiograph.

the lumbar and thoracic regions of the spinal column as the size of the film would allow. The second showed about two inches of the upper part of the structure which appeared on the first radiograph and as much as possible of the remaining superimposed skeletal structure. Thus the two radiographs revealed in each subject the proximal parts of the femora, the pelvis, the spinal column at least to the level of the seventh cervical vertebra, and the shoulder girdle. Sometimes a considerable portion of the cervical spine appeared, this depending on the height of the subject.

When a subject was very tall, three radiographs were taken. These radiographs, however, were not included in the study since distortion in them would not be similar in distribution to that on other subjects' radiographs.

Equipment Used

The following equipment (see Figure 1) was used in the radiographic procedure:

- * 220 V Rotary Converter.
- * Stabilized 5-30 Radiographic Unit.
- * Tube stand with tripod base for Coolidge Tube, with protective shield and adapter.
- * Potter-Bucky diaphragm with vertical stand.
- * 4 Rayspeed cassettes, 14 by 17 inches, with Hi-Speed screens.
- * Automatic hand-timing unit.
- 1194 Agfa X-ray films.
- Adhesive tape, 2 by 12 inches, on floor below center and perpendicular to the plane of the Potter-Bucky diaphragm.
- 2 chairs, the backs of which were used as rests for the hands of the subjects.
- Brass wire plumb line, hung in center front of the Potter-Bucky diaphragm.
- Lead letters and numbers.

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* Equipment loaned by General Electric X-Ray Corporation of New York City.

80 unbleached muslin robes.

For developing the radiographs:
- 2 safe lights.
- * Four 5-gallon size solution tanks.
- * 36 Developing hangers, 14 by 17 inches.
- * 1 Floating timer.
- * 1 Interval timer.
- Developing chemicals -- 46 gallons developer, and 37 gallons hypo.

Allocation of Work

The investigator and her assistant administered the plan of work used in radiography and photography.** The General Electric x-ray specialist took the radiographs and a technical expert developed them. A specialist in photography planned the photographic procedure and developed the photographs.

Procedure with Each Subject

Each subject, when he came for his radiographs, was asked to fill out a questionnaire.*** After this, in preparing for his radiographs, he followed directions placed in the dressing room.#

Position of the subject at the x-ray apparatus. All subjects stood with the back toward the Potter-Bucky diaphragm. To eliminate variability in the eversion of the feet, each subject was asked to stand

* Equipment loaned by General Electric X-Ray Corporation of New York City.

** Immediately following the taking of the radiographs of each subject, photographs of the back and side view of the body in the nude were taken. These photographs were taken in order that data would be available for a study of the contour of the body in relation to the alignment of its skeletal structure. The surface aspect of the body, however, is not a part of this study.

*** See Appendix, page 172.

See Appendix, page 173.

with the inner borders of the feet touching the sides of the adhesive tape on the floor. No directions were given to establish the heels in the same coronal plane. The hands rested on the chair-backs only to increase the confidence of the subject to maintain a position without swaying during the time required for the two exposures. The entire time of the subject at the x-ray apparatus was approximately a minute and a half.

To stabilize the subject's position the immobilizing device was fastened across the pelvis for the first radiograph and across the chest for the second radiograph. Care was taken each time not to disturb the self-established balance of the subject.

Just before each exposure it was noted whether the hands of the subject were resting on the chair-backs or were pushing against them, since the latter would interfere with an easy hanging position of the shoulder girdle. The resting position of the hands in the hanging position of the shoulder girdle were in every case achieved before the radiograph was taken.

Position of the two x-ray films in relation to the subject. The Potter-Bucky diaphragm was moved up or down the vertical standard as needed in order to place the x-ray film back of the parts of the body to be radiographed. The position of the first film was determined with reference to the level of the gluteal fold of the subject, that is, the diaphragm was so placed that the x-ray film would have its lower edge about two inches below the level of the gluteal fold of the subject. The upper edge of the first film was marked on the right upright of the vertical standard as a guide for the location of the second film.

Immediately after the exposure of the first x-ray film, the cassette containing the exposed film was replaced by another cassette containing the second film. Then the diaphragm was moved up the vertical rods of the standard into a position overlapping the position of the first film by two inches. Care was taken not to jar the apparatus or the subject. The second exposure was then made.

Directions to each subject. The habitual posture of the subject in the standing position was desired, therefore as few directions as possible were given. The first directions were as follows: "Stand with the inner borders of your feet touching the adhesive tape on the floor. Move back until the buttocks touch the apparatus. Stand with your weight evenly divided between the feet, and without leaning against the apparatus for support. Rest your hands easily on the chair-backs."

Final directions to each subject just before the film was exposed were: "Distribute your weight evenly between your feet, stand easily, let your shoulders hang and your hands rest easily."

Immediately after the first film was exposed, the subject was asked to maintain the same position. Following the second film exposure, he was told to go to an adjoining room where two photographs, back and side view, of the nude body in the standing position would be taken.

Elimination of disturbing factors. In order to reduce to a minimum any factor that might cause psychological disturbance of the subject and hence increase muscle tension, only the x-ray technician and the investigator were with the subject during the radiographic procedure. The work of each of these persons was performed as quickly and as quietly as possible, as follows:

The technician:

Placing lead letter and number for marking film
Placing cassette containing film for exposure
Centering the Coolidge tube
Checking the focal film distance
Determining the time exposure of the film and the amount of electric current needed
Taking the radiograph

The investigator:

Directions, or demonstration if necessary, of the position of the subject's body relative to the x-ray apparatus
Placing the film in relation to the subject
Directions to the subject
Fastening the compression band in place
Releasing the Potter-Bucky diaphragm into movement

Distortion in the Radiographs

To equalize distortion on the right and left sides of the skeletal structure, the centering points of the Coolidge tube for the two radiographs of each subject were standardized. For the pelvic radiograph the center of the pelvis was chosen as the centering point; for the thoracic radiograph, the center of the thorax was chosen as the centering point. Through the use of these two centering points for the radiographs of each subject, distortion was equalized on the right and left sides of the skeletal structure; also, the distortion appeared in like distribution in all the radiographs.

Marking the Radiographs

An aluminum holder containing the letter "R" and the number of the subject was taped to the cassette in the lower corner back of the right side of the subject. A brass wire plumb line hung at center front of the Potter-Bucky diaphragm at all times. Thus the identification

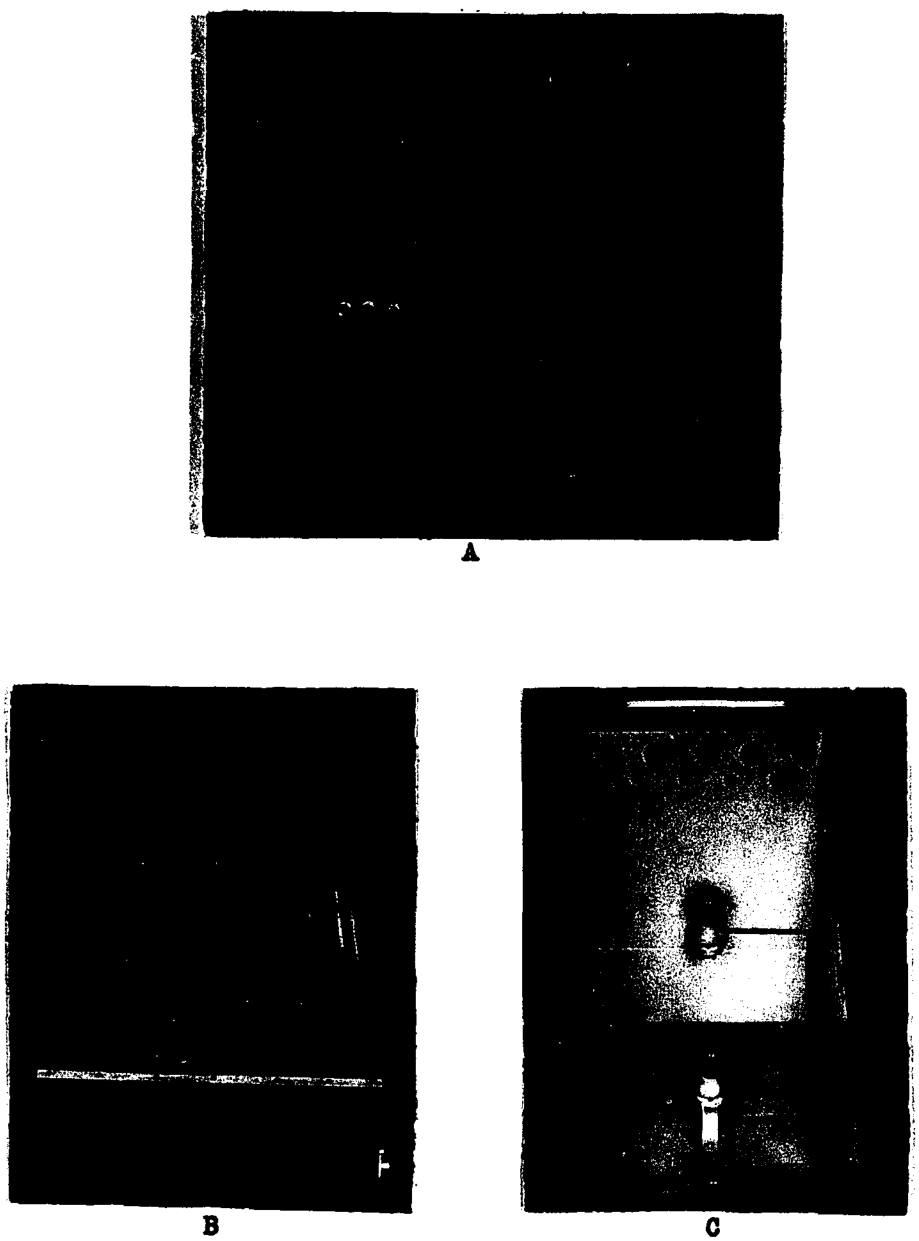

Figure 2. The view-box. A shows a side view; B, a front view; and C, an inside view.

number of the subject, the identification of his right side, and the plumb line were radiographed simultaneously with the skeletal structure.

Taking a Second Set of Radiographs of Thirty Subjects

To make available the source of data for determining reliability of deviations from bilateral symmetry in the skeletal structure a second set of radiographs was taken on thirty of the subjects. From one to three weeks elapsed between the taking of the first and the second set of radiographs of these subjects. Both sets were taken under identical conditions.

Equipment Used for Study and Measurement of Radiographs

A view-box and various instruments were needed in the study and measurement of the radiographs.

The view-box

The view-box (see Figure 2), especially designed for the study, was supported on pedestals 28 inches high to allow the investigator to work in a standing position; its length was sufficient to allow the two radiographs of each subject to be placed in proper apposition to each other. The dimensions of the view-box were as follows: 30 inches high at the back, 9 inches high at the front, 22 inches wide, and 32 inches deep from front to back. The top of the box slanted from front to back at an angle of 120 degrees from the vertical so that the eyes could be focused easily on any part of the radiographs. A piece of steel was fastened along the front edge of the top of the box to be used as a guide for the T-square. The top of the box was made in the form of a frame to support two blue tinted opal glasses, 14 by 17 inches, placed end to end. These were held in place by very small clips. Larger clips were fastened on each side of the supporting wooden framework to hold the radiographs in place over the opal glasses for study. To furnish illumination three 200 Watt Victor Argon lamps were placed 12 inches apart on the base of the box in the median line and on a slant parallel with the top of the box. Electric switches at the right hand side of the base of the box controlled each of these lamps. Round holes along the sides, back, and bottom of the box provided ventilation. On the top of the box to the right of the blue tint glasses was placed a flat paragon scale. Over this scale was a magnifying glass, 7 by 3 inches, supported on a standard. To the left of the blue tint glasses a list of the measurements, in the order in which they were to be taken, was placed on the wooden framework.

The instruments

The instruments used in marking and measuring the radiographs were as follows:

T squares, sizes 18, 36 and 42 inches
Two scribers
Two hairspring dividers
Three xylonite triangles, sizes 8, 9, and 10 inches
Three xylonite semicircular protractors, sizes 5, 8 and 10 inches.
Two flat paragon scales
One arrow bow pencil

Matching the Thoracic and Pelvic Radiographs of Each Subject

Since there are such anomalies as a transitional vertebra in the lumbar region[1] and more than five lumbar vertebrae, some additional guide besides the two-inch overlap of x-ray films was needed in matching the

1. Albert B. Ferguson, M.D., The Clinical and Roentgenographic Interpretation of Lumbosacral Anomalies. Radiology, Volume XXII (May, 1934), page 552.

thoracic and pelvic radiographs of each subject. A careful study was made of the structural conformation of the lateral processes of the lower thoracic and the upper lumbar vertebrae in the first and second sets of radiographs of thirty of the subjects taken at different times, but under similar conditions. It was found that in each subject, in both sets of his radiographs, only identical vertebrae would match when the thoracic and pelvic radiographs were overlapped to show the complete picture of the spinal column. Hence a more exact guide than the two-inch overlap of the two radiographs of each subject was found in the characteristic structure of the transverse processes of each vertebra.

To avoid any possible mistakes in the juxtaposition of the radiographs they were always placed on the view-box with the side marked "R" on the right side. In this way any marking with the scriber always appeared on the same surface of each radiograph and the resultant roughness enabled the sense of touch to confirm the sense of sight in the proper placement of the radiographs for study and measurement.

The pelvic radiograph was placed on the view-box first. Then by using the T square as a guide the plumb line in the radiograph was brought into perpendicular relation to the front edge of the view-box and the radiograph was fastened in place with the clips. Next the thoracic radiograph was placed on the view-box beyond the pelvic radiograph and moved into position to superimpose identical vertebrae on the two radiographs. At the same time identical vertebrae were being superimposed, the plumb line in thethoracic radiograph was brought into perpendicular relation with the front edge of the view-box and fastened in position. In this manner the true alignment of the two radiographs with each other and with the base of the view-box was determined by means of the plumb line and the vertebrae.

In the majority of subjects a slight shift of the body occurred between the taking of the two radiographs and the continuity of the plumb line at the junction of the pelvic and the thoracic radiographs was broken. The deviation from continuity, however, was so slight that there was no difficulty in superimposing the proper vertebrae.

After the two radiographs were placed properly and firmly fastened on the view-box a scriber was used to puncture perpendicularly the overlapping parts of the two radiographs on the right and left sides in a horizontal line and about two-thirds the distance from the center. Using the scriber, with the T square as a guide, a vertical line was marked through the punctures in one radiograph onto the next. The continuity of these vertical lines served as one of the guides in aligning the radiographs after the overlapping parts were cut away.

The radiographs were then removed from the illuminator and a fine pencil line was drawn across each through the two punctures. This line was used as a guide for cutting the unneeded portion from each film with a large paper cutter.

By means of this procedure the pelvic and thoracic radiographs when placed end to end on the view-box presented the complete picture of the skeletal structure with which this study is concerned.

Preliminary Study of Skeletal Deviation

Bilateral asymmetry in the alignment of the skeletal framework in the so-called normal body implies deviation from symmetrical position of parts of the skeleton through change in relationship at the joints.

In order to determine (1) the probable direction and plane of movement which produced various asymmetries of alignment shown on the radiographs, and (2) the measurements which should be taken, it was necessary to reproduce skeletal asymmetries comparable to those on the radiographs. This was done with the following inanimate skeletal structures: a pelvis with attached, flexible spinal column; separate femoral bones, shoulder girdle, ribs and vertebrae; and a completely assembled skeleton. These skeletal structures were manipulated until, by trial and error, various asymmetries comparable to those on the radiographs were produced. In each instance direction and plane of movement of a part in relation to a central axis and in relation to other parts, and the nature of movement in the various joints concerned were noted; the dimensional and angulation changes between parts were observed; and possible points of reference for measurement of these changes were discovered.

Gray says that the kinds of movement admissible in joints are often more or less combined in the various joints to produce an infinite variety of movement.[1] When a great variety of movement is possible, a great variety of asymmetry is, no doubt, also possible. For this reason, the experimental study was limited to movements of the pelvis, the femora, the spinal column, and the shoulder girdle in the sagittal, coronal, and transverse planes, but such limitation was made with complete awareness that probably little, if any movement occurs singly at one joint or takes place purely in one of the anatomical planes.

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1. Gray, op. cit., page 282.

A B

Figure 3. Bilateral symmetry in the pelvis and lower spine. A is a photograph of the inanimate pelvis balanced on the tuberosities of the ischia; B is a radiograph of a pelvis resting on the femora in the standing position. It approximates bilateral symmetry and presents very similar relationships to those shown in A.

The pelvis at rest on the tuberosities of the ischia

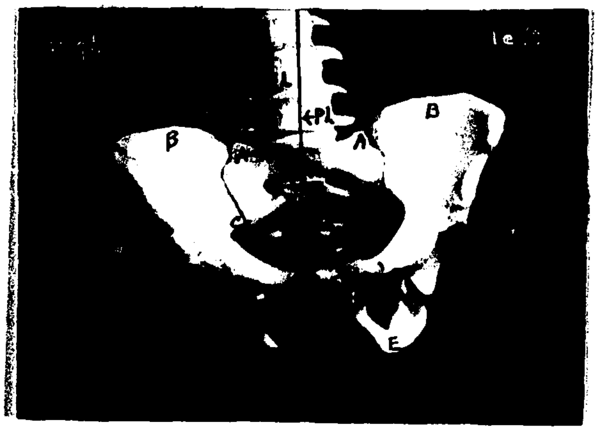
The inanimate pelvic skeleton with attached spinal column (see Figure 3) was suspended in a manner to allow its weight to rest on the tuberosities of the ischia (E-E). A plumb line (PL) comparable to the central vertical axis on the radiographs was hung so that it bisected the top of the sacrum. Translating the view of the pelvic skeleton into a two-dimensional picture as shown in Figure 3, the following is noted: the true pelvic opening (marked with a dotted line) is oval in shape; the coccyx (O) appears in the pubic arch; the obturator foramina (X-X) show similarly their full size and shape; the body of the fifth lumbar vertebra (5L) is distinct in outline and shows no overlapping on the upper part of the sacrum; the spines of the ischia (Sp-Sp) appear within the obturator foramina; the plumb line bisects the pubic symphysis (S). The parts of the right and left sides of the pelvis which are sufficiently definite in outline for comparison in position are the crests of the ilia (B-B), the wings of the sacrum (A-A), the posterior inferior spines of the ilia (C-C), the laterosuperior borders of the acetabula (D-D), and the tuberosities of the ischia (E-E).

A B

Figure 4. Marked anteroposterior tilt of the pelvis. A shows the inanimate skeletal pelvis with its weight resting anterior to the tuberosities of the ischia; B shows a radiograph of a pelvis similar in appearance in a subject in the standing position.

The pelvis rotated in a sagittal plane

The pelvic skeleton was rocked forward in a sagittal plane on a median coronal axis to increase its anteroposterior tilt and to cause its weight to be borne on the anterior part of each ischium (see Figure 4). The resulting picture is similar on the right and left halves, but the appearance of relationship of parts is changed from that shown in Figure 3 in the following ways: the opening of the true pelvis (marked with a dotted line) is more circular in shape and the vertical distance between the posterior inferior spines of the ilia (C-C) and the anterior rim of the true pelvis (R-R) is increased; the coccyx (O) appears within the rimof the true pelvis; the obturator foramina (X-X) show less distance between their upper and lower borders, their full size being lost to view; and the spines of the ischia (Sp-Sp) appear within the rim of the true pelvis.



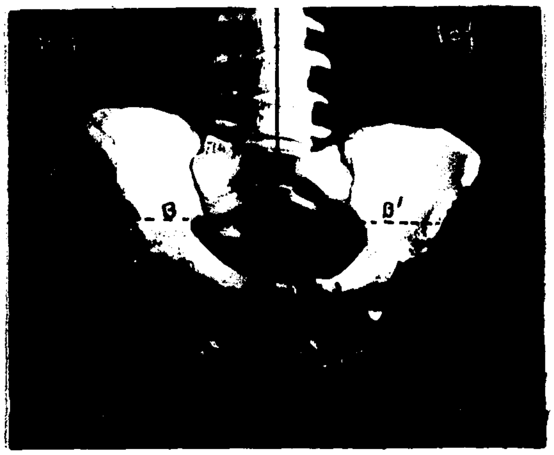
A

B

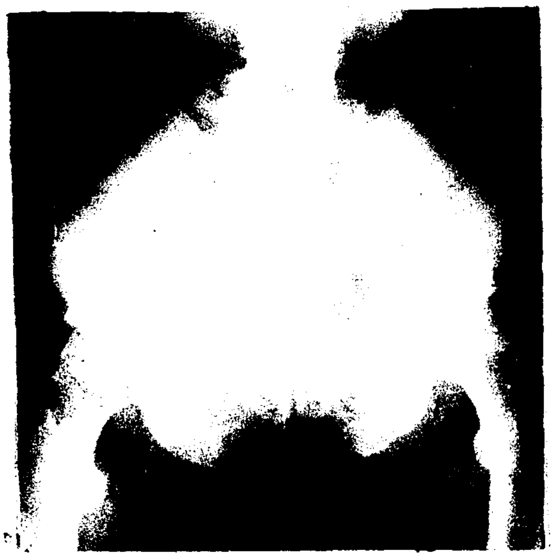
Figure 5. Lateral tilt of the pelvis. A shows the inanimate pelvis resting on the right ischial tuberosity; B is a radiograph of a pelvis tilted laterally in a subject in the standing position.

The pelvis rotated on a coronal plane

The pelvic skeleton was tilted laterally to rest on the right tuberosity of the ischium (E), that is, it was rotated as evenly as possible in a coronal plane around a median sagittal axis (see Figure 5). This lateral angulation of the pelvis results in a greater height of the left than of the right side of the pelvis. This is evident at the wings of the sacrum (A-A), at the crests of the ilia (B-B), at the posterior inferior spines of the ilia (C-C), and at the lower borders of the tuberosities of the ischia (E-E). The pubic symphysis (S) slants laterally and appears to the left of the plumb line (PL). The obturator foramina (X-X) are different in size. Below the level of the sacrum, identical lateral parts of the pelvis are farther from the plumb line on the left than on the right side; the reverse is true of parts above the level of the sacrum. The fourth lumbar vertebra (4L) shows more area to the right than to the left of the plumb line.



A

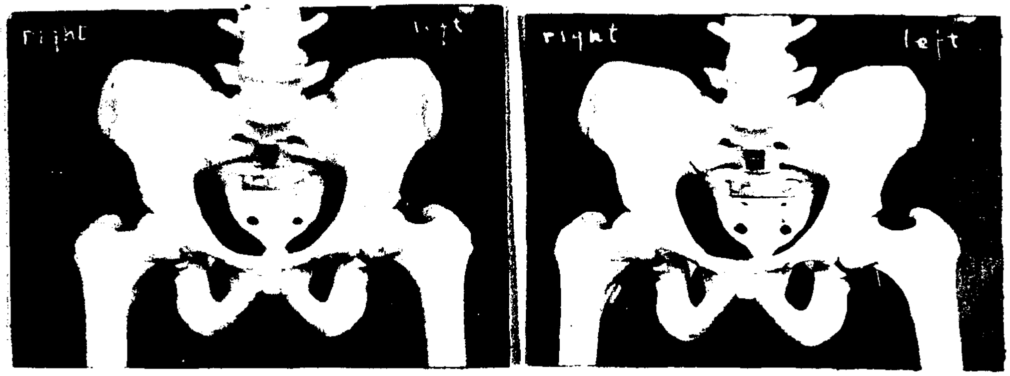


B

Figure 6. Horizontal rotation of the pelvis. A shows the inanimate pelvis rotated to the left; B is a radiograph of the pelvis rotated to the left in a subject in the standing position.

<u>The pelvis rotated in a transverse plane</u>

The pelvic skeleton was rotated to the left (counterclockwise) in a transverse plane around a median vertical axis, maintaining the contact of the tuberosities of the ischia (E-E) with the supporting surface (see Figure 6). The results are a decreased width of the right ilium (B) and an increased width of the left ilium (B'); in contrast to this there is an increased width of the right obturator foramen (X) and a decreased width of the left obturator foramen (X'). Diagonal distances between lateral identical parts of the pelvis and the center of the top of the sacrum are greater on the left than on the right side.



A B

C

Figure 7. Rotation of the femora. A shows the femora in similar relation to the pelvis; B shows the right femur in inward rotation, the left femur in outward rotation; C is a radiograph of a subject in the standing position in which the left femur shows more outward rotation than the right femur.

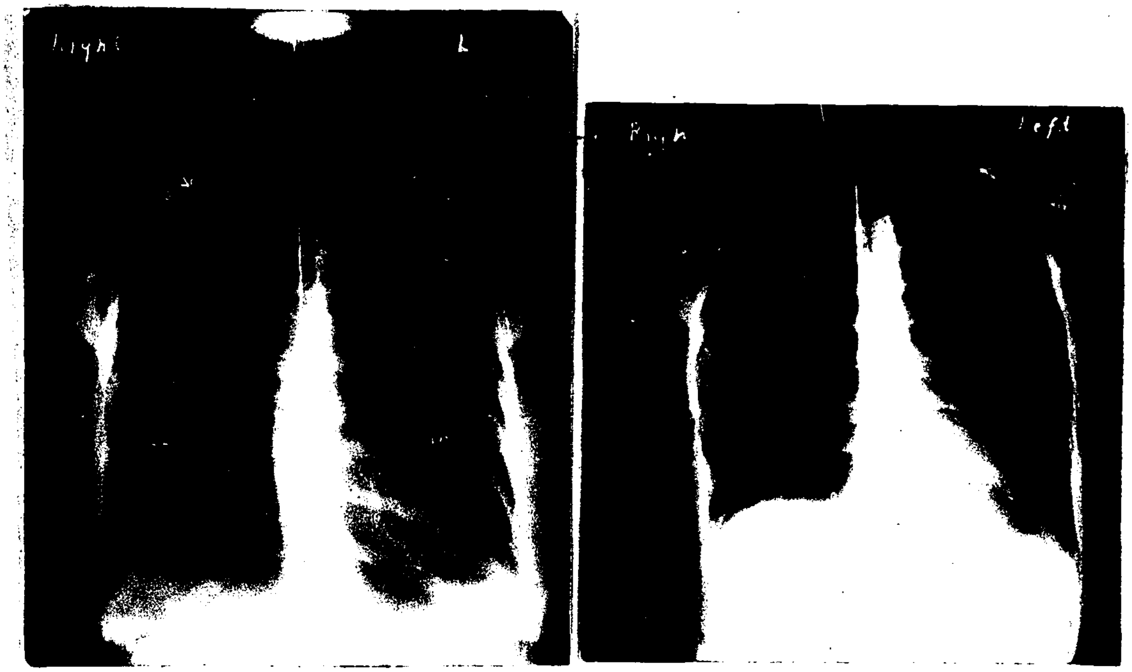
The femora in horizontal rotation and in lateral deviation

Figure 7A shows the femora in similar relationship to the pelvis; Figure 7B shows the right femur in outward rotation and the left femur in inward rotation. When the femur is rotated outward the changing position of the greater trochanter causes the neck of the femur to appear shorter from the beginning of the rotation; at the same time the small trochanter becomes more prominent in the inside of the femoral shaft (see right femur, Figure 7A). When the femur is rotated inward the changing position of the great trochanter first causes the neck of the femur to appear longer, but with continued inward rotation it finally appears shorter; at the same time the small trochanter becomes less prominent on the inside of the femoral shaft, finally disappearing back of it (see left femur, Figure 7B).

When the pelvis with femora attached is rotated in the coronal plane, that is, tilted laterally, the femoral heads are changed in their relative height in a manner similar to the change in relative height of the ilia (see figure 5B, page 27a). As the pelvis and femora move in coronal rotation, one femur in its proximal portion moves away from the central vertical line while the other femur in its proximal portion moves toward it. Thus coronal rotation of the pelvis and femora produces greater height of the ilium and the femoral head and greater prominence of the proximal portion of the femur on the same side of the structure.

The spinal column in lateral deviation

It is logical to expect that any change in position of the sacral table as the base of support for the spinal column will tend to result in some change in position of the spinal column. Because of the flexibility of the inanimate spinal column little experimentation was done with it other than to note the reactionary movement in its portion next to the pelvis (lumbar spine) when the pelvis was placed in various positions. With an increase in the anteroposterior tilt of the pelvis the sacral table becomes more slanting and the spine sags forward (see Figure 4B, page 26a). With a lateral tilt of the pelvis to raise its left side, the reactionary response in the spine is a lateral angulation of the fifth lumbar vertebra and a sagging to the right of the superimposed lumbar vertebrae as shown in Figure 5A and B, page 27a.



A B

Figure 8. The shoulder girdle and upper thorax. A is a radiograph of the thorax in which the shoulder girdle and upper thorax are fairly symmetrical; B is one in which both structures are higher on the left side.

The shoulder girdle and upper thorax in coronal rotation

When one side of the shoulder girdle is raised higher than the other (see Figure 8B) the main changes are shown in the relative heights of its parts in the following locations: at the scapular inferior angles (IA), and at the lateral points of intersection of the clavicle with the second rib (Cl). The study of various radiographs indicated that change in height of the right and left halves of the upper thorax is evident in the comparative height of the shadows of the crossing of the first and second ribs (R).

Summary

Movement of the inanimate skeletal structures in the coronal, transverse, and sagittal planes produces asymmetries which may in general be summarized as follows:

1. Rotation in the coronal plane produces lateral angulation which is accompanied by bilateral asymmetry in vertical, horizontal, and diagonal relationships.
2. Rotation in a transverse plane produces bilateral asymmetry in horizontal and in diagonal relationships.
3. Lateral movement in a coronal plane produces bilateral asymmetry in horizontal and in diagonal relationships.
4. Anteroposterior movement in a sagittal plane when equal bilaterally produces change in vertical relationships; when unequal bilaterally, it produces bilateral difference in diagonal and in vertical relationships.

The measurements on the radiographs were limited to the above types of bilateral asymmetries.

Procedure in Taking Trial Measurements on the Radiographs

It was necessary to take trial measurements on the radiographs in order to gain skill in taking measurements, to discover errors in taking and reading measurements, to establish the reliability of points of reference for the various measurements, and to determine which measurements were subject to continued gross error.

<u>Radiographs used in the trial measurements</u>

For the trial measurements the radiographs of ninety subjects were used. Only essential markings were made on these radiographs, namely, the central vertical axis, the centers of the heads of the femora, a vertical line on each ilium from the center of the head of the femur, a line bisecting each femoral neck, and the center of each vertebra. For a description of these markings, see "points of reference", pages 35 to 40.

<u>First trial measurements.</u> The radiographs of sixty of the ninety subjects were used for the first measurements. Sixty-eight different measurements (excluding those on the cervical vertebrae and lateral curves of the spinal column) were taken on the radiographs of each subject, thirty-seven of these being taken on both the right and the left sides of the skeletal structure. Thus a total of 105, or more, measurements were made on the radiographs of each subject. After the complete set of measurements had been taken, a week was allowed to intervene before the same measurements were taken again on the same radiographs.

The results of the successive measurements were compared to determine whether any changes in procedure or in measurements should be made before beginning the second trial measurements. It was found that there was a frequent error of ten-fiftieths of an inch, which was assumed to be a reading error. To rectify this, a magnifying glass was placed over the paragon scale.

During the measurement procedure some difficulty had been experienced in the exact location of a few of the points of reference. It was found that the measurements in which such points of reference had been used showed a varying degree of gross error. Such measurements were either eliminated or their points of reference were changed. In those cases in which elimination of measurements resulted in the loss of measurement of certain types of deviation, other measurements with more specific points of reference were substituted.

Second trial measurements. For the second trial measurements the radiographs of thirty subjects of the first trial measurements and those of thirty new subjects were used. The radiographs of the first thirty subjects were remeasured in order to determine what influence, if any, certain changes in the points of reference had on the accuracy of measurement. In this second trial, fifty-four measurements (excluding those on the cervical vertebrae and lateral curves of the spinal column) were taken on the radiographs of each subject. These measurements were repeated a second time for comparison of results.

Points of reference

The following is a description of all points of reference which were used in making the trial and the final measurements on the various parts of the skeletal structure.

The central vertical axis. The central vertical axis is a vertical line arbitrarily placed on each radiograph. It was drawn with a scriber through the center of the top of the sacrum parallel to the plumb line on the radiograph. The center of the top of the sacrum was chosen for two reasons: (1) the sacrum is the base of support of the spinal column and its attached structures, and (2) in bilateral asymmetry it is assumed that weight divides evenly at the top of the sacrum to be transferred through each half of the pelvis into the two supporting lower extremities.

Sacral wings. The points of reference on the wings of the sacrum were the superior parts of their borders.

Sacral axis. The sacral axis was a line drawn to bisect the width of the sacrum. When the sacral axis was used as a point of reference, the measurement was taken at right angles to this axis.

Sacral table.* This point of reference was a line drawn about an inch below and parallel to the sacral table.

Crests of the ilia. The points of reference on the crests of the ilia were the superior parts of their borders.

Posterior inferior spine of the ilium. The medial point of the ilium at the inferior end of its sacral articulation was used as a point of reference on the ilium.

Far ilium. The far ilium refers to the posterior inferior spine of the ilium located on the side of the axis opposite to the deviating skeletal part.

Acetabulum. The point of reference on the acetabulum was its latero-superior border on the ilium.

Obturator foramen. The borders of the obturator foramen at its greatest horizontal width and at its greatest vertical depth was used for points of reference.

Anterior rim of the true pelvis. The points of reference on the anterior rim of the true pelvis were (a) those in the same sagittal plane as the medial borders of the obturator foramina and (b) those in the same sagittal plane as the posterior inferior spines of the ilia.

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* Albert B. Ferguson, M.D., New York Orthopedic Hospital, suggested that the lateral angulation of the sacral table should be measured in addition to the lateral angulation of the sacral wings since the latter are sometimes quite different in conformation.

The pubic symphysis. The center of the pubic symphysis was used as its point of reference.

Pubic symphysis axis. The axis of the pubic symphysis was a line bisecting the space between the right and left pubic bones. When the pubic symphysis axis was used as a point of reference, the measurement was taken at right angles to this axis.

Tuberosities of the ischia. The inferior borders of the tuberosities of the ischia were used as points of reference.

Center of the femoral head. In some of the trial measurements the upper part of the fovea capitis on the head of the femur was used as a point of reference for measurement. However, this was an indefinite marking on many radiographs. It was then necessary to find a hypothetical center of the head of the femur. This was established by means of the arrow bow pencil. The steel point of the pencil was placed at the point of junction of the shadow of the ischium and the head of the femur as a center for describing a semicircle on the head and neck of the femur. The steel point was next placed at the point of junction of the shadow of the ilium and the head of the femur, and another semicircle was drawn to cross the first semicircle in two places. A line was then drawn through the two points of intersection of the semicircles and extended through the femoral head to the central vertical axis. This line in general bisected the femoral neck. Its point of intersection with the head of the femur was considered the center of the femoral head (see Figure 9, page 38).

Femoral heads. When the femoral head is mentioned as a point of reference, it refers to the superior borders of the femoral head.*

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* Note that this establishes a second point of reference on the femoral head.

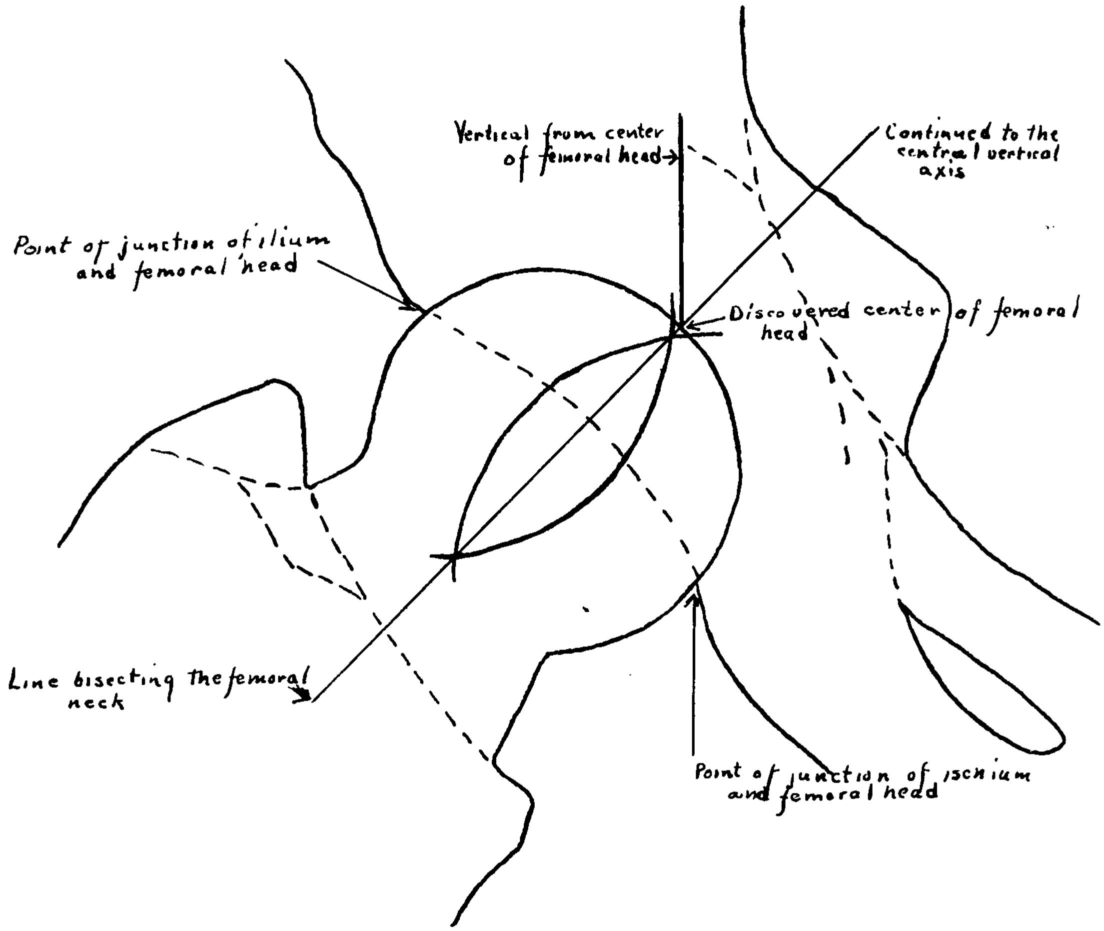

Figure 9. Method of finding the center of the femoral head, and the line bisecting the femoral neck.

<u>Femoral</u> <u>neck</u>. The point of reference on the femoral neck was the bisecting line of the femoral neck (see Figure 9).

<u>Vertical</u> <u>from</u> <u>femoral</u> <u>head</u>. On some of the pelvic radiographs the outer portion of the ilium was lacking. It became necessary, therefore, to establish a vertical line on the ilium as a point of reference for horizontal measurement. This was done by drawing a vertical line on the ilium from the center of the femoral head (see Figure 9).

Small trochanter. The medial border of the small trochanter was unreliable as a point of reference, since rotation of the thigh increases or decreases its prominence without producing necessarily a corresponding change in the position of the femoral shaft. Hence the point of reference was established at the proximal intersection of the shadow of the small trochanter with that of the shaft of the femur.

Great trochanter. The point of reference for the great trochanter was established at the intersection of the shadow of the great trochanter with that of the neck of the femur.

The vertebrae. Two lines were drawn on the body of each vertebra to connect its diagonally opposite corners. The point of crossing of these lines was assumed to be the center of the vertebra.[1]

The fifth lumbar vertebra. Because of the overlapping of the shadow of the body of the fifth lumbar vertebra with the shadow of the upper sacrum on many of the radiographs, the lower corners of the body of the fifth lumbar vertebra were too indistinct to be used for finding the center of this vertebra. Therefore a line was drawn through the fifth lumbar vertebra parallel to the slant of its body.

Lateral curve of the spinal column. In determining the angulation lines of lateral curvature of the spinal column, it was necessary first to locate the vertebra in the curvature which was farthest from the axis. From the center of this vertebra a connecting line was drawn to the center of the nearest vertebra above, and to the center of the

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1. Albert B. Ferguson, M.D., The Study and Treatment of Scoliosis. The Southern Medical Journal. Volume XXIII (February, 1930), page 117.

nearest vertebra below which were on, or across, the central vertical axis.

Scapular inferior angles. The lowest border of the inferior angles of the scapulae were used as their points of reference.

The clavicles. It seemed desirable to use the acromion processes as a point of reference for the clavicles, but one or both of these processes were often lacking on the radiographs. Hence it was necessary to seek a point nearer to the center of the structure on the shoulder girdle. At first the superior borders of the clavicles were tried but measurement of their angulation was subject to gross error. The coracoid process was invariably indistinct, so the latero-superior point of intersection of the shadow of the clavicle and the second rib finally determined the point of reference.

The upper thorax. The latero-superior point at which the shadows of the first and second ribs intersect on the radiographs determined the points of reference for the upper thorax.

Measurements selected for experimentation

Before the final selection of measurements was made, fifty-five measurements were subjected to experimentation. These measurements are classified into two groups according to the method used in taking them: (1) angulation, and (2) distance. Distance measurements are further classified by their direction into (a) horizontal, (b) diagonal, and (c) vertical. The distance measurements (except for the pubic symphysis and for the vertebrae) were taken on both the right and left sides of the skeletal structure. The experimental measurements follow:

Angulation measurements

a. Sacral wings
b. Sacral table
c. Crests of the ilia
d. Ilia, posterior inferior spines
e. Femoral heads
f. Tuberosities of the ischia
g. Scapular inferior angles
h. Clavicles at their superior borders
i. Femoral necks
j. Sacral axis
k. Pubic symphysis axis
l. Lateral curves of the spinal column
m. Anterior rim of true pelvis at points in sagittal planes of posterior inferior spines of the ilia
n. Anterior rim of true pelvis at points in sagittal planes of medial borders of obturator foramina
o. Upper thorax
p. Clavicles
q. Fifth lumbar vertebra

Distance measurements

Horizontal

a. Posterior inferior spine of ilium to axis
b. Ilium crosswise just above the level of the acetabulum
c. Ilium at medial border just above level of acetabulum to axis
d. Obturator foramen at its greatest width
e. Pubic symphysis to axis
f. Small trochanter to axis
g. Great trochanter to axis
h. Center of femoral head to axis
i. Center of each vertebra to axis
j. Fovea capitis to axis
k. External border of ilium to axis, at level of posterior inferior spine of ilium
l. Ilium at top of sacroiliac joint to axis
m. Ilium at posterior inferior spine to axis
n. Small trochanter at most medial border to tuberosity of ischium at lateral border
o. Posterior inferior spine of ilium to vertical from femoral head

Diagonal

a. Great trochanter to acetabulum
b. Small trochanter to acetabulum
c. Great trochanter to posterior inferior spine of ilium
d. Small trochanter to posterior inferior spine of ilium
e. Femoral head

f. Great trochanter to far ilium
g. Small trochanter to far ilium
h. Femoral head to far ilium
i. Acetabulum to posterior inferior spine of ilium
j. Sacroiliac joint length
k. Anterior rim of the true pelvis at a point in the sagittal plane of the most medial border of the obturator foramen to the posterior inferior spine of ilium
l. Medio-superior border of pubic bone to posterior inferior spine of ilium
m. Great trochanter at its medio-superior border to acetabulum
n. Small trochanter at its medial border to sacral axis
o. Great trochanter at its medio-superior border to sacral axis
p. Femoral head at fovea capitis to sacral axis
q. Small trochanter to pubic symphysis axis
r. Great trochanter topubic symphysis axis
s. Femoral head at fovea capitis to pubic symphysis axis
t. Great trochanter to center of femoral head

Vertical

a. Obturator foramen at its greatest vertical depth
b. Anterior rim of true pelvis to posterior inferior spine of ilium
c. Inferior border of lateral process of fifth lumbar vertebra to nearest border of sacrum

Selecting the Measurements for All Radiographs

The selection of the final measurements for all radiographs was made by subjecting asymmetries determined by preliminary measurement to certain arbitrarily established criteria. These criteria were constructed on the basis of the results of repetition of trial measurements to determine gross error and the results of preliminary statistical treatment of data. All measurements which did not conform to the established criteria were eliminated.

Preliminary treatment of data

To discover which asymmetries were both reliable and related to other asymmetries, two preliminary statistical procedures were used, as follows:

Determining the reliability of asymmetries. Bilateral measurements were made on the first and second sets of radiographs of thirty subjects taken at two different times under identical conditions. From these measurements the asymmetries on the first and second radiographs of each subject were determined for reliability data. The measurements were all those which had not been discarded because of gross error after the first trial measurements (see Table II, page 70). To discover the extent to which asymmetries are reliable the specific asymmetries determined on one set of radiographs of a subject were correlated with the same specific asymmetries determined on a second set of radiographs of the same subject taken at a later time. The data were subjected to the Pearson product-moment formula,[1] as follows:

$$r = \frac{\Sigma xy}{N\sigma_x\sigma_y} \; *$$

Determining the intercorrelation of asymmetries. The asymmetries entering into the preliminary study of intercorrelation were those resulting from the measurements which were taken on the radiographs of the sixty subjects used in the second trial measurements. The measurements were those which had not been discarded because of gross error, but they did not include asymmetries determined by measurements which were added later (see page 81). The various asymmetries were intercorrelated using the Pearson product-moment formula.

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1. Henry E. Garret, Statistics in Psychology and Education, page 168.

* For computational expression of this formula, see Appendix, page 174.

Criteria for the selection of final measurements

The selection of final measurements was based on the following arbitrarily established criteria:

1. Gross error. A measurement was considered subject to gross error if more than one-fiftieth inch difference occurred when the measurement was taken four different times on the same radiograph.

2. Reliability. The asymmetry determined by a measurement was considered too much subject to chance when its reliability was less than .60.

3. Intercorrelation. Two criteria were established on the basis of preliminary intercorrelation, as follows: (a) when more than one measurement seemed to indicate the same type of deviation of a part of the structure, the measurement whose resulting asymmetry showed the higher intercorrelation with other asymmetries was retained; and (b) an asymmetry must show a correlation of .60 or better with one or more asymmetries in order to retain its measurement.*

Measurements that were eliminated

The following measurements** were eliminated on the basis of the established criteria:

* Although the asymmetries determined by measurements of the shoulder girdle and upper thorax did not conform to this criterion, they were retained for study in relation to handedness.

** See pages 40 to 42 for the list of experimental measurements.

<u>On the basis of gross error</u>

<u>Angulation measurements</u>

(h) Clavicles at their superior borders
(j) Sacral axis
(k) Pubic symphysis axis

<u>Horizontal distance measurements</u>

(j) Fovea capitis to axis
(k) External border of ilium to axis, at level of posterior inferior spine of ilium
(n) Small trochanter at most medial border to tuberosity of ischium at lateral border

<u>Diagonal distance measurements</u>

(l) Medio-superior border of pubic bone to posterior inferior spine of ilium
(m) Great trochanter at its medio-superior border to acetabulum
(n) Small trochanter at its medial border to sacral axis
(o) Great trochanter at its medio-superior border to sacral axis
(p) Femoral head at fovea capitis to sacral axis
(q) Small trochanter to pubic symphysis axis
(r) Great trochanter to pubic symphysis axis
(s) Femoral head at fovea capitis to pubic symphsis axis

<u>Vertical distance measurement</u>

(c) Inferior border of lateral process of fifth lumbar vertebra to nearest border of sacrum

<u>On the basis of reliability</u>

<u>Angulation measurement</u>

(m) Anterior rim of true pelvis at points in sagittal planes of posterior inferior spines of the ilia

<u>Horizontal distance measurement</u>

(m) Ilium at posterior inferior spine to axis

<u>Diagonal distance measurements</u>

(g) Small trochanter to far ilium
(i) Acetabulum to posterior inferior spine of ilium
(j) Sacroiliac joint length

On the basis of intercorrelation

Angulation measurement

(n) Anterior rim of true pelvis at points in sagittal planes of medial borders of obturator foramena.

Horizontal distance measurement

(l) Ilium at top of sacroiliac joint to axis

Diagonal distance measurement

(k) Anterior rim of the true pelvis at a point in the sagittal plane of the most medial border of the obturator foramen to the posterior inferior spine of the ilium

Measurements that were retained

The measurements listed below were taken on the entire set of radiographs of 516 subjects, of which 497 entered into the final study. The measurements include those that were added following the intercorrelation of preliminary data (see pages 78 to 81). The key given with each skeletal part is used throughout the remainder of the study to designate the asymmetry of that part. When a skeletal part occurs more than once under a type of measurement, it is because its position was measured in relation to a corresponding number of points of reference.

Angulation measurements (see Figure 10, page 47).

Key	Skeletal part
A1	Sacral wings
A2	Sacral table
A3	Crests of the ilia
A4	Ilia, at posterior inferior spines
A5	Femoral heads
A6	Tuberosities of ischia
A7	Femoral necks
A8	Scapular inferior angles (see Figure 13, page 51)
A9	Clavicles (see Figure 13, page 51)
A10	Upper thorax (see Figure 13, page 51)
D1	Fifth lumbar vertebra
E	Lateral curve of spinal column (see Figure 11, page 49)

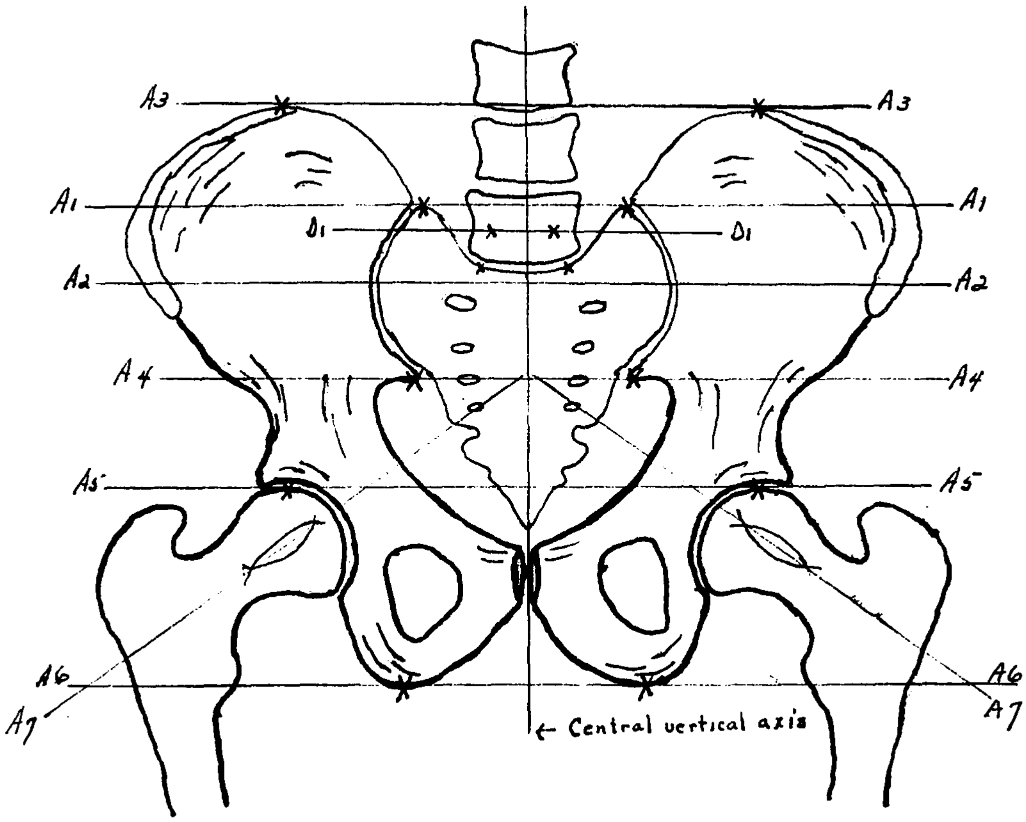

Figure 10. Angulation measurements in the pelvis, the femoral heads, and the fifth lumbar vertebra. For each measurement an x marks the bilateral points of reference, except for A2 and D1. A2 is an angulation measurement taken parallel to the slant of the sacral table; D1 is an angulation measurement which bisects the sides of the fifth lumbar vertebra.

Distance measurements

Horizontal distance (see Figure 11, page 49)

Key	Skeletal part
B1	Ilium at level of posterior inferior spine
B2	Posterior inferior spine of ilium
B3	Ilium at level just above acetabulum
B4	Ilium at medial border just above level of acetabulum
B5	Obturator foramen
B8	Pubic symphysis
C1	Small trochanter
C2	Great trochanter
C3	Femoral head
D	Spinal column as a whole (Summation of D2, D3, D4)
D2	Lumbar spine, excluding fifth lumbar vertebra
D3	Thoracic spine
D4	Cervical spine

Vertical distance (see Figure 11, page 49)

B6	Obturator Foramen
B7	Anterior rim of true pelvis

Diagonal distance (see Figure 12, page 51)

B9	Great trochanter
C4	Great trochanter
C5	Small trochanter
C6	Great trochanter
C7	Small trochanter
C8	Femoral head
C9	Great trochanter
U10	Femoral head

Objectivity of Measurement

This study did not lend itself to the usual procedure in establishing its objectivity, that is, by having another individual make the same measurements on the same radiographs, for these reasons: (a) to measure the radiographs required a degree of skill which obviously could not have been acquired except through a certain amount of experience with the radiographs and (b) the points of reference marked on the radiographs either by the investigator or another individual would unwittingly in-

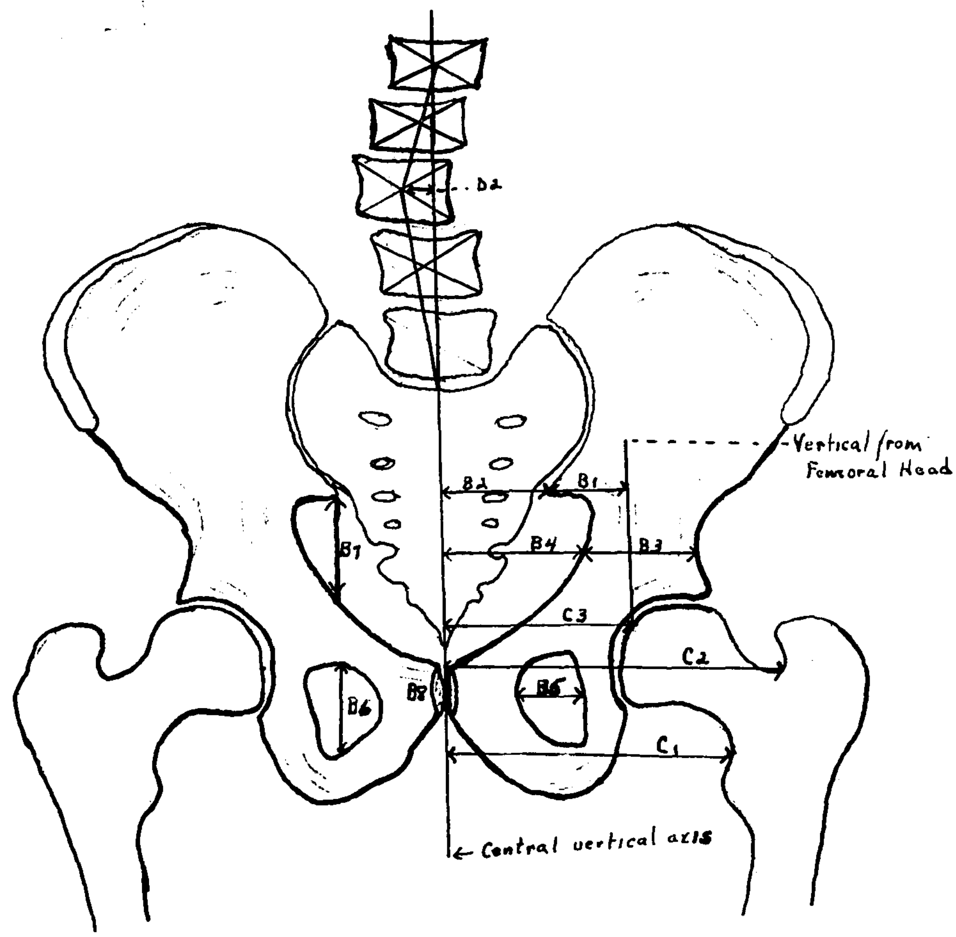

Figure 11. Horizontal and vertical distance measurements in the pelvis, the femora, and the spine. The limiting points of each measurement are marked thus: < >. All of these measurements except B8 and D2 were taken bilaterally, although they are illustrated on one side only. D3 and D4 were taken the same as D2.

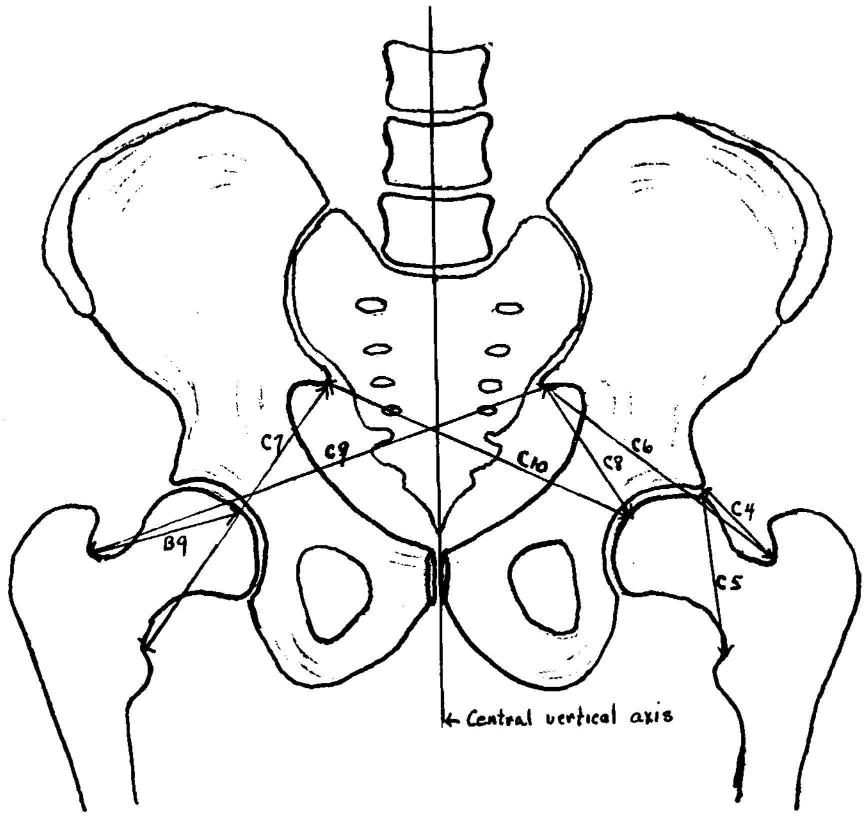

Figure 12. Diagonal distance measurements in the pelvis and the proximal femora. The limiting points of each measurement are marked thus: ‹ › . All of these measurements were taken bilaterally although they are illustrated on one side only.

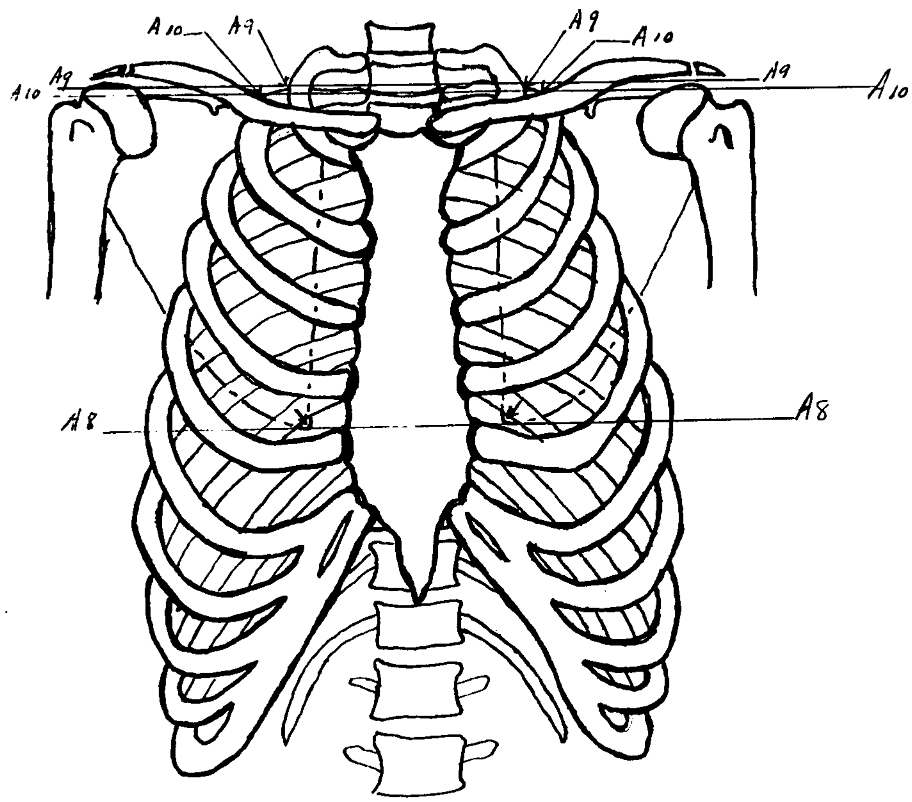

Figure 13. Angulation measurements in the shoulder girdle and upper thorax. Arrows point to the bilateral points of reference for each measurement.

fluence the second person attempting to verify the measurements.

It is assumed that objectivity is assured on the following bases:

1. Only those asymmetries with an established reliability of .60 or better were determined in the final measurements.
2. All measurements had been repeated by the investigator four times on the radiographs of sixty subjects in preliminary study. No measurement was retained whose results showed more than one-fiftieth of an inch error at any time.
3. As will be shown later, the results of the intercorrelations of asymmetries on the four sets of data were (a) consistent and (b) logical in meaning.

Taking the Final Measurements

As preliminary preparation for the final measurements, the radiographs to be measured were arranged into two groups according to sex and in order of the age of the subjects. The measurements were listed in the order in which they were to be taken and placed on the wooden framework of the view-box to the left of the blue tint glass.

Points of reference marked on all radiographs

Great care was exercised in marking the points of reference on each radiograph. Besides the necessary pencil line markings, small punctures were made with the scriber at the intersection of the parts of the structure, at angles, and on projections which were used as points of reference. The following is a list of the points of reference* marked on all radiographs:

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* See pages 35 to 40 for description of points of reference.

Central vertical axis
Line bisecting the femoral neck
Center of the head of the femur
Vertical line upward on the ilium from the center of femoral head
Center of pubic symphysis
Center of each vertebra
Angulation lines of lateral curves of the spinal column
Ilia at posterior inferior spines
Small trochanters
Great trochanters
Acetabula
Sacral table
Clavicles
Upper thorax
Angulation line of the fifth lumbar vertebra

How the measurements were made

Since measurements were of two types -- angulation and distance -- two different procedures were used in taking the measurements, as follows:

Angulation measurements. All angulation measurements were taken with a protractor which was graduated to one-half degrees. With the center of the straight edge of the protractor on the central vertical axis, the protractor was rotated to make its straight edge coincide with the points of reference on the right and left sides of the skeletal part whose angulation was to be determined. The degree of angulation was read on the arc of the protractor at the point where it crossed the central vertical axis. Thus if the left side of the straight edge of the protractor was higher, the measurement was less than 90 degrees; if the right side was higher, the measurement was more than 90 degrees.

Angulation measurements were recorded to the nearest half degree.

Distance measurements. All distance measurements were taken with the hairspring dividers by placing their points on the points of reference of the parts concerned, then reading the distance between the two points of the dividers on the paragon scale under the magnifying glass. For horizontal distance measurements the T square and triangle were used to determine the horizontal relationship of parts; for vertical distance measurements the T square was used to determine the vertical relationship of parts.

Distance measurements were recorded to the nearest fiftieth of an inch. For ease in recording, one-fifth of an inch was considered the unitp and one-fiftieth of an inch, a tenth of a unit. Thus a measurement which was one and four-fiftieths inches was recorded as 5.4.

Number of measurements

Final measurements were taken on the radiographs of 516 subjects.* Sixty-five measurements were taken on the radiographs of each subject, exclusive of the measurement of angulation of lateral curvature of the spinal column and measurements on such cervical vertebrae as appeared on each thoracic radiograph. The total number of measurements on all radiographs was approximately 35,000.

Recording the measurements

The measurements were recorded on special form blanks.** As each measurement was determined by the investigator it was stated to a secretary who first repeated the measurement orally for verification, then recorded it. The same secretary recorded all measurements. All the angulation measurements were taken first on the radiograph of the subject, then the distance measurements were taken, first on the left side, then

* As will be shown later, only 497 of these subjects entered into the final study.

** For a sample record of original measurements, see Appendix, page 175 on the right side, in an established order, working from the upper part of the radiograph downward.

ORGANIZATION AND ANALYSIS OF DATA

Preliminary to the final treatment of data the reliability of the bilateral skeletal asymmetries was determined and used as one of the criteria for the selection of final measurements (see page 42).

Further procedure in the organization and analysis of data follows.

Determining the Deviations

An asymmetry is the degree of difference in the position of identical lateral skeletal structures measured on the radiograph. A lateral angulation asymmetry is the degree of angulation of identical lateral structures in reference to the central vertical axis. A distance asymmetry is the difference between the positions of identical lateral structures in relation to the central vertical axis or in relation to some other part of the skeletal structure. Asymmetry in the position of any vertebra of the spinal column is the distance between the center of the vertebra and the central vertical axis. When an asymmetry occurs on the left side of the skeletal structure, it is recorded as minus (-); when on the right side, as plus (+).

To illustrate the procedure in determining asymmetries, measurements on the radiographs of one subject are given as follows:

Angulation measurements		Asymmetries
A1*	91.0	+10
A2	91.0	+10
A3	90.0	0
A4	91.0	+10
A5	90.5	+ 5
A6	91.0	+10
A7	56.5 (rt.); 60.0 (left)	+40
A8	92.5	+25
A9	89.5	+ 5
A10	94.0	+40
D1	91.5	+15
E**		

Deviations on the radiographs of one subject

Distance measurements	Left	Right	Asymmetries
B1***	7.2	7.6	+ 4
B2	10.3	10.4	+ 1
B3	10.5	9.9	- 6
B4	15.3	15.6	+ 3
B5	5.7	5.6	- 1
B6	5.2	4.9	- 3
B7	15.7	16.3	+ 6
B8		.3	+ 3
B9	13.7	14.3	+ 6
C1	22.6	23.5	+ 9
C2	30.1	31.4	+13
C3	17.5	18.0	+ 5
C4	9.6	10.5	+ 9
C5	16.6	17.1	+ 5
C6	26.7	27.5	+ 8

(continued)

* The angulation of A1, the wings of the sacrum, is 91.0 degrees. The asymmetry is the difference between 90.0 and 91.0 degrees. To eliminate the use of decimal points, and to show that the right sacral wing is higher than the left, the asymmetry is expressed as 10.

** There was no angulation of lateral curve of spinal column in this radiograph since the spinal column deviated from the central vertical axis and did not return to it.

*** B1 shows that the horizontal distance on the ilium between the left posterior inferior spine of the ilium and a vertical from the center of the left femoral head is 7.2; the corresponding distance on the right is 7.6. The asymmetry or difference between the two measurements is .4 and it is expressed as 4 to eliminate the decimal point and show that the greater distance occurs on the right side.

Distance measurements	Left	Right	Asymmetries
C7	29.0	29.3	+ 3
C8	14.4	14.7	+ 3
C9	44.4	45.2	+ 8
C10	30.6	30.9	+ 3
D2-4L*	.6		- 6
-3L	.5		- 5
-2L	.7		- 7
-1L	.6		- 6
D3-12T	.6		- 6
-11T	.5		- 5
-10T	.3		- 3
- 9T	.4		- 4
- 8T	.7		- 7
- 7T	.8		- 8
- 6T	.7		- 7
- 5T	.6		- 6
- 4T	.7		- 7
- 3T	.9		- 9
- 2T	1.2		- 12
- 1T	1.3		- 13

The skeletal asymmetries on the radiographs of all the subjects were determined in the same manner as those recorded above.** The computation of asymmetries was repeated by a second person for the purpose of eliminating error.

Grouping the Data for Statistical Treatment

The data were organized for analysis into four groups according to sex and age, as follows:

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* D2-4L shows that the horizontal distance between the center of the body of the fourth lumbar vertebra and the central vertical axis is .6 and that the position of this vertebra is to the left of the axis. Its asymmetry is expressed as -6.

** For sample record of asymmetries, see Appendix, page 176.

Young Women	(Y.W.)	17 to 22 years, inclusive	121 subjects
Young Men	(Y.M.)	17 to 22 years, inclusive	182 subjects
Older Women	(O.W.)	23 to 41 years, inclusive	94 subjects
Older Men	(O.M.)	23 to 41 years, inclusive	100 subjects

The data were grouped according to age and sex for the following reasons:

1. The differences, if any, between age-sex groupings was sought in the following: degree of asymmetry, correlation of asymmetries, patterns of asymmetry, and intercorrelation of patterns of asymmetry.
2. The age limits as given were chosen for the following reasons:
   a. The lower age limit was fixed at 17 years and the upper age limit at 41 years for the reason that there were too few subjects below and above these age limits to yield reliable data.*
   b. Twenty-two years was chosen as the age limit of the younger group for these reasons:
      (1) Ages 17 to 22 are primarily undergraduate college ages, and ages 22 years and over are primarily post-graduate ages. Any factors which might or might not influence skeletal asymmetry would probably tend to be similar within each of these groups.
      (2) The distribution of ages indicated a definite decrease in the number of individuals at each age level above 22 years.*

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* For a frequency distribution of all subjects whose radiographs were subjected to measurement, see Appendix, page 177.

(3) According to the theory of growth of bone,[1] undoubtedly this age limit would make adequate allowance for the completion of growth. Assuming that the growth factor might have an influence on bilateral asymmetry, such influence would be limited to the subjects in the younger groups.

3. The separation into these particular age-sex groups gave four sets of data sufficiently equal in size to be given separate statistical treatment.

4. To eliminate combination of ages into two groups and to treat age as a factor would tend to be misleading for the following reasons:

   a. Curvilinearity might obscure relationships.

   b. The number of cases is not sufficient to justify fitting curvilinear lines of regression.

Computing the Intercorrelation of Asymmetries

To determine the interrelationship between the various asymmetries in the age and sex groups, the intercorrelation of asymmetries in each of the four sets of data was computed by means of the Pearson product-moment formula. Intercorrelation was determined on the four sets of data separately in order to obtain data for further treatment in relation to age and sex.

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1. Committee on Growth and Development of the Child, White House Conference, Growth and Development of the Child, Part II, Anatomy and Physiology. Chapter II, particularly pages 47-55.

Searching for Patterns of Asymmetry

The preliminary experimentation with movement of inanimate skeletal structures to produce asymmetries similar to those on the radiographs indicated that there are various types of asymmetry which occur simultaneously with any one kind of movement, that various kinds of movement produce similar types of asymmetry, and that probably no one type of movement occurs singly in the many jointed skeletal structure. For these reasons the intercorrelation data were subjected to further analysis and statistical treatment to determine if possible not only the asymmetries which tend to occur together consistently, but also the kinds of movement which tend to take place simultaneously in the joints to produce consistently a group of asymmetries.

In the search for patterns of asymmetry only one table of intercorrelation of asymmetries was used, the patterns discovered in this to be tried later in each of the four sets of data. The table used was made up of the average intercorrelations of the same asymmetries of the four sets of data.*

The difference in the degree of the various correlations of asymmetries indicated that it might logically be assumed that those asymmetries which would occur together consistently in a pattern would have a higher correlation among themselves than with other skeletal asymmetries not in the pattern. Two criteria, therefore, would maintain for each pattern, namely (A) a similar degree of correlation of asymmetries within the pattern, and (B) a lesser and similar degree of correlation with

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* See Appendix, Table XXX, page 178.

asymmetries not in the pattern. The range of degree of correlation for Criterion A and for Criterion B would not be known until after the patterns were discovered.

For convenience in noting the degree of correlation of the various asymmetries the correlations within a range of ten degrees were placed in columns in a table.* The following steps were then taken in the search for patterns of asymmetry.

1. The asymmetries of similar degree of correlation were placed in a table for inspection in relation to Criterion A, that is, similarity of correlation.
2. When the correlations of any one asymmetry with each other asymmetry in the trial group did not conform to Criterion A the asymmetry was eliminated to be tried in another pattern.
3. The average correlation of each asymmetry with all other asymmetries within the trial group was determined as a further check of conformity with Criterion A.
4. The correlations of each asymmetry within the trial pattern with those asymmetries not in the trial pattern were inspected to determine whether they conformed to Criterion B, that is, a similarly less degree of relationship than the relationships maintaining within the pattern. When the correlation of any asymmetry outside the pattern with an asymmetry within the pattern was similar to the correlations maintaining in the pattern, the correlation of this asymmetry with all others in the pattern was inspected to determine conformity

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* See Appendix, Table XXXII, page 179.

with Criterion A. If there was conformity with Criterion A, this asymmetry was placed in the pattern.

5. The average correlation of each asymmetry within the pattern with other asymmetries not in the pattern was determined as a further check of conformity with Criterion B.

The above procedure was continued until all the asymmetries were subjected to trial in a pattern. In this manner the patterns of asymmetry as they occurred in the average intercorrelation of asymmetries in the age-sex groups was discovered.

Constructing the Patterns of Asymmetry for Each of the Four Groups of Subjects

On the basis of the discovered patterns of asymmetry resulting from the preceding analysis of data, patterns were constructed from the intercorrelation of asymmetries in each of the age-sex groups. These patterns were then subjected to the same criteria used in the discovery of patterns to determine whether they would remain the same in the age-sex groups. As will be shown later, the validity of the foregoing procedure rests in the logical interpretations that are possible from the asymmetries as they are grouped in the separate patterns.

Computing the Intercorrelation of Patterns of Asymmetry

In order to determine whether patterns of asymmetry tend to occur together, similarly as asymmetries tend to occur together, the intercorrelation of the patterns of asymmetry in each of the four sets of data was determined by means of the following formula:[1]

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1. Truman L. Kelley, Statistical Method, formula 147, page 197.

$$r^{*}_{(1+2+\ldots a)(I+II+\ldots b)} = \frac{\overset{ab}{\underset{I}{S}} r_{pQ}}{\sqrt{a + \overset{(a^2-a)}{\underset{I}{S}} r_{pq}}\ \sqrt{b + \overset{(b^2-b)}{\underset{I}{S}} r_{PQ}}}$$

Determining the Relationship of Skeletal Asymmetries to Age and Sex

In order to determine whether the degree of skeletal asymmetry was related to age or sex, the significant differences of asymmetries in the four sets of data were computed, as follows:

1. A table of average degree of the various asymmetries, regardless of signs, occurring in each of the four sets of data was constructed.** The signs, which indicated whether the asymmetries occurred on the right or left half of the structure, were disregarded to prevent the right and left asymmetries from cancelling each other.
2. Sigma of the various asymmetries being considered regardless of signs*** was computed by means of the following formula:[1]

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* For expression of formula for the correlation of the sums of scores of two variables with two variables, see Appendix, page 174.

** See Appendix, Table XXXI, page 178.

*** For computation formula, see Appendix, page 174.

1. Garrett, *op. cit.*, page 26.

$$\sigma = \sqrt{\frac{\Sigma FD^2}{N}}$$

3. The significant difference of the means of the asymmetries*
was computed by means of the following formulae:[1]

a. $$\sigma_{(diff.)} = \sqrt{\sigma^2_{(av.1)} + \sigma^2_{(av.2)}}$$

b. $$\text{Sig. diff.} = \frac{D}{\sigma_{diff.}}$$

Determining the Relationship of Asymmetries of the Shoulder Girdle and Upper Thorax to Handedness

To determine whether there was any relation between the asymmetries of the shoulder girdle and upper thorax and handedness, the following analysis was made for each of the age and sex groups of subjects:

1. Percentages were determined, as follows:
   a. Of right-handed and of left-handed subjects.
   b. Of left asymmetry, of right asymmetry, and of no asymmetry in A8, A9, A10, and in the slant of the upper thoracic spine for right-handed and for left-handed subjects.

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* For computation formula, see Appendix, page 174.

1. Garrett, *op. cit.*, pages 129 and 133.

2. The average degree of asymmetry was determined for A8, A9, and A10 when they occurred on the left side and when they occurred on the right side.

3. The percentage of right asymmetry and of left asymmetry in A8, A9, A10, and in the upper thoracic spine was compared for right-handed and for left-handed subjects.

4. The difference in degree in each asymmetry when it occurred on the left and when it occurred on the right with right-handedness was determined. This was repeated for left-handedness. Then the results were compared.

5. The relation between the slant of the upper thoracic spine and the asymmetries of the shoulder girdle was analyzed similarly as the relation of each of these asymmetries with handedness was analyzed.

Analyzing the Data on the Spinal Column

Little or no relationship was shown between the asymmetries of the various regions of the spinal column; likewise, there was little or no relationship between asymmetries in either the thoracic or cervical regions of the spinal column and other asymmetries in the skeletal structure. For this reason attempts were made to analyze the spinal column in other ways. These attempts showed that an adequate statistical treatment and analysis of the spinal column, in part and as a whole, required measurement data that were not collected in this study. The data collected, however, on horizontal asymmetries of the vertebrae and on angulation of lateral curves of the spinal column were given further analysis to determine, if possible, the tendency of the spinal column to compensate lateral deviations to one side with lateral deviations to the other side. The following computations were made:

1. The percentage of spines deviating to only one side of the central vertical axis
2. The percentage of spines deviating to the left only, and to the right only
3. The percentage of spines with one lateral curve, with a second lateral curve, with a third lateral curve, and with a fourth lateral curve.
4. The average degree of angulation and the average number of vertebrae in the first, the second, the third, and the fourth lateral curves

CHAPTER III

BILATERAL SKELETAL ASYMMETRIES AND THEIR INTERRELATIONSHIP

In the 497 subjects studied it was found that every subject was bilaterally asymmetrical to some extent in each of the following skeletal units: pelvis, femora, spinal column, thorax, and shoulder girdle. It is the purpose of this chapter to present first, the asymmetries in these skeletal units, second, the reliability or extent to which they may be considered habitual and functional, and third, the interrelationship of the asymmetries.

BILATERAL SKELETAL ASYMMETRIES

Asymmetries in the position of lateral identical structures are classified according to the type of measurement used to determine them, as follows: (a) lateral angulation, (b) horizontal distance relationship, (c) vertical distance relationship, and (d) diagonal distance relationship. Although each type may occur in all of the skeletal units studied, the measurements taken on the radiographs limited the asymmetries to the following: lateral angulation in all five of the skeletal units; bilateral differences in horizontal relationships in the pelvis, the femora, and the spinal column; bilateral differences in vertical relationships in the pelvis and the femora combined, and in the femora alone.

The types of asymmetry found in the various parts of the five anatomical units are shown in Table I, page 68. Asymmetry in bilateral

TABLE I

Bilateral Skeletal Asymmetries

Type of Asymmetry	Skeletal Structure	Key to Asymmetry*
	Pelvis, posterior arch	
L.A.**	Sacral wings	A1
L.A.	Sacral table	A2
L.A.	Crests of ilia	A3
L.A; H.D.	Posterior inferior spines of ilia	A4;B2
H.D.	Medial borders of ilia	B4
H.D.	Horizontal surfaces of ilia	B1;B3
	Pelvis, anterior arch	
V.D.	Anterior rim of true pelvis	B7
L.A.	Tuberosities of ischia	A6
H.D.	Pubic symphysis	B8
H.D; V.D.	Obturator foramina	B5;B6
	Femora	
L.A; H.D; D.D.	Head	A5;C3;C8;C10
L.A.	Neck	A7
D.D; H.D.	Great trochanter	B9;C2;C3;C6;C9
H.D; D.D.	Small trochanter	C1;C5;C7
	Spinal column	
L.A.	Fifth lumbar vertebra	D1
H.D.	First four lumbar vertebrae	D2
H.D.	Twelve thoracic vertebrae	D3
H.D.	Cervical vertebrae (varying number)	D4
L.A.	Lateral curve of spinal column	E
L.A.	Upper thorax	A10
	Shoulder girdle	
L.A.	Scapular inferior angles	A8
L.A.	Clavicles	A9

* For illustration of the measurement of asymmetries, see Figures 10 to 13 inclusive, pages 47, and 49 to 51.

** L.A. means lateral angulation; H.D., horizontal distance; V.D., vertical distance; D.D., diagonal distance.

The table should be read across as follows: As an example, the heads of the femora show lateral angulation asymmetry (A5), horizontal distance asymmetry (C3) in relation to the central vertical axis, and diagonal distance asymmetry in relation both to the near (C8) and the far (C10) ilium.

alignment occurred in the following locations: in the sacrum, the ilia, the ischia, and the pubes of the pelvis; in the head, the neck, the great trochanter, and the small trochanter of the femora; in all the vertebrae of the spinal column; in the scapulae and the clavicles of the shoulder girdle; and in the upper part of the thorax.

In moving the inanimate skeletal structures in the coronal, the sagittal, and the transverse planes to produce asymmetries similar to those on the radiographs, similar changes occurred in the bilateral relationships of the skeletal parts with the different kinds of movement.* Asymmetry in the position of lateral identical parts undoubtedly accompanies deviation in the relationship at many joints, such deviation occurring with a combination of various types of movement. For this reason the asymmetries common to different directions and planes of movement of the skeletal parts are considered in Chapter IV where the asymmetries are merged into patterns.

RELIABILITY OF BILATERAL SKELETAL ASYMMETRIES

The correlation of the same specific asymmetries measured in two sets of radiographs of thirty of the subjects taken under identical conditions at two different times established the reliability of the asymmetries, that is, the extent to which they may be considered habitual and functional. The reliability of each asymmetry that was measured, both experimentally** and on the entire set of radiographs is shown in Table II, page 70. This table shows also the key for each asymmetry, the skeletal

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* See pages 24 to 33.

** This excludes experimental measurements that were discarded because of gross error.

TABLE II

Reliability of Bilateral Skeletal Asymmetries

Key to Asymmetry	Skeletal Structure	Point of Reference	Type of Asymmetry	Reliability
A1	Sacral wings	C.V.A.*	L.A.	.98
A2	Sacral table	C.V.A.	L.A.	.95
A3	Crests of ilia	C.V.A.	L.A.	.95
A4	P.I. spines of ilia	C.V.A.	L.A.	.95
A5	Femoral heads	C.V.A.	L.A.	.93
A6	Tuberosities of ischia	C.V.A.	L.A.	.91
A7	Femoral necks	C.V.A.	L.A.	.84
A8	Scapular inferior angles	C.V.A.	LL.A.	.83
A9	Clavicles	C.V.A.	L.A.	.71
A10	Upper thorax	C.V.A.	L.A.	.88
(Am)**	True pelvis, anterior rim	C.V.A.	L.A.	.32
(An)***	True pelvis, anterior rim	C.V.A.	L.A.	.84
B1	P.I. spine of ilium	Vertical from femoral head	H.D.	.73
B2	P.I. spine of ilium	C.V.A.	H.D.	.92
B3	Ilium, above acetabulum	Its lateral borders	H.D.	.60
B4	Ilium, medial border (same level as B3)	C.V.A.	H.D.	.86
B5	Obturator foramen	Its lateral borders	H.D.	.62
B6	Obturator foramen	Its vertical borders	V.D.	.66
B7	True pelvis, anterior rim	Ilium	V.D.	.77
B8	Pubic symphysis	C.V.A.	H.D.	.78
B9	Great trochanter	Femoral head	D.D.	.75
(H1)***	P.S. spine of ilium	C.V.A.	H.D.	.78
(Hm)**	Ilium, level of P.I. spine	Its lateral borders	H.D.	.57
C1	Small trochanter	C.V.A.	H.D.	.81
C2	Great trochanter	C.V.A.	H.D.	.85
C3	Femoral head, center	C.V.A.	H.D.	.88
C4	Great trochanter	Acetabulum	D.D.	.91
C5	Small trochanter	Acetabulum	D.D.	.86
C6	Great trochanter	Ilium	D.D.	.82
C7	Small trochanter	Ilium	D.D.	.83
C8	Femoral head, center	Ilium	D.D.	.77
C9	Great trochanter	Far ilium	D.D.	.64
C10	Femoral head, center	Far ilium	D.D.	.74
(Dg)**	Small trochanter	Far ilium	D.D.	.59
(Di)**	Acetabulum	Ilium	D.D.	.57
(Dj)**	Sacroiliac joint	Its vertical Borders	D.D.	.59
(Dk)***	True pelvis, anterior rim	Ilium	D.D.	.82
D1	Fifth lumbar vertebra	C.V.A.	H.D.	.92
D2	First four lumbar vertebrae	C.V.A.	H.D.	.91
D2-3	Thoracicolumbar vertebrae[f]	C.V.A.	H.D.	.87
D3	Twelve thoracic vertebrae	C.V.A.	H.D.	.83
D3a	Upper thoracic vertebrae[ff]	C.V.A.	H.D.	.73
D4	Cervical vertebrae# "	C.V.A.	H.D.	.73 minus

B8	Pubic symphysis	C.V.A.	H.D.	.78
B9	Great trochanter	Femoral head	D.D.	.75
(Hl)***	P.S. spine of ilium	C.V.A.	H.D.	.78
(Hm)**	Ilium, level of P.I. spine	Its lateral borders	H.D.	.57
C1	Small trochanter	C.V.A.	H.D.	.81
C2	Great trochanter	C.V.A.	H.D.	.85
C3	Femoral head, center	C.V.A.	H.D.	.88
C4	Great trochanter	Acetabulum	D.D.	.91
C5	Small trochanter	Acetabulum	D.D.	.86
C6	Great trochanter	Ilium	D.D.	.82
C7	Small trochanter	Ilium	D.D.	.83
C8	Femoral head, center	Ilium	D.D.	.77
C9	Great trochanter	Far ilium	D.D.	.64
C10	Femoral head, center	Far ilium	D.D.	.74
(Dg)**	Small trochanter	Far ilium	D.D.	.59
(Di)**	Acetabulum	Ilium	D.D.	.57
(Dj)**	Sacroiliac joint	Its vertical borders	D.D.	.59
(Dk)***	True pelvis, anterior rim	Ilium	D.D.	.82
D1	Fifth lumbar vertebra	C.V.A.	H.D.	.92
D2	First four lumbar vertebrae	C.V.A.	H.D.	.91
D2-3	Thoracicolumbar vertebrae[f]	C.V.A.	H.D.	.87
D3	Twelve thoracic vertebrae	C.V.A.	H.D.	.83
D3a	Upper thoracic vertebrae[ff]	C.V.A.	H.D.	.75
D4	Cervical vertebrae[#]	C.V.A.	H.D.	.73 minus
E	Lateral spinal curve[##]	C.V.A.	L.A.	.83 plus

* C.V.A. means central vertical axis; L.A., lateral angulation; H.D., horizontal distance; V.D., vertical distance; D.D., diagonal distance; P.I., posterior inferior; P.S., posterior superior.

** Discarded on basis of reliability below .60.

*** Discarded on basis of preliminary intercorrelation.

f Includes eleventh and twelfth thoracic, and first and second lumbar vertebrae.

ff Includes the first four thoracic vertebrae.

\# Since the number of cervical vertebrae varied in the thirty subjects whose radiographs furnished reliability data, the reliability of the position of the cervical vertebrae was not determined. It is assumed however that it will be less than .73, but probably above .60.

\## Reliability could not be established since there were only ten of the thirty subjects radiographed at two different times whose spinal columns showed lateral curves of the type measured in this study. It is assumed that reliability lies between .83 and .91 since these are the reliabilities of the thoracic and the lumbar spine respectively.

TThis table should be read across as follows: A1, the sacral wings, measured in relation to the central vertical axis, show lateral angulation asymmetry in bilateral position. The reliability of their asymmetry is .98.

part concerned, the point of reference for measurement, and the type of asymmetry.

Since it was arbitrarily decided not to include asymmetries whose reliability on 30 subjects was not .60 or above, all asymmetries with a reliability below .60 were eliminated from the final measurements on the radiographs. The asymmetries measured on the radiographs of the thirty subjects have a reliability ranging in value from .32 to .98. Ten of the asymmetries measured on the entire set of radiographs have a reliability of .90 or above; fifteen, of .80 to .90; seven, of .70 to .80; and only four, of .60 to .70. There were five asymmetries with a reliability below .60 which were discarded from final measurement.

A comparison of the means and standard deviations of the asymmetries in the first and second radiographs of thirty of the 497 subjects of the study with the means and standard deviations of the asymmetries in the radiographs of each of the four groups of subjects shows that there is similarity both in average degree of asymmetry and in variability of degree of asymmetry.*

A study of Table III, page 72, indicates that a higher degree of reliability tends to exist when the position of bilateral identical skeletal parts is measured in relation to the central vertical axis. For this reason the asymmetries were grouped for further analysis, as follows: (1) asymmetries measured in relation to the central vertical axis, and (2) asymmetries measured in relation to another part of the skeletal structure.

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* See Appendix, Table XXXIV, page 181.

TABLE III

Reliability of Bilateral Skeletal Asymmetries Measured in Relation to the Central Vertical Axis

Skeletal Structure	Key to Asymmetry	Type of Asymmetry	Reliability
Pelvis, posterior arch			
Sacral wings	A1	L.A.*	.98
Sacral table	A2	L.A.	.95
Crests of ilia	A3	L.A.	.95
Posterior inferior spines of ilia	A4	L.A.	.95
Posterior inferior spines of ilia	B2	H.D.	.92
Medial borders of ilia	B4	H.D.	.86
Pelvis, anterior arch			
Tuberosities of ischia	A6	L.A.	.91
Pubic symphysis	B8	H.D.	.78
Femora			
Heads	A5	L.A.	.93
Necks	A7	L.A.	.84
Head, center	C3	H.D.	.88
Great trochanter	C2	H.D.	.85
Small trochanter	C1	H.D.	.81
Spinal column			
Fifth lumbar vertebra	D1	L.A.	.92
First four lumbar vertebrae	D2	H.D.	.91
Thoracicolumbar vertebrae (four)	D2-3	H.D.	.87
Twelve thoracic vertebrae	D3	H.D.	.83
Thoracic vertebrae (first four)	D3a	H.D.	.73
Upper thorax	A10	L.A.	.88
Shoulder girdle			
Scapular inferior angles	A8	L.A.	.83
Clavicles	A9	L.A.	.71

* L.A. means lateral angulation; H.D., horizontal distance.

The table should be read across as follows: The sacral wings of the posterior arch of the pelvis (A1) show lateral angulation asymmetry in their bilateral position. The reliability of their asymmetry is .98.

Reliability of Asymmetries Measured in Relation to the Central Vertical Axis

The bilateral skeletal asymmetries that were measured in relation to the central vertical axis are presented in Table III, page 72. Since the position of the top of the sacrum is the most stable of all parts of the skeletal structure studied (r = .98), the units of the skeletal structure and their asymmetries were recorded in the order of their increasing distance from the top of the sacrum. Thus the relationship that tends to exist between the degree of reliability of asymmetries and the distance of the deviating part of the structure from the top of the sacrum is shown.

The least reliable asymmetries in the various units of the skeletal structure are as follows: in the pelvis, lateral angulation at the tuberosities of the ischia (A6 = .91) and horizontal distance asymmetry at the pubic symphysis (B8 = .78); in the femora, lateral angulation of the neck of the femur (A7 = .87) and horizontal distance asymmetry at the small trochanter (C1 = .81); in the spinal column, horizontal distance asymmetry of the upper thoracic spine (D3a = .73); in the shoulder girdle, lateral angulation of the clavicles (A9 = .71); and in the thorax, lateral angulation of its upper region (A10 = .88).

All of these asymmetries are located at a greater distance from the top of the sacrum than are other asymmetries of higher reliability in the same unit of the skeletal structure. The relationship of the degree of reliability to the location of asymmetry is in general as follows: when bilateral skeletal asymmetries are the same type and in the same skeletal unit, their reliability tends to decrease as the deviating part increases in distance from the top of the sacrum.

Reliability of Asymmetries Measured in Relation to Skeletal Parts

The reliability of each of the bilateral skeletal asymmetries that were measured in relation to various parts of the skeletal structure is shown in Table IV, page 75. The units of the skeletal structure and their asymmetries are recorded, as in Table III, in order of their increasing distance from the top of the sacrum. When the distances of skeletal parts from the top of the sacrum are similar, their asymmetries are recorded in the order of the increasing length of measurement which was used to determine them.

Bilateral skeletal asymmetry tends to occur to some extent in all parts of the structure, therefore when lateral identical skeletal parts are used as points of reference for measurement of asymmetry of parts farther from the top of the sacrum, it follows that the measured asymmetry includes both asymmetry of the point of reference and of the skeletal part under consideration. As the distance between a skeletal part and its point of reference for measurement increases, more bony surface and more joints intervene between the two, thus allowing asymmetry of a greater area of skeletal structure to influence the relationship of the two.

Of the two units of structure presented in Table IV, the least reliable asymmetries are as follows: in the pelvis, the horizontal distance asymmetry on the surfaces of the ilia just above the acetabula (B3 = .60) and the horizontal distance asymmetry of the obturator foramina (B5 = .62); in the femora, the diagonal distance asymmetry at the great trochanters (C9 = .64).

Comparing the above asymmetries with other asymmetries in Table IV, the general relationship between degree of reliability of asymmetries

TABLE IV

Reliability of Bilateral Skeletal Asymmetries
Measured in Relation to Various Parts
of the Skeletal Structure

Skeletal Structure	Key to Asymmetry	Point of Reference	Type of Asymmetry	r*
Pelvis, posterior arch				
P.I. spine of ilium	B1	Vertical from center of femoral head	H.D.	.73
Surface of ilium	B3	Lateral borders of ilium	H.D.	.60
Pelvis, anterior arch				
True pelvis, anterior rim	B7	Posterior inferior spine of ilium	V.D.	.77
Obturator foramen	B6	Vertical borders of obturator foramen	V.D.	.66
Obturator foramen	B5	Lateral borders of obturator foramen	H.D.	.62
Femur				
Great trochanter	C4	Acetabulum	D.D.	.91
Small trochanter	C5	Acetabulum	D.D.	.86
Small trochanter	C7	P.I. spine of ilium	D.D.	.83
Great trochanter	C6	P.I. spine of ilium	D.D.	.82
Head, center	C8	P.I. spine of ilium	D.D.	.77
Great trochanter	B9	Center of femoral head	D.D.	.75
Head, center	C10	Far ilium	D.D.	.74
Great trochanter	C9	Far ilium	D.D.	.64

* r means reliability of skeletal asymmetry; H.D., horizontal distance; V.D., vertical distance; D.D., diagonal distance; P.I., posterior inferior.

The table should be read across as follows: In the posterior arch of the pelvis, the posterior inferior spines of the ilia (B1), each measured in relation to a vertical from the center of the femoral head on the same side, show horizontal distance asymmetry in their bilateral position. The reliability of their asymmetry is .73.

and their location seems to be as follows: when bilateral skeletal asymmetries are of the same type, their reliability tends to decrease in degree (a) as the deviating skeletal part increases in distance from the top of the sacrum and/or (b) as a greater number of joints and more area of skeletal structure lie between the deviating part and the top of the sacrum.

<u>Change in Weight Distribution</u>

For a large majority of the subjects the continuity of the plumb line was broken when the spinal column on the pelvic and thoracic radiographs was matched to produce a continuous structure.

The continuity of the plumb line on the pelvic and thoracic radiographs in two sets of radiographs of thirty-three subjects is shown in Table V, page 77. Since the x-ray apparatus was stable in position and the position of the subject was stabilized by the compression device during the exposure of the x-ray film, the change in weight distribution took place during the lapse of from thirty to forty-five seconds between the two x-ray exposures.

Of the thirty-three subjects, two showed no change in weight distribution in either set of radiographs, thirteen showed no change in weight distribution in one set of radiographs, and eighteen showed change in weight distribution in both sets of radiographs. Of the latter, fourteen shifted weight in the same direction both times they were radiographed, and four shifted in different directions each time.

TABLE V

Continuity of Plumb Line in Two Sets of Radiographs of Thirty-Three Subjects

Number of Subjects	Shift in Position of Plumb Line on Thoracic Radiograph
2	No shift in either thoracic radiograph
13	No shift in the thoracic radiograph of one set
18	Shift in thoracic radiographs of both sets
14	Shift in same direction in both thoracic radiographs
4	Shift in different direction in each thoracic radiograph
17	Shift toward the thigh farther from the central vertical axis
14	Shift away from the thigh farther from the central vertical axis

A study of the direction of shift of weight in relation to the thigh which was farther from the central vertical axis showed that seventeen subjects shifted toward the thigh which was farther from the central vertical axis and fourteen subjects shifted away from the thigh which was farther from the central vertical axis. While it is doubtless true that shifting the weight of the body is an influencing factor in the reliability of bilateral asymmetry of the skeletal structure, there is no way either of determining the degree of influence or of eliminating it. It would seem, however, that the position of the femora relative to the central vertical axis is not associated with the direction of lateral sway of the body, but that movement, while maintaining the equilibrium, occurs in varying direction. This conclusion is verified by the study of Hellebrandt and others in the following statement, "We observed that sway is inseparable from the upright stance and that the center of weight shifts incessantly during the maintenance of a natural comfortable posture."[1]

Factors Associated with Reliability of Bilateral Skeletal Asymmetries

An analysis of Tables III, IV, and V shows that in general the following factors are associated with reliability of position of various parts of the skeletal structure in the function of maintaining equilibrium in the standing position:

1. Distance of skeletal structure from the top of the sacrum
2. Distance of skeletal structure from the central vertical axis
3. Number of joints between any skeletalstructure and the sacrum
4. Area of skeletal structure between any distal part of the skeletal structure and the sacrum
5. Constant movement, or dynamic condition of the human body

INTERRELATIONSHIP OF BILATERAL SKELETAL ASYMMETRIES

The results of the preliminary and the final intercorrelation of bilateral skeletal asymmetries are given in the following discussion.

Preliminary Intercorrelation

The results of the preliminary intercorrelation of bilateral skeletal asymmetries measured on the radiographs of sixty subjects are shown in Table VI, page 79. This table reveals the following:

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1. Frances A. Hellebrandt, Dorris Kubin, Winnifred M. Longfeld, and L.E.A. Kelso, The Base of Support in Stance, The Physiotherapy Review, Volume 17, Number 6 (November-December, 1937), page 231.

TA

Preliminary Intercorrelation of Bilatera

Pre. Key*	Final Key**	Ab A2	Ac A3	Ad A4	Ae A5	Am	An	Af A6	Ai A7	Ag A8	Hl	Hm	Ha B2	Hb B3	
Aa	A1	.84	.79	.68	.74	.07	.64	.74	.53	.28	-.03	-.54	.59	-.30	.
Ab	A2		.76	.68	.71	-.07	.48	.68	.52	.16	-.07	-.53	.65	-.17	.
Ac	A3			.84	.89	-.05	.57	.86	.38	.44	-.10	-.44	.73	-.28	.
Ad	A4				.88	-.33	.28	.69	.43	.08	-.05	-.12	.71	-.11	.
Ae	A5					-.17	.67	.83	.51	.16	.04	-.63	.82	-.21	.
Am							.17	-.16	.29	-.31	.15	-.33	-.29	-.27	-.
An								.47	.63	.22	-.25	-.70	.47	-.47	.
Af	A6								.28	.43	.01	-.38	.65	-.18	.
Ai	A7									-.03	.03	-.72	.37	-.66	.
Ag	A8										.28	.29	.05	.38	-.
Hl												-.01	.02	-.28	.
Hm													-.18	-.66	-.
Ha	B2													-.07	.
Hb	B3														.
Hc	B4														
Hd	B5														
Va	B6														
Di															
Dk															
Dj															
He	B8														
Da	C4														
Db	C5														
Dc	C6														
Dd	C7														
De	C8														
Dh	C10														
Df	C9														
Dg															
Hf	C1														
Hg	C2														

* Pre. key means preliminary key. This key was used to designate the asymmetries
For interpretation of the preliminary key see

** The final key was used to designate the asymmetries which were retained for meas
final key see

TABLE VI

y Intercorrelation of Bilateral Skeletal Asymmetries of Sixty Subjects

Ai A7	Ag A8	Hl	Hm	Ha B2	Hb B3	Hc B4	Hd B5	Va B6	Di	Dk	Dj	He B8	Da C4	Db C5	Dc C6	Dd D7	De C8	Dh C10	Df C9
.53	.28	-.03	-.54	.59	-.30	.55	-.13	-.23	-.01	.11	.27	.50	.45	.30	.28	.11	.21	-.22	.17
.52	.16	-.07	-.53	.65	-.17	.50	-.17	-.29	-.01	.17	.19	.49	.41	.36	.14	.10	.14	-.20	-.13
.38	.44	-.10	-.44	.73	-.28	.66	-.34	-.35	.10	.28	.26	.71	.43	.05	.35	.29	.72	.04	.16
.43	.08	-.05	-.12	.71	-.11	.71	-.34	.12	.28	.46	-.07	.77	.35	.41	.40	.40	.40	.02	.05
.51	.16	.04	-.63	.82	-.21	.79	-.36	-.15	.02	.11	.07	.81	.55	.43	.22	.13	.18	.03	.05
.29	-.31	.15	-.33	-.29	-.27	-.55	.66	.50	-.76	-.04	.04	-.58	.11	.06	-.43	-.40	-.88	-.66	-.37
.63	.22	-.25	-.70	.47	-.47	.36	.12	.28	-.23	-.37	-.16	.33	.60	.42	.04	.01	-.08	-.29	-.10
.28	.43	.01	-.38	.65	-.18	.68	-.46	-.50	.15	.17	.74	.61	.40	.33	.20	-.04	.10	-.12	-.02
	-.03	.03	-.72	.37	-.66	.24	.36	.37	.78	.03	.10	.15	.52	.50	.02	.11	-.05	-.02	-.19
		.28	.29	.05	.38	-.02	-.38	-.31	-.09	.11	.59	.02	-.25	.08	.00	-.28	.21	-.28	-.11
			-.01	.02	-.28	.05	.21	.18	-.16	-.26	.28	-.09	.01	.14	-.04	.02	.15	-.09	.12
				-.18	-.66	-.12	-.41	-.30	.01	.14	-.10	-.02	-.47	-.43	.22	.10	.38	.46	.32
					-.07	.94	-.44	-.28	.11	.07	.08	.86	.26	.27	.25	.06	.21	.17	-.03
						.08	-.56	-.40	.66	.01	-.01	.20	-.08	-.46	.30	.08	.12	.54	.40
							-.45	.80	.50	.03	.07	.96	.28	.06	.22	.32	.40	.47	.32
								.73	-.57	-.56	-.12	-.75	.27	.15	-.35	-.39	.03	-.01	-.22
									-.42	-.22	-.35	-.47	.17	.17	-.59	.05	-.20	-.26	-.15
										.08	-.10	.57	-.12	-.16	.65	.52	.59	.78	.55
											-.15	.04	-.09	.06	.20	.18	.36	-.20	-.25
												.17	.05	.18	-.02	.11	-.04	-.05	.13
													.22	.42	.50	.23	.39	.54	.54
														.57	.46	.18	.07	-.11	.35
															.21	.51	.19	-.06	.06
																.70	.82	.55	.81
																	.57	.40	.54
																		.38	.49
																			.68

to designate the asymmetries in their treatment preliminary to taking the final measurements on a

s which were retained for measurement and study in the four age-sex groups of subjects. For inter

BLE VI

Skeletal Asymmetries of Sixty Subjects

Hc B4	Hd B5	Va B6	Di	Dk	Dj	He B8	Da C4	Db C5	Dc C6	Dd D7	De C8	Dh C10	Df C9	Dg	Hf C1	Hg C2	Hh C3
55	-.13	-.23	-.01	.11	.27	.50	.45	.30	.28	.11	.21	-.22	.17	-.36	.58	.56	.44
50	-.17	-.29	-.01	.17	.19	.49	.41	.36	.14	.10	.14	-.20	-.13	-.38	.58	.52	.47
66	-.34	-.35	.10	.28	.26	.71	.43	.05	.35	.29	.72	.04	.16	-.42	.81	.71	.66
71	-.34	.12	.28	.46	-.07	.77	.35	.41	.40	.40	.40	.02	.05	-.43	.69	.67	.67
79	-.36	-.15	.02	.11	.07	.81	.55	.43	.22	.13	.18	.03	.05	-.40	.78	.81	.75
55	.66	.50	-.76	-.04	.04	-.58	.11	.06	-.43	-.40	-.88	-.66	-.37	-.26	-.45	-.46	-.47
36	.12	.28	-.23	-.37	-.16	.33	.60	.42	.04	.01	-.08	-.29	-.10	-.22	.47	.39	.31
68	-.46	-.50	.15	.17	.74	.61	.40	.33	.20	-.04	.10	-.12	-.02	-.46	.63	.65	.66
24	.36	.37	.78	.03	.10	.15	.52	.50	.02	.11	-.05	-.02	-.19	-.28	.32	.32	.11
02	-.38	-.31	-.09	.11	.59	.02	-.25	.08	.00	-.28	.21	-.28	-.11	-.22	.14	-.04	.19
05	.21	.18	-.16	-.26	.28	-.09	.01	.14	-.04	.02	.15	-.09	.12	.29	.08	-.04	.00
12	-.41	-.30	.01	.14	-.10	-.02	-.47	-.43	.22	.10	.38	.46	.32	.31	-.22	-.43	-.07
94	-.44	-.28	.11	.07	.08	.86	.26	.27	.25	.06	.21	.17	-.03	-.31	.84	.82	.86
08	-.56	-.40	.66	.01	-.01	.20	-.08	-.46	.30	.08	.12	.54	.40	.33	.08	.04	.17
	-.45	.80	.50	.03	.07	.96	.28	.06	.22	.32	.40	.47	.32	-.03	.91	.92	.95
		.73	-.57	-.56	-.12	-.75	.27	.15	-.35	-.39	.03	-.01	-.22	.06	-.48	-.46	-.65
			-.42	-.22	-.35	-.47	.17	.17	-.59	.05	-.20	-.26	-.15	.08	-.31	-.31	-.42
				.08	-.10	.57	-.12	-.16	.65	.52	.59	.78	.55	.35	.41	.42	.56
					-.15	.04	-.09	.06	.20	.18	.36	-.20	-.25	-.42	-.13	-.01	.12
						.17	.05	.18	-.02	.11	-.04	-.05	.13	-.02	-.01	.03	-.01
							.22	.42	.50	.23	.39	.54	.54	.05	.92	.87	.95
								.57	.46	.18	.07	-.11	.35	-.07	.37	.45	.21
									.21	.51	.19	-.06	.06	-.07	.24	.35	.24
										.70	.82	.55	.81	.31	.49	.62	.46
											.57	.40	.54	.47	.35	.37	.28
												.38	.49	.11	.34	.50	.54
													.68	.59	.40	.32	.53
														.71	.40	.51	.30
															.05	-.01	.02
																.96	.86
																	.87

in their treatment preliminary to taking the final measurements on all radiographs.

rement and study in the four age-sex groups of subjects. For interpretation of the

1. Two of the asymmetries, An and Af,* are similar in type and both occur on the anterior arch of the pelvis. The asymmetry An has a reliability of .84 and an average correlation of .61 with five other asymmetries. The asymmetry Af has a reliability of .91 and an average correlation of .70 with twelve other asymmetries. This analysis shows that asymmetry An can be discarded.
2. The asymmetries Hl and Dk, with a reliability of .78 and of .82, respectively, show no correlation above .60 with any other asymmetry. Since it had arbitrarily been determined that an asymmetry must show a correlation of .60 or better with one or more asymmetries, Hl and Dk were discarded from the final measurements despite their satisfactory reliability.
3. All other asymmetries with a reliability of .60 or better show a correlation of .60 or above with one to twelve other asymmetries.

The analysis of the preliminary intercorrelation led to the elimination of An, Hl, and Dk from the asymmetries to be measured on the radiographs of the four groups of subjects. The asymmetry Ag, although it shows a relatively low correlation with all other asymmetries, was retained for study in relation to handedness. With the exception of the

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* The key to each asymmetry is interpreted as follows: An refers to lateral angulation of the anterior rim of the true pelvis at points in the sagittal planes of the medial borders of the obturator foramina; Af refers to lateral angulation of the tuberosities of the ischia; Hl refers to horizontal distance asymmetry of the posterior superior spines of the ilia; Dk refers to diagonal distance asymmetry of the anterior rim of the true pelvis at points in the sagittal planes of the medial borders of the obturator foramina; Ag refers to lateral angulation of the scapular inferior angles.

asymmetries showing a reliability below .60,* the remaining ones were retained for final measurement. To these were added eight other asymmetries whose reliability was later found to be above .60 but whose intercorrelation with other asymmetries was not determined in this preliminary study of interrelationship. The asymmetries added, then, to those retained following the preliminary intercorrelation were as follows: horizontal distance asymmetry (B1) to substitute for Hm, lateral angulation asymmetry (A9) of the clavicles, lateral angulation asymmetry (A10) of the upper thorax, angulation of lateral curves of spinal column (E), vertical distance asymmetry (B7) of the anterior rim of the true pelvis, diagonal distance asymmetry (B9) of the great trochanter, horizontal distance asymmetry (D) of all the vertebrae except the fifth lumbar, lateral angulation asymmetry (D1) of the fifth lumbar vertebra.

Final Intercorrelation of Bilateral Skeletal Asymmetries

The intercorrelations of bilateral skeletal asymmetries measured on the radiographs of four groups of subjects -- young women (Y.W.), young men (Y.M.), older women (O.W.), and older men (O.M.) -- are shown in Table VII, page 82. The data in this table are so arranged that a comparison between the correlations of asymmetries of the four groups of subjects can readily be made. An analytical study of these data reveals the following:

1. The four sets of intercorrelation data are consistent in the following manner:

    a. The degree of correlation between the same asymmetries

* These asymmetries are Am, Hm, Di, Dj, Dg (see Table II, page 70).

TABLE VII

Intercorrelation of Bilateral Skeletal Asymmetries Measur

Subjects		Intercorr														
		A2	A3	A4	A5	A6	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6
Y.W.	A1	.88	.82	.72	.71	.68	.48	.17	.21	.20	.42	.70	-.01	.53	-.34	-.31
Y.M.		.88	.76	.75	.76	.71	.40	.04	.00	.07	.43	.71	-.13	.72	-.29	-.25
O.W.		.90	.77	.70	.70	.76	.21	.11	.08	.15	.41	.62	.04	.64	-.42	-.27
O.M.		.88	.77	.71	.73	.72	.38	.03	.08	-.07	.54	.64	.07	.71	-.49	-.43
Y.W.	A2		.77	.71	.70	.64	.47	.09	.16	.21	.43	.68	-.05	.52	-.32	-.31
Y.M.			.68	.70	.69	.59	.35	.02	-.01	.11	.35	.64	-.16	.64	-.22	-.22
O.W.			.73	.65	.64	.70	.21	.19	.11	.22	.39	.52	.05	.57	-.42	-.30
O.M.			.83	.74	.75	.71	.45	.02	.09	-.07	.56	.65	-.01	.72	-.43	-.35
Y.W.	A3			.86	.91	.85	.54	.13	.15	.15	.66	.76	.02	.74	-.50	-.34
Y.M.				.74	.85	.72	.52	-.01	.00	.04	.49	.66	-.17	.71	-.28	-.17
O.W.				.82	.91	.86	.48	.08	.10	.14	.50	.76	-.06	.76	-.38	-.09
O.M.				.87	.93	.79	.54	-.10	-.07	-.14	.71	.74	-.04	.83	-.51	-.37
Y.W.	A4				.85	.85	.43	.12	.13	.18	.64	.68	.06	.68	-.50	-.37
Y.M.					.79	.70	.36	-.13	-.05	-.02	.46	.60	-.04	.63	-.33	-.22
O.W.					.80	.79	.34	.06	-.07	-.02	.41	.64	.01	.63	-.33	-.12
O.M.					.86	.78	.42	-.10	-.10	-.16	.65	.69	.03	.77	-.54	-.41
Y.W.	A5					.89	.55	.15	.11	.10	.73	.74	.04	.80	-.54	-.25
Y.M.						.76	.52	-.11	-.04	-.04	.57	.69	-.12	.77	-.37	-.22
O.W.						.88	.45	.08	.09	.12	.51	.74	-.08	.75	-.40	-.05
O.M.						.80	.51	-.06	-.09	-.13	.73	.72	-.01	.83	-.54	-.34
Y.W.	A6						.40	.10	.09	.12	.63	.68	.10	.68	-.59	-.43
Y.M.							.29	-.09	.00	-.04	.44	.61	-.05	.65	-.40	-.35
O.W.							.22	.14	.12	.08	.49	.67	.06	.68	-.54	-.31
O.M.							.28	.11	.02	-.11	.57	.63	.13	.69	-.59	-.55
Y.W.	A7							.09	.00	.10	.16	.50	-.46	.32	.19	.36
Y.M.								-.09	.03	-.06	.02	.39	-.48	.31	.26	.40
O.W.								-.06	-.09	.13	.01	.41	-.53	.31	.36	.48
O.M.								-.09	.04	.02	.23	.47	-.42	.37	.11	.23
Y.W.	A8								.53	.46	.13	.10	.10	.09	-.03	-.01
Y.M.									.46	.43	-.07	-.01	.06	-.04	-.09	-.12
O.W.									.41	.50	-.08	.03	.04	-.05	-.11	-.05
O.M.									.44	.41	-.05	-.10	.20	-.08	-.13	-.05
Y.W.	A9									.41	.11	.09	.12	.14	-.12	-.12
Y.M.										.47	-.10	.01	-.02	-.07	-.08	.01
O.W.										.36	.07	.05	.13	.03	-.14	-.07
O.M.										.40	-.13	.02	.12	-.06	-.03	.00
Y.W.	A10										.05	.12	.10	.04	.03	-.07
Y.M.											-.01	.06	.07	.06	-.03	-.12
O.W.											-.09	.16	-.14	.03	.06	.15
O.M.											-.16	-.16	.10	-.20	.10	.14

TABLE VII

tion of Bilateral Skeletal Asymmetries Measured on the Radiographs of Four Groups of Subjects*

Intercorrelation of Asymmetries

A8	A9	A10	B1	B2	B3	B4	B5	B6	B7	B8	B9	C1	C2	C3	C4	C5	C6	C7	C
.17	.21	.20	.42	.70	-.01	.53	-.34	-.31	.47	.57	-.05	.60	.65	.59	.41	.39	.34	.25	.2
.04	.00	.07	.43	.71	-.13	.72	-.29	-.25	.49	.67	.09	.73	.74	.70	.38	.43	.39	.27	.2
.11	.08	.15	.41	.62	.04	.64	-.42	-.27	.41	.62	-.03	.60	.56	.63	.27	.32	.24	.14	.1
.03	.08	-.07	.54	.64	.07	.71	-.49	-.43	.56	.65	.00	.69	.55	.69	.35	.43	.42	.31	.3
.09	.16	.21	.43	.68	-.05	.52	-.32	-.31	.46	.56	-.03	.59	.60	.59	.46	.44	.37	.29	.2
.02	-.01	.11	.35	.64	-.16	.64	-.22	-.22	.40	.56	.07	.64	.65	.61	.31	.40	.32	.24	.2
.19	.11	.22	.39	.52	.05	.57	-.42	-.30	.38	.56	.01	.54	.51	.58	.29	.34	.26	.17	.1
.02	.09	-.07	.56	.65	-.01	.72	-.43	-.35	.54	.69	-.01	.72	.60	.71	.27	.49	.46	.35	.3
.13	.15	.15	.66	.76	.02	.74	-.50	-.34	.67	.78	-.10	.81	.81	.79	.52	.45	.52	.32	.3
-.01	.00	.04	.49	.66	-.17	.71	-.28	-.17	.50	.69	.08	.74	.76	.72	.44	.39	.39	.13	.2
.08	.10	.14	.50	.76	-.06	.76	-.38	-.09	.47	.73	.00	.72	.70	.74	.48	.54	.33	.15	.1
-.10	-.07	-.14	.71	.74	-.04	.83	-.51	-.37	.68	.83	-.05	.86	.73	.85	.48	.53	.55	.36	.4
.12	.13	.18	.64	.68	.06	.68	-.50	-.37	.72	.76	-.19	.78	.74	.77	.39	.33	.59	.49	.6
-.13	-.05	-.02	.46	.60	-.04	.63	-.33	-.22	.55	.66	-.10	.70	.72	.67	.38	.35	.47	.34	.4
.06	-.07	-.02	.41	.64	.01	.63	-.33	-.12	.49	.62	-.07	.61	.56	.61	.29	.41	.30	.29	.3
-.10	-.10	-.16	.65	.69	.03	.77	-.54	-.41	.67	.78	-.06	.80	.65	.79	.39	.48	.56	.51	.5
.15	.11	.10	.73	.74	.04	.80	-.54	-.25	.72	.86	-.19	.87	.84	.85	.53	.43	.52	.24	.3
-.11	-.04	-.04	.57	.69	-.12	.77	-.37	-.22	.57	.78	-.01	.80	.79	.79	.39	.38	.36	.07	.1
.08	.09	.12	.51	.74	-.08	.75	-.40	-.05	.46	.76	-.06	.72	.68	.73	.42	.46	.22	.01	.0
-.06	-.09	-.13	.73	.72	-.01	.83	-.54	-.34	.68	.85	-.15	.86	.71	.85	.38	.48	.47	.28	.3
.10	.09	.12	.63	.68	.10	.68	-.59	-.43	.64	.76	-.13	.77	.75	.75	.46	.36	.49	.26	.3
-.09	.00	-.04	.44	.61	-.05	.65	-.40	-.35	.49	.62	.06	.68	.67	.65	.33	.28	.32	.07	.0
.14	.12	.08	.49	.67	.06	.68	-.54	-.31	.46	.73	-.11	.65	.60	.70	.30	.38	.21	.04	-.0
.11	.02	-.11	.57	.63	.13	.69	-.59	-.55	.57	.68	-.19	.67	.56	.68	.22	.45	.36	.28	.2
.09	.00	.10	.16	.50	-.46	.32	.19	.36	.09	.28	.05	.40	.37	.29	.52	.40	.02	-.01	.1
-.09	.03	-.06	.02	.39	-.48	.31	.26	.40	-.01	.24	.19	.35	.36	.23	.49	.31	.10	-.10	.0
-.06	-.09	.13	.01	.41	-.53	.31	.36	.48	-.01	.17	.19	.31	.29	.21	.57	.53	.06	.07	.2
-.09	.04	.02	.23	.47	-.42	.37	.11	.23	.16	.34	.15	.44	.41	.37	.58	.26	.25	.01	.1
	.53	.46	.13	.10	.10	.09	-.03	-.01	.12	.15	.02	.19	.16	.13	.06	.03	.07	.03	.0
	.46	.43	-.07	-.01	.06	-.04	-.09	-.12	-.04	-.06	-.05	-.09	-.09	-.06	-.17	-.02	-.12	-.03	-.0
	.41	.50	-.08	.03	.04	-.05	-.11	-.05	-.03	-.02	-.17	-.12	-.11	-.04	-.16	-.08	-.22	-.22	-.1
	.44	.41	-.05	-.10	.20	-.08	-.13	-.05	-.05	-.04	-.08	-.09	-.20	-.08	-.21	-.07	-.10	-.02	-.0
		.41	.11	.09	.12	.14	-.12	-.12	.12	.14	.09	.15	.15	.13	.16	.11	.15	.18	.1
		.47	-.10	.01	-.02	-.07	-.08	.01	-.12	-.09	.09	-.06	-.04	-.09	.01	.06	-.01	.05	-.0
		.36	.07	.05	.13	.03	-.14	-.07	.12	.07	-.16	.03	-.02	.06	-.10	-.15	-.08	-.24	-.1
		.40	-.13	.02	.12	-.06	-.03	.00	-.14	-.08	.07	-.07	-.15	-.08	-.12	-.01	-.13	-.08	-.1
			.05	.12	.10	.04	.03	-.07	.07	.08	.08	.12	.12	.09	-.02	-.05	.13	.16	.1
			-.01	.06	.07	.06	-.03	-.12	.06	.01	-.03	.01	.01	.02	-.09	-.08	.00	.08	.0
			-.09	.16	-.14	.03	.06	.15	-.07	-.02	-.02	-.02	-.02	.03	.11	.08	-.17	-.25	-.1
			-.16	-.16	.10	-.20	.10	.14	-.18	-.19	.07	-.16	-.30	-.18	-.10	-.12	-.12	-.12	-.0

TABLE VII

tries Measured on the Radiographs of Four Groups of Subjects*

Intercorrelation of Asymmetries

4	B5	B6	B7	B8	B9	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	D1	D2	D3
3	-.34	-.31	.47	.57	-.05	.60	.65	.59	.41	.39	.34	.25	.27	.08	.03	.76	-.65	-.28
2	-.29	-.25	.49	.67	.09	.73	.74	.70	.38	.43	.39	.27	.26	.12	.04	.71	-.56	-.17
4	-.42	-.27	.41	.62	-.03	.60	.56	.63	.27	.32	.24	.14	.10	.04	.00	.76	-.57	-.13
1	-.49	-.43	.56	.65	.00	.69	.55	.69	.35	.43	.42	.31	.34	.27	.26	.78	-.66	-.22
2	-.32	-.31	.46	.56	-.03	.59	.60	.59	.46	.44	.37	.29	.28	.10	.05	.86	-.69	-.21
4	-.22	-.22	.40	.56	.07	.64	.65	.61	.31	.40	.32	.24	.20	.10	.00	.78	-.66	-.22
7	-.42	-.30	.38	.56	.01	.54	.51	.58	.29	.34	.26	.17	.14	.07	.03	.83	-.70	-.22
2	-.43	-.35	.54	.69	-.01	.72	.60	.71	.27	.49	.46	.35	.38	.28	.29	.82	-.71	-.30
4	-.50	-.34	.67	.78	-.10	.81	.81	.79	.52	.45	.52	.32	.38	.23	.22	.68	-.55	-.23
1	-.28	-.17	.50	.69	.08	.74	.76	.72	.44	.39	.39	.13	.24	.18	.13	.53	-.39	-.10
6	-.38	-.09	.47	.73	.00	.72	.70	.74	.48	.54	.33	.15	.16	.08	.03	.57	-.45	-.10
3	-.51	-.37	.68	.83	-.05	.86	.73	.85	.48	.53	.55	.36	.43	.37	.39	.64	-.53	-.20
8	-.50	-.37	.72	.76	-.19	.78	.74	.77	.39	.33	.59	.49	.60	.15	.20	.61	-.44	-.22
3	-.33	-.22	.55	.66	-.10	.70	.72	.67	.38	.35	.47	.34	.40	.13	.03	.54	-.37	-.06
3	-.33	-.12	.49	.62	-.07	.61	.56	.61	.29	.41	.30	.29	.31	-.11	-.12	.43	-.34	-.07
7	-.54	-.41	.67	.78	-.06	.80	.65	.79	.39	.48	.56	.51	.53	.28	.31	.57	-.47	-.09
0	-.54	-.25	.72	.86	-.19	.87	.84	.85	.53	.43	.52	.24	.34	.29	.32	.61	-.41	-.14
7	-.37	-.22	.57	.78	-.01	.80	.79	.79	.39	.38	.36	.07	.18	.15	.15	.50	-.32	-.04
5	-.40	-.05	.46	.76	-.06	.72	.68	.73	.42	.46	.22	.01	.00	.00	-.02	.50	-.35	-.07
3	-.54	-.34	.68	.85	-.15	.86	.71	.85	.38	.48	.47	.28	.32	.31	.40	.56	-.41	-.07
3	-.59	-.43	.64	.76	-.13	.77	.75	.75	.46	.36	.49	.26	.33	.21	.20	.59	-.44	-.22
5	-.40	-.35	.49	.62	.06	.68	.67	.65	.33	.28	.32	.07	.07	.09	.02	.49	-.31	-.05
3	-.54	-.31	.46	.73	-.11	.65	.60	.70	.30	.38	.21	.04	-.05	-.02	-.02	.57	-.37	.00
9	-.59	-.55	.57	.68	-.19	.67	.56	.68	.22	.45	.36	.28	.28	.15	.27	.63	-.57	-.23
[illegible]	.19	.36	.09	.28	.05	.40	.37	.29	.52	.40	.02	-.01	.11	-.07	-.13	.39	-.27	-.05
[illegible]	.26	.40	-.01	.24	.19	.35	.36	.23	.49	.31	.10	-.10	.06	-.01	-.16	.22	-.18	-.04
[illegible]	.36	.48	-.01	.17	.19	.31	.29	.21	.57	.53	.06	.07	.23	-.02	-.11	.17	-.26	-.14
[illegible]	.11	.23	.16	.34	.15	.44	.41	.37	.58	.26	.25	.01	.14	.17	.07	.29	-.33	-.10
	-.03	-.01	.12	.15	.02	.19	.16	.13	.06	.03	.07	.03	.06	.08	.04	.09	-.08	-.14
	-.09	-.12	-.04	-.06	-.05	-.09	-.09	-.06	-.17	-.02	-.12	-.03	-.07	-.12	-.04	.08	-.02	.08
	-.11	-.05	-.03	-.02	-.17	-.12	-.11	-.04	-.16	-.08	-.22	-.22	-.17	-.24	-.18	.25	-.25	-.07
	-.13	-.05	-.05	-.04	-.08	-.09	-.20	-.08	-.21	-.07	-.10	-.02	-.09	-.10	-.01	.05	.01	-.04
	-.12	-.12	.12	.14	.09	.15	.15	.13	.16	.11	.15	.18	.13	.07	.04	.14	-.09	-.06
	-.08	.01	-.12	-.09	.09	-.06	-.04	-.09	.01	.06	-.01	.05	-.07	-.05	-.11	.09	-.07	.03
	-.14	-.07	.12	.07	-.16	.03	-.02	.06	-.10	-.15	-.08	-.24	-.17	-.04	.04	.02	-.23	-.15
	-.03	.00	-.14	-.08	.07	-.07	-.15	-.08	-.12	-.01	-.13	-.08	-.12	-.10	-.12	.14	-.21	-.03
	.03	-.07	.07	.08	.08	.12	.12	.09	-.02	-.05	.13	.16	.19	.06	-.02	.22	-.21	-.16
	-.03	-.12	.06	.01	-.03	.01	.01	.02	-.09	-.08	.00	.08	.05	-.02	.01	.14	-.12	.00
	.06	.15	-.07	-.02	-.02	-.02	-.02	.03	.11	.08	-.17	-.25	-.19	-.14	-.16	.32	-.25	-.02
	.10	.14	-.18	-.19	.07	-.16	-.30	-.18	-.10	-.12	-.12	-.12	-.08	-.10	-.08	.06-	.05	-.09

Y.W.	A7	.09	.00	.10	.16	.50	-.46	.32	.19	.36	.09
Y.M.		-.09	.03	-.06	.02	.39	-.48	.31	.26	.40	-.01
O.W.		-.06	-.09	.13	.01	.41	-.53	.31	.36	.48	-.01
O.M.		-.09	.04	.02	.23	.47	-.42	.37	.11	.23	.16
Y.W.	A8		.53	.46	.13	.10	.10	.09	-.03	-.01	.12
Y.M.			.46	.43	-.07	-.01	.06	-.04	-.09	-.12	-.04
O.W.			.41	.50	-.08	.03	.04	-.05	-.11	-.05	-.03
O.M.			.44	.41	-.05	-.10	.20	-.08	-.13	-.05	-.05
Y.W.	A9			.41	.11	.09	.12	.14	-.12	-.12	.12
Y.M.				.47	-.10	.01	-.02	-.07	-.08	.01	-.12
O.W.				.36	.07	.05	.13	.03	-.14	-.07	.12
O.M.				.40	-.13	.02	.12	-.06	-.03	.00	-.14
Y.W.	A10				.05	.12	.10	.04	.03	-.07	.07
Y.M.					-.01	.06	.07	.06	-.03	-.12	.06
O.W.					-.09	.16	-.14	.03	.06	.15	-.07
O.M.					-.16	-.16	.10	-.20	.10	.14	-.18
Y.W.	B1					.48	.32	.86	-.71	-.43	.90
Y.M.						.28	.38	.75	-.70	-.55	.90
O.W.						.35	.46	.82	-.66	-.46	.90
O.M.						.40	.38	.85	-.76	-.55	.96
Y.W.	B2						.00	.69	-.31	-.20	.47
Y.M.							-.14	.76	-.19	-.17	.34
O.W.							-.03	.76	-.22	-.05	.34
O.M.							-.13	.75	-.38	-.30	.42
Y.W.	B3							.26	-.53	-.50	.40
Y.M.								.06	-.60	-.56	.42
O.W.								.14	-.51	-.60	.52
O.M.								.17	-.55	-.55	.41
Y.W.	B4								-.63	-.38	.85
Y.M.									-.52	-.41	.76
O.W.									-.52	-.30	.76
O.M.									-.71	-.53	.84
Y.W.	B5									.77	-.80
Y.M.										.79	-.76
O.W.										.71	-.66
O.M.										.84	-.81
Y.W.	B6										-.58
Y.M.											-.64
O.W.											-.52
O.M.											-.66
Y.W.	B7										
Y.M.											
O.W.											
O.M.											
Y.W.	B8										
Y.M.											
O.W.											
O.M.											
Y.W.	B9										
Y.M.											
O.W.											
O.M.											

.00	.10	.16	.50	-.46	.32	.19	.36	.09	.28	.05	.40	.37	.29	.52	.40	.02	-.01	.11	[illegible]
.03	-.06	.02	.39	-.48	.31	.26	.40	-.01	.24	.19	.35	.36	.23	.49	.31	.10	-.10	.06	[illegible]
-.09	.13	.01	.41	-.53	.31	.36	.48	-.01	.17	.19	.31	.29	.21	.57	.53	.06	.07	.23	[illegible]
.04	.02	.23	.47	-.42	.37	.11	.23	.16	.34	.15	.44	.41	.37	.58	.26	.25	.01	.14	[illegible]
.53	.46	.13	.10	.10	.09	-.03	-.01	.12	.15	.02	.19	.16	.13	.06	.03	.07	.03	.06	[illegible]
.46	.43	-.07	-.01	.06	-.04	-.09	-.12	-.04	-.06	-.05	-.09	-.09	-.06	-.17	-.02	-.12	-.03	-.07	[illegible]
.41	.50	-.08	.03	.04	-.05	-.11	-.05	-.03	-.02	-.17	-.12	-.11	-.04	-.16	-.08	-.22	-.22	-.17	[illegible]
.44	.41	-.05	-.10	.20	-.08	-.13	-.05	-.05	-.04	-.08	-.09	-.20	-.08	-.21	-.07	-.10	-.02	-.09	[illegible]
	.41	.11	.09	.12	.14	-.12	-.12	.12	.14	.09	.15	.15	.13	.16	.11	.15	.18	.13	[illegible]
	.47	-.10	.01	-.02	-.07	-.08	.01	-.12	-.09	.09	-.06	-.04	-.09	.01	.06	-.01	.05	-.07	[illegible]
	.36	.07	.05	.13	.03	-.14	-.07	.12	.07	-.16	.03	-.02	.06	-.10	-.15	-.08	-.24	-.17	[illegible]
	.40	-.13	.02	.12	-.06	-.03	.00	-.14	-.08	.07	-.07	-.15	-.08	-.12	-.01	-.13	-.08	-.12	[illegible]
		.05	.12	.10	.04	.03	-.07	.07	.08	.08	.12	.12	.09	-.02	-.05	.13	.16	.19	[illegible]
		-.01	.06	.07	.06	-.03	-.12	.06	.01	-.03	.01	.01	.02	-.09	-.08	.00	.08	.05	[illegible]
		-.09	.16	-.14	.03	.06	.15	-.07	-.02	-.02	-.02	-.02	.03	.11	.08	-.17	-.25	-.19	[illegible]
		-.16	-.16	.10	-.20	.10	.14	-.18	-.19	.07	-.16	-.30	-.18	-.10	-.12	-.12	-.12	-.08	[illegible]
			.48	.32	.86	-.71	-.43	.90	.90	-.34	.84	.82	.90	.29	.19	.80	.43	.64	[illegible]
			.28	.38	.75	-.70	-.55	.90	.82	-.26	.76	.70	.84	.05	.11	.58	.30	.61	[illegible]
			.35	.46	.82	-.66	-.46	.90	.88	-.21	.78	.74	.87	.21	.19	.76	.42	.53	[illegible]
			.40	.38	.85	-.76	-.55	.96	.92	-.27	.86	.72	.92	.27	.38	.77	.55	.72	[illegible]
				.00	.69	-.31	-.20	.47	.71	-.17	.75	.75	.75	.42	.41	.30	.17	.26	[illegible]
				-.14	.76	-.19	-.17	.34	.66	.03	.73	.73	.72	.34	.37	.20	.05	.08	[illegible]
				-.03	.76	-.22	-.05	.34	.65	.02	.72	.69	.73	.43	.42	.19	.05	.04	[illegible]
				-.13	.75	-.38	-.30	.42	.67	-.09	.72	.52	.70	.30	.41	.22	.13	.14	[illegible]
					.26	-.53	-.50	.40	.35	-.21	.22	.24	.31	-.22	-.19	.38	.19	.26	[illegible]
					.06	-.60	-.56	.42	.24	-.23	.11	.05	.20	-.39	-.26	.21	.19	.31	[illegible]
					.14	-.51	-.60	.52	.36	-.19	.17	.16	.32	-.30	-.26	.41	.25	.27	[illegible]
					.17	-.55	-.55	.41	.26	-.17	.20	.08	.24	-.29	-.14	.31	.31	.33	[illegible]
						-.63	-.38	.85	.92	-.30	.90	.88	.93	.34	.23	.69	.33	.54	[illegible]
						-.52	-.41	.76	.90	-.13	.92	.88	.96	.24	.31	.47	.21	.42	[illegible]
						-.52	-.30	.76	.94	-.12	.91	.85	.94	.37	.37	.58	.30	.39	[illegible]
						-.71	-.53	.84	.95	-.15	.95	.76	.96	.35	.46	.66	.45	.58	[illegible]
							.77	-.80	-.74	.22	-.62	-.62	-.69	-.06	.00	-.62	-.28	-.36	[illegible]
							.79	-.76	-.63	.28	-.52	-.45	-.61	.19	.02	-.28	-.21	-.39	[illegible]
							.71	-.66	-.70	.17	-.48	-.44	-.55	.01	.11	-.39	-.10	-.07	[illegible]
							.84	-.81	-.75	.22	-.70	-.50	-.73	-.02	-.24	-.57	-.49	-.49	[illegible]
								-.58	-.46	.14	-.36	-.37	-.43	.11	.12	-.49	-.32	-.35	[illegible]
								-.64	-.49	.21	-.41	-.36	-.49	.21	.05	-.29	-.23	-.32	[illegible]
								-.52	-.42	.20	-.25	-.21	-.36	.23	.22	-.34	-.16	-.19	[illegible]
								-.66	-.55	.19	-.51	-.35	-.54	.04	-.22	-.42	-.46	-.42	[illegible]
									.91	-.32	.85	.83	.90	.21	.17	.85	.55	.70	[illegible]
									.83	-.24	.76	.71	.84	.03	.09	.58	.33	.63	[illegible]
									.82	-.23	.72	.67	.80	.10	.13	.72	.45	.60	[illegible]
									.90	-.23	.84	.70	.90	.25	.37	.78	.62	.76	[illegible]
										-.33	.95	.92	.98	.31	.24	.73	.37	.58	[illegible]
										-.19	.91	.85	.95	.16	.22	.49	.21	.49	[illegible]
										-.12	.88	.83	.94	.28	.30	.62	.31	.35	[illegible]
										-.22	.95	.76	.98	.32	.45	.68	.49	.61	[illegible]
											-.18	-.06	-.36	.35	.13	.04	.10	-.37	[illegible]
											.03	.26	-.17	.76	.27	.52	.36	-.07	[illegible]
											.05	.20	-.12	.54	.29	.31	.27	-.06	[illegible]
											-.03	.03	-.19	.63	.07	.33	.19	.01	[illegible]

	-.40	-.35	.49	.62	.06	.68	.67	.65	.33	.28	.32	.07	.07	.09	.02	.49	-.31	[illegible]
8	-.54	-.31	.46	.73	-.11	.65	.60	.70	.30	.38	.21	.04	-.05	-.02	-.02	.57	-.37	.00
9	-.59	-.55	.57	.68	-.19	.67	.56	.68	.22	.45	.36	.28	.28	.15	.27	.63	-.57	-.23
2	.19	.36	.09	.28	.05	.40	.37	.29	.52	.40	.02	-.01	.11	-.07	-.13	.39	-.27	-.05
1	.26	.40	-.01	.24	.19	.35	.36	.23	.49	.31	.10	-.10	.06	-.01	-.16	.22	-.18	-.04
1	.36	.48	-.01	.17	.19	.31	.29	.21	.57	.53	.06	.07	.23	-.02	-.11	.17	-.26	-.14
7	.11	.23	.16	.34	.15	.44	.41	.37	.58	.26	.25	.01	.14	.17	.07	.29	-.33	-.10
9	-.03	-.01	.12	.15	.02	.19	.16	.13	.06	.03	.07	.03	.06	.08	.04	.09	-.08	-.14
4	-.09	-.12	-.04	-.06	-.05	-.09	-.09	-.06	-.17	-.02	-.12	-.03	-.07	-.12	-.04	.08	-.02	.08
5	-.11	-.05	-.03	-.02	-.17	-.12	-.11	-.04	-.16	-.08	-.22	-.22	-.17	-.24	-.18	.25	-.25	-.07
8	-.13	-.05	-.05	-.04	-.08	-.09	-.20	-.08	-.21	-.07	-.10	-.02	-.09	-.10	-.01	.05	.01	-.04
4	-.12	-.12	.12	.14	.09	.15	.15	.13	.16	.11	.15	.18	.13	.07	.04	.14	-.09	-.06
7	-.08	.01	-.12	-.09	.09	-.06	-.04	-.09	.01	.06	-.01	.05	-.07	-.05	-.11	.09	-.07	.03
3	-.14	-.07	.12	.07	-.16	.03	-.02	.06	-.10	-.15	-.08	-.24	-.17	-.04	.04	.02	-.23	-.15
6	-.03	.00	-.14	-.08	.07	-.07	-.15	-.08	-.12	-.01	-.13	-.08	-.12	-.10	-.12	.14	-.21	-.03
4	.03	-.07	.07	.08	.08	.12	.12	.09	-.02	-.05	.13	.16	.19	.06	-.02	.22	-.21	-.16
06	-.03	-.12	.06	.01	-.03	.01	.01	.02	-.09	-.08	.00	.08	.05	-.02	.01	.14	-.12	.00
03	.06	.15	-.07	-.02	-.02	-.02	-.02	.03	.11	.08	-.17	-.25	-.19	-.14	-.16	.32	-.25	-.02
20	.10	.14	-.18	-.19	.07	-.16	-.30	-.18	-.10	-.12	-.12	-.12	-.08	-.10	-.08	.06-	.05	-.09
86	-.71	-.43	.90	.90	-.34	.84	.82	.90	.29	.19	.80	.43	.64	.65	.78	.34	-.16	-.06
75	-.70	-.55	.90	.82	-.26	.76	.70	.84	.05	.11	.58	.30	.61	.57	.84	.25	-.12	-.02
82	-.66	-.46	.90	.88	-.21	.78	.74	.87	.21	.19	.76	.42	.53	.67	.81	.27	-.19	-.07
85	-.76	-.55	.96	.92	-.27	.86	.72	.92	.27	.38	.77	.55	.72	.71	.90	.48	-.33	-.14
69	-.31	-.20	.47	.71	-.17	.75	.75	.75	.42	.41	.30	.17	.26	.07	.10	.54	-.45	-.16
76	-.19	-.17	.34	.66	.03	.73	.73	.72	.34	.37	.20	.05	.08	-.02	-.06	.49	-.34	-.09
76	-.22	-.05	.34	.65	.02	.72	.69	.73	.43	.42	.19	.05	.04	.00	-.06	.47	-.35	-.07
75	-.38	-.30	.42	.67	-.09	.72	.52	.70	.30	.41	.22	.13	.14	.05	.09	.55	-.43	-.11
26	-.53	-.50	.40	.35	-.21	.22	.24	.31	-.22	-.19	.38	.19	.26	.40	-.47	-.03	-.04	-.02
06	-.60	-.56	.42	.24	-.23	.11	.05	.20	-.39	-.26	.21	.19	.31	.24	.46	-.06	.11	.00
14	-.51	-.60	.52	.36	-.19	.17	.16	.32	-.30	-.26	.41	.25	.27	.34	.47	.02	.03	.11
17	-.55	-.55	.41	.26	-.17	.20	.08	.24	-.29	-.14	.31	.31	.33	.33	.49	.16	-.10	.04
	-.63	-.38	.85	.92	-.30	.90	.88	.93	.34	.23	.69	.33	.54	.54	.63	.40	-.21	.02
	-.52	-.41	.76	.90	-.13	.92	.88	.96	.24	.31	.47	.21	.42	.34	.46	.49	-.31	-.02
	-.52	-.30	.76	.94	-.12	.91	.85	.94	.37	.37	.58	.30	.39	.42	.48	.42	-.30	-.10
	-.71	-.53	.84	.95	-.15	.95	.76	.96	.35	.46	.66	.45	.58	.54	.63	.63	-.45	-.13
		.77	-.80	-.74	.22	-.62	-.62	-.69	-.06	.00	-.62	-.28	-.36	-.50	-.59	-.29	.18	.16
		.79	-.76	-.63	.28	-.52	-.45	-.61	.19	.02	-.28	-.21	-.39	-.32	-.58	-.22	.11	.03
		.71	-.66	-.70	.17	-.48	-.44	-.55	.01	.11	-.39	-.10	-.07	-.31	-.40	-.33	.15	.03
		.84	-.81	-.75	.22	-.70	-.50	-.73	-.02	-.24	-.57	-.49	-.49	-.48	-.63	-.44	.29	.14
			-.58	-.46	.14	-.36	-.37	-.43	-.11	.12	-.49	-.32	-.35	-.33	-.35	-.28	.26	.17
			-.64	-.49	.21	-.41	-.36	-.49	.21	.05	-.29	-.23	-.32	-.27	-.46	-.21	.11	.06
			-.52	-.42	.20	-.25	-.21	-.36	.23	.22	-.34	-.16	-.19	-.27	-.39	-.27	.15	.06
			-.66	-.55	.19	-.51	-.35	-.54	.04	-.22	-.42	-.46	-.42	-.34	-.46	-.39	.31	.21
				.91	-.32	.85	.83	.90	.21	.17	.85	.55	.70	.65	.76	.38	-.20	-.05
				.83	-.24	.76	.71	.84	.03	.09	.58	.33	.63	.49	.73	.34	-.20	-.04
				.82	-.23	.72	.67	.80	.10	.13	.72	.45	.60	.53	.69	.25	-.21	-.05
				.90	-.23	.84	.70	.90	.25	.37	.78	.62	.76	.69	.83	.48	-.34	-.15
					-.33	.95	.92	.98	.31	.24	.73	.37	.58	.55	.67	.45	-.26	-.07
					-.19	.91	.85	.95	.16	.22	.49	.21	.49	.35	.54	.44	-.25	-.01
					-.12	.88	.83	.94	.28	.30	.62	.31	.35	.46	.52	.42	-.28	-.08
					-.22	.95	.76	.98	.32	.45	.68	.49	.61	.57	.71	.56	-.38	-.13
						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.04	.10	-.37	.13	-.41	-.04	-.07	.00

Y.W.	B6	-.58	-.4
Y.M.		-.64	-.4
O.W.		-.52	-.4
O.M.		-.66	-.5
Y.W.	B7		.9
Y.M.			.8
O.W.			.8
O.M.			.9
Y.W.	B8		
Y.M.			
O.W.			
O.M.			
Y.W.	B9		
Y.M.			
O.W.			
O.M.			
Y.W.	C1		
Y.M.			
O.W.			
O.M.			
Y.W.	C2		
Y.M.			
O.W.			
O.M.			
Y.W.	C3		
Y.M.			
O.W.			
O.M.			
Y.W.	C4		
Y.M.			
O.W.			
O.M.			
Y.W.	C5		
Y.M.			
O.W.			
O.M.			
Y.W.	C6		
Y.M.			
O.W.			
O.M.			
Y.W.	C7		
Y.M.			
O.W.			
O.M.			
Y.W.	C8		
Y.M.			
O.W.			
O.M.			
Y.W.	C9		
Y.M.			
O.W.			
O.M.			

-.58	-.46	.14	-.36	-.37	-.43	-.11	.12	-.49	-.32	-.35	[illegible]
-.64	-.49	.21	-.41	-.36	-.49	.21	.05	-.29	-.23	-.32	[illegible]
-.52	-.42	.20	-.25	-.21	-.36	.23	.22	-.34	-.16	-.19	[illegible]
-.66	-.55	.19	-.51	-.35	-.54	.04	-.22	-.42	-.46	-.42	[illegible]
	.91	-.32	.85	.83	.90	.21	.17	.85	.55	.70	[illegible]
	.83	-.24	.76	.71	.84	.03	.09	.58	.33	.63	[illegible]
	.82	-.23	.72	.67	.80	.10	.13	.72	.45	.60	[illegible]
	.90	-.23	.84	.70	.90	.25	.37	.78	.62	.76	[illegible]
		-.33	.95	.92	.98	.31	.24	.73	.37	.58	[illegible]
		-.19	.91	.85	.95	.16	.22	.49	.21	.49	[illegible]
		-.12	.88	.83	.94	.28	.30	.62	.31	.35	[illegible]
		-.22	.95	.76	.98	.32	.45	.68	.49	.61	[illegible]
			-.18	-.06	-.36	.35	.13	.04	.10	-.37	[illegible]
			.03	.26	-.17	.76	.27	.52	.36	-.07	[illegible]
			.05	.20	-.12	.54	.29	.31	.27	-.06	[illegible]
			-.03	.03	-.19	.63	.07	.33	.19	.01	[illegible]
				.95	.95	.41	.31	.72	.43	.55	[illegible]
				.96	.95	.34	.30	.58	.32	.48	[illegible]
				.87	.89	.42	.33	.62	.37	.38	[illegible]
				.80	.96	.44	.43	.72	.51	.58	[illegible]
					.93	.49	.36	.75	.42	.50	[illegible]
					.90	.53	.37	.71	.36	.44	[illegible]
					.86	.50	.44	.68	.42	.36	[illegible]
					.79	.48	.36	.65	.36	.49	[illegible]
						.37	.31	.73	.39	.60	[illegible]
						.21	.27	.52	.23	.50	[illegible]
						.37	.36	.64	.32	.39	[illegible]
						.36	.46	.71	.49	.62	[illegible]
							.73	.40	.26	.10	[illegible]
							.56	.62	.34	.10	[illegible]
							.77	.49	.31	.22	[illegible]
							.52	.64	.39	.36	[illegible]
								.25	.49	.06	[illegible]
								.28	.51	.11	[illegible]
								.37	.51	.24	[illegible]
								.39	.60	.33	[illegible]
									.74	.75	[illegible]
									.63	.61	[illegible]
									.72	.71	[illegible]
									.76	.84	[illegible]
										.67	[illegible]
										.60	[illegible]
										.70	[illegible]
										.75	[illegible]
											[illegible]
											[illegible]
											[illegible]
											[illegible]

.71	-.66	-.70	.17	[illegible]	-.44	[illegible]	.01	.11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.84	-.81	-.75	.22	-.70	-.50	-.73	-.02	-.24	-.57	-.49	-.49	-.48	-.63	-.44	.29	.14
	-.58	-.46	.14	-.36	-.37	-.43	-.11	.12	-.49	-.32	-.35	-.33	-.35	-.28	.26	.17
	-.64	-.49	.21	-.41	-.36	-.49	.21	.05	-.29	-.23	-.32	-.27	-.46	-.21	.11	.06
	-.52	-.42	.20	-.25	-.21	-.36	.23	.22	-.34	-.16	-.19	-.27	-.39	-.27	.15	.06
	-.66	-.55	.19	-.51	-.35	-.54	.04	-.22	-.42	-.46	-.42	-.34	-.46	-.39	.31	.21
		.91	-.32	.85	.83	.90	.21	.17	.85	.55	.70	.65	.76	.38	-.20	-.05
		.83	-.24	.76	.71	.84	.03	.09	.58	.33	.63	.49	.73	.34	-.20	-.04
		.82	-.23	.72	.67	.80	.10	.13	.72	.45	.60	.53	.69	.25	-.21	-.05
		.90	-.23	.84	.70	.90	.25	.37	.78	.62	.76	.69	.83	.48	-.34	-.15
			-.33	.95	.92	.98	.31	.24	.73	.37	.58	.55	.67	.45	-.26	-.07
			-.19	.91	.85	.95	.16	.22	.49	.21	.49	.35	.54	.44	-.25	-.01
			-.12	.88	.83	.94	.28	.30	.62	.31	.35	.46	.52	.42	-.28	-.08
			-.22	.95	.76	.98	.32	.45	.68	.49	.61	.57	.71	.56	-.38	-.13
				-.18	-.06	-.36	.35	.13	.04	.10	-.37	.13	-.41	-.04	-.07	.00
				.03	.26	-.17	.76	.27	.52	.36	-.07	.50	-.13	.08	-.11	-.01
				.05	.20	-.12	.54	.29	.31	.27	-.06	.36	-.16	.09	.06	.01
				-.03	.03	-.19	.63	.07	.33	.19	.01	.35	-.25	-.03	.00	-.01
					.95	.95	.41	.31	.72	.43	.55	.55	.58	.45	-.27	-.07
					.96	.95	.34	.30	.58	.32	.48	.45	.46	.48	-.31	-.04
					.87	.89	.42	.33	.62	.37	.38	.48	.45	.44	-.27	-.08
					.80	.96	.44	.43	.72	.51	.58	.61	.64	.59	-.43	-.12
						.93	.49	.36	.75	.42	.50	.59	.55	.49	-.33	-.09
						.90	.53	.37	.71	.36	.44	.57	.39	.50	-.35	-.06
						.86	.50	.44	.68	.42	.36	.55	.44	.43	-.26	-.02
						.79	.48	.36	.65	.36	.49	.56	.57	.44	-.40	-.13
							.37	.31	.73	.39	.60	.54	.67	.47	-.29	-.08
							.21	.27	.52	.23	.50	.39	.56	.47	-.29	-.05
							.37	.36	.64	.32	.39	.47	.54	.46	-.33	-.06
							.36	.46	.71	.49	.62	.59	.71	.58	-.42	-.13
								.73	.40	.26	.10	.26	.04	.37	-.25	-.06
								.56	.62	.34	.10	.51	-.12	.21	-.17	-.04
								.77	.49	.31	.22	.38	.09	.35	-.23	-.09
								.52	.64	.39	.36	.56	.17	.24	-.23	-.13
									.25	.49	.06	.09	-.02	.28	-.20	-.01
									.28	.51	.11	.16	-.08	.27	-.21	-.01
									.37	.51	.24	.19	.03	.30	-.22	.11
									.39	.60	.33	.28	.23	.39	-.32	-.15
										.74	.75	.81	.73	.29	-.13	.00
										.63	.61	.86	.48	.25	-.19	-.07
										.72	.71	.84	.73	.18	-.08	-.02
										.75	.84	.92	.73	.40	-.30	-.15
											.67	.46	.34	.14	-.05	.02
											.60	.53	.26	.13	-.09	.03
											.70	.54	.46	.07	-.08	.00
											.75	.62	.50	.32	-.22	-.07
												.46	.62	.20	-.05	-.03
												.50	.64	.13	-.07	-.06
												.50	.62	.00	-.14	-.11
												.73	.74	.37	-.33	-.21
													.80	.04	.06	.10
													.63	.04	-.04	-.03

O.M.	
Y.W.	C2
Y.M.	
O.W.	
O.M.	
Y.W.	C3
Y.M.	
O.W.	
O.M.	
Y.W.	C4
Y.M.	
O.W.	
O.M.	
Y.W.	C5
Y.M.	
O.W.	
O.M.	
Y.W.	C6
Y.M.	
O.W.	
O.M.	
Y.W.	C7
Y.M.	
O.W.	
O.M.	
Y.W.	C8
Y.M.	
O.W.	
O.M.	
Y.W.	C9
Y.M.	
O.W.	
O.M.	
Y.W.	C10
Y.M.	
O.W.	
O.M.	
Y.W.	D1
Y.M.	
O.W.	
O.M.	
Y.W.	D2
Y.M.	
O.W.	
O.M.	

* The four groups of subjects are young women (Y.W.), young men (Y.M.), older women (O.W.), ar

.80	.96	.44	.43	.72	.51	.58	.61	.64
	.93	.49	.36	.75	.42	.50	.59	.55
	.90	.53	.37	.71	.36	.44	.57	.39
	.86	.50	.44	.68	.42	.36	.55	.44
	.79	.48	.36	.65	.36	.49	.56	.57
		.37	.31	.73	.39	.60	.54	.67
		.21	.27	.52	.23	.50	.39	.56
		.37	.36	.64	.32	.39	.47	.54
		.36	.46	.71	.49	.62	.59	.71
			.73	.40	.26	.10	.26	.04
			.56	.62	.34	.10	.51	-.12
			.77	.49	.31	.22	.38	.09
			.52	.64	.39	.36	.56	.17
				.25	.49	.06	.09	-.02
				.28	.51	.11	.16	-.08
				.37	.51	.24	.19	.03
				.39	.60	.33	.28	.23
					.74	.75	.81	.73
					.63	.61	.86	.48
					.72	.71	.84	.73
					.76	.84	.92	.73
						.67	.46	.34
						.60	.53	.26
						.70	.54	.46
						.75	.62	.50
							.46	.62
							.50	.64
							.50	.62
							.73	.74
								.80
								.63
								.82
								.79

, young men (Y.M.), older women (O.W.), and older men (O.M.).

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	.93	.49	.36	.75	.42	.50	.59	.55	.49	-.33	-.09
	.90	.53	.37	.71	.36	.44	.57	.39	.50	-.35	-.06
	.86	.50	.44	.68	.42	.36	.55	.44	.43	-.26	-.02
	.79	.48	.36	.65	.36	.49	.56	.57	.44	-.40	-.13
		.37	.31	.73	.39	.60	.54	.67	.47	-.29	-.08
		.21	.27	.52	.23	.50	.59	.56	.47	-.29	-.05
		.37	.36	.64	.32	.39	.47	.54	.46	-.33	-.06
		.36	.46	.71	.49	.62	.59	.71	.58	-.42	-.13
			.73	.40	.26	.10	.26	.04	.37	-.25	-.06
			.56	.62	.34	.10	.51	-.12	.21	-.17	-.04
			.77	.49	.31	.22	.38	.09	.35	-.23	-.09
			.52	.64	.39	.36	.56	.17	.24	-.23	-.13
				.25	.49	.06	.09	-.02	.28	-.20	-.01
				.28	.51	.11	.16	-.08	.27	-.21	-.01
				.37	.51	.24	.19	.03	.30	-.22	.11
				.39	.60	.33	.28	.23	.39	-.32	-.15
					.74	.75	.81	.73	.29	-.13	.00
					.63	.61	.86	.48	.25	-.19	-.07
					.72	.71	.84	.73	.18	-.08	-.02
					.75	.84	.92	.73	.40	-.30	-.15
						.67	.46	.34	.14	-.05	.02
						.60	.53	.26	.13	-.09	.03
						.70	.54	.46	.07	-.08	.00
						.75	.62	.50	.32	-.22	-.07
							.46	.62	.20	-.05	-.03
							.50	.64	.13	-.07	-.06
							.50	.62	.00	-.14	-.11
							.73	.74	.37	-.33	-.21
								.80	.04	.06	.10
								.63	.04	-.04	-.03
								.82	.09	-.02	-.06
								.79	.25	-.18	-.15
									.00	.14	.13
									-.02	.07	.01
									-.01	-.01	-.05
									.26	-.18	-.13
										-.83	-.30
										-.86	-.33
										-.78	-.15
										-.82	-.35
											.57
											.56
											.53
											.53

der women (O.W.), and older men (O.M.).

in each of the four sets of data is similar.

b. When the correlations are read by line or by column, they change similarly for the four sets of data.

c. The degree of correlation in the four sets of data is of similar value within similar areas of the table.

d. The summation of the correlations of any one asymmetry with all other asymmetries, regardless of sign, is similar in the four sets of data.*

2. The asymmetries lend themselves to grouping according to degree of correlation in all four sets of data, as indicated by the following: when two or more asymmetries show a similar degree of correlation in the age-sex groups, they likewise show a similar degree of correlation with other asymmetries. This is illustrated in Table VIII, page 84, which presents only a partial picture of what may be found in Table VII, page 82. In Table VIII the areas of correlations of similar degree are indicated by enclosing lines.

In view of the similarity of intercorrelation of asymmetries in the four sets of data, it would seem that neither age nor sex affect the general picture of bilateral skeletal asymmetry to any marked extent; also, that the subjects participating in the study may be considered an adequate sampling of any group of students of Physical Education and Health.

The similarity of degree of intercorrelation of various groups of asymmetries suggests that there are factors of movement which blend

* See Appendix, Table XXXV, page 182.

TABLE VIII*

The Tendency of Asymmetries to Combine into Groups According to Their Degree of Intercorrelation

Subjects		Intercorrelation of Asymmetries								
		A4	A5	B5	B6	C1	C2	C3	C9	C10
Y.W.**	A3	.86	.91	-.50	-.34	.81	.81	.79	.23	.22
Y.M.		.74	.85	-.28	-.17	.74	.76	.72	.18	.13
O.W.		.82	.91	-.38	-.09	.72	.70	.74	.08	.03
O.M.		.87	.93	-.51	-.37	.86	.73	.85	.37	.39
Y.W.	A4		.85	-.50	-.37	.78	.74	.77	.15	.20
Y.M.			.79	-.33	-.22	.70	.72	.67	.13	.03
O.W.			.80	-.33	-.12	.61	.56	.61	-.11	-.12
O.M.			.86	-.54	-.41	.80	.65	.79	.28	.31
Y.W.	A5			-.54	-.25	.87	.84	.85	.29	.32
Y.M.				-.37	-.22	.80	.79	.79	.15	.15
O.W.				-.40	-.05	.72	.68	.73	.00	-.02
O.M.				-.54	-.34	.86	.71	.85	.31	.40
Y.W.	B5				.77	-.62	-.62	-.69	-.50	-.59
Y.M.					.79	-.52	-.45	-.61	-.32	-.58
O.W.					.71	-.48	-.44	-.55	-.31	-.40
O.M.					.84	-.70	-.50	-.73	-.48	-.63
Y.W.	B6					-.36	-.37	-.43	-.33	-.35
Y.M.						-.41	-.36	-.49	-.27	-.46
O.W.						-.25	-.21	-.36	-.27	-.39
O.M.						-.51	-.35	-.54	-.34	-.46
Y.W.	C1						.95	.95	.55	.58
Y.M.							.96	.95	.45	.46
O.W.							.87	.89	.48	.45
O.M.							.80	.96	.61	.64
Y.W.	C2							.93	.59	.55
Y.M.								.90	.57	.39
O.W.								.86	.55	.44
O.M.								.79	.56	.57
Y.W.	C3								.54	.67
Y.M.									.39	.56
O.W.									.47	.54
O.M.									.59	.71
Y.W.	C9									.80
Y.M.										.63
O.W.										.82
O.M.										.79

* This table is a portion of Table VII, 82.

** Y.W. means young women; Y.M., young men; O.W., older women; O.M., older men.

*** The degree of intercorrelation tends to group the asymmetries in each of the age-sex groups as follows: (A3, A4, A5); (B5, B6); (C1, C2, C3); (C9, C10).

to produce a pattern or configuration of asymmetries. For this reason further analysis of the asymmetries and their correlations is given in Chapter IV where the asymmetries are merged into patterns.

SUMMARY

Bilateral asymmetry in the alignment of the skeletal framework was discovered to some extent in all of the 497 subjects participating in the study. Of the five skeletal units subjected to measurement, none was found to be completely symmetrical in any subject. Occasionally there was symmetry in the location of identical lateral parts, but this occurred only when the parts were subjected to one type of measurement -- never when they were subjected to two. The reliability, or extent to which asymmetries may be considered habitual, functional and capable of consistent measurement ranged in degree from .60 to .98.

The reliability of asymmetry tends to decrease as (a) the distance of the deviating part from the top of the sacrum increases, (b) the distance of the deviating part from the central vertical axis increases, (c) the number of joints between the deviating part and the sacrum increases, and/or (d) the area of skeletal structure between the deviating part and the sacrum increases.

Maintenance of equilibrium in the standing position is accompanied by movement in a varying direction. Direction of movement is not necessarily associated with or influenced by asymmetry in the position of the femora as the supporting structures.

Bilateral skeletal asymmetries show a marked similarity of intercorrelation in the four sets of data, indicating that neither age nor

sex tend to affect the general picture of asymmetry to any great extent. Furthermore, the asymmetries lend themselves to similar combination in the age-sex groups, according to their degree of intercorrelation.

CHAPTER IV

PATTERNS OF BILATERAL SKELETAL ASYMMETRY

A pattern of bilateral asymmetry in skeletal alignment is a configuration formed by those asymmetries which consistently occur together each time an individual assumes a standing position with his weight distributed evenly between the feet. A pattern then is constructed by bringing together that group of asymmetries which maintain a similar degree of relationship with each other and a lesser degree of relationship with other asymmetries of the skeletal structure.

This chapter will present (1) the patterns of bilateral skeletal asymmetry discovered in the average correlations of asymmetries in the four groups of subjects; and (2) the patterns of bilateral skeletal asymmetry of each of the age-sex groups.

BILATERAL SKELETAL ASYMMETRIES GROUPED TO FORM PATTERNS

Table IX, page 88, shows the configurations of asymmetries that emerged from similarity of correlation of asymmetries among themselves, and lesser correlation with other asymmetries in the skeletal structure.

The asymmetries of Group A maintain the highest correlation among themselves, the range of average degree of correlation being .82 to .91. The range of degree of average correlation of these asymmetries with other asymmetries of the skeletal structure was .40 to .43.*

* For the correlations of the asymmetries within the various groups with other skeletal asymmetries, see Appendix, Table XXXVI, page 183.

TABLE IX

Grouping of Bilateral Skeletal Asymmetries According to the Conformity of Their Degree of Correlation to Criterion A and Criterion B

Group		Intercorrelation of Asymmetries						Average	Range of Average r*
(A)		B4	B7	B8	C1	C2	C3		.82 to .91
	B1	.82	.92	.88	.81	.72	.83	.84	
	B4		.80	.93	.92	.84	.95	.88	
	B7			.87	.79	.73	.88	.83	
	B8				.92	.84	.96	.91	
	C1					.90	.94	.88	
	C2						.87	.82	
	C3							.91	
(B)		A2	A3	A4	A5	A6			.74 to .81
	A1	.89	.78	.72	.73	.72		.77	
	A2		.75	.70	.70	.67		.74	
	A3			.82	.90	.81		.81	
	A4				.83	.78		.79	
	A5					.83		.79	
	A6							.76	
(C)		C7	C8						.70 to .72
	C6	.71	.73					.72	
	C7		.68					.70	
	C8							.70	
(D)		B6							.78
	B5	.78							
(E)		D2							.82
	D1	-.82							
(F)		C10							.76
	C9	.76							
(G)		A9	A10						.41 to .46
	A8	.46	.45					.46	
	A9		.41					.44	
	A10							.43	

* The criterion for a trial grouping was similarity of correlation of asymmetries. The range of correlation maintaining within the pattern was discovered after the pattern was formed.

The asymmetries of Group B maintain the second highest degree of correlation among themselves, the range of average correlation being .74 to .81. The range of average degree of correlation of these asymmetries with other asymmetries of the skeletal structure is .36 to .41.

The asymmetries of Group C maintain a correlation among themselves ranging from .70 to .72; the average correlations of these asymmetries with other skeletal asymmetries ranges from .31 to .41. Correlation of the two asymmetries in group D is .78; the average correlation maintained with asymmetries outside the group is .30 and .39. The two asymmetries of Group E show a correlation of .82; with asymmetries not in the group the average correlation is .27 and .33. The two asymmetries in Group F show a correlation of .76; with asymmetries not in the group the average correlation is .30.

The asymmetries of Group G maintain a relatively low range of correlation among themselves -- .41 to .46. The correlation of these asymmetries with other asymmetries not in the pattern is at no time above .16 and the average correlation ranges from .04 to .05. Thus the asymmetries of Group G are fairly low in their interrelationship, but they definitely show little or no relationship with any other skeletal asymmetries.

Each group of asymmetries in Table IX may be considered to represent a pattern of bilateral skeletal asymmetry. The patterns are hereafter designated by number, and each is made up of asymmetries as follows:

Pattern I -- B1, B4, B7, B8, C1, C2, C3.
Pattern II -- A1, A2, A3, A4, A5, A6.
Pattern III -- C6, C7, C8.
Pattern IV -- B5, B6.
Pattern V -- C9, C10.
Pattern VI -- D1, D2.
Pattern VII -- A8, A9, A10.

PATTERNS OF BILATERAL SKELETAL ASYMMETRY IN EACH OF THE AGE AND SEX GROUPS

In the presentation of the patterns of bilateral skeletal asymmetry in the age and sex groups each pattern is treated in the following manner:

1. A table is presented which shows the intercorrelation of bilateral skeletal asymmetries of the pattern in the age-sex groups.
2. The location of bilateral asymmetries is given in terms of the deviating skeletal structures included in the pattern.
3. The asymmetries of the pattern are interpreted in terms of the type or types of skeletal deviation which tend to occur together to produce the pattern. This interpretation is made on the basis of the results of the preliminary experimentation in movement of inanimate skeletal structures to duplicate asymmetries shown on the radiographs.* Thus the factors of movement which blend to produce a configuration of asymmetries are determined.
4. A comparison of the pattern in the age-sex groups is made: (1) on the basis of the average intercorrelation of asymmetries in each group and (2) on the basis of the asymmetry in each group which shows the highest average correlation with other asymmetries in the same group.

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* See pages 24 to 33, inclusive.

Pattern I
Lateral and Rotatory Deviation in the Pelvis and Femora

The intercorrelation of bilateral skeletal asymmetries in Pattern I in each of the age-sex groups is shown in Table X, page 92. The asymmetries in this pattern occur in the posterior arch of the pelvis at the posterior inferior spines of the ilia (B1) and at the medial borders of the ilia just above the level of the acetabula (B4); in the anterior arch of the pelvis at the pubic symphysis (B8) and at points perpendicular to the posterior inferior spines of the ilia (B7); and in the femora at the center of their heads (C3), at their great trochanters (C2), and at their small trochanters (C1).

These asymmetries in the pelvis were produced experimentally by no one type of movement of the inanimate pelvis, but by different types of movement in the recognized planes of the body, the combined results of which presented the pelvic asymmetries shown in Pattern I. These movements were rotation of the pelvis in a coronal plane, rotation in a transverse plane, and bilaterally unequal anteroposterior rotation in a sagittal plane. The asymmetries of the femora, when in contact with the acetabula of the pelvis were produced by coronal rotation of the two structures combined. The bilateral measurements of the asymmetries in Pattern I show differences in horizontal and vertical relationships of the pelvis and femora. The positive intercorrelation of the asymmetries indicates that coronal rotation, horizontal rotation, and bilaterally unequal anteroposterior rotation of the pelvis tend to occur with lateral deviation of the femora to produce similar horizontal and vertical asymmetries in the bilateral position of various parts of the pelvis and femora. Thus when the pelvis is prominent on the left side, it tends

TABLE X

Pattern I: Intercorrelation of Asymmetries Occurring with Lateral and Rotatory Deviation in the Pelvis and Femora

Group of Subjects		Intercorrelation of Asymmetries						Average r
		B4	B7	B8	C1	C2	C3	
Young Women	B1	.86	.90	.90	.84	.82	.90	.87
	B4		.85	.92	.90	.88	.93	.89
	B7			.91	.85	.83	.90	.87
	B8				.95	.92	.98	.93
	C1					.95	.95	.91
	C2						.93	.89
	C3							.93
	All asymmetries							.90
Young Men	B1	.75	.90	.82	.76	.70	.84	.80
	B4		.76	.90	.92	.88	.96	.86
	B7			.83	.76	.71	.84	.80
	B8				.91	.85	.95	.88
	C1					.96	.95	.88
	C2						.90	.83
	C3							.91
	All asymmetries							.85
Older Women	B1	.82	.90	.88	.78	.74	.87	.83
	B4		.76	.94	.91	.85	.94	.87
	B7			.82	.72	.67	.80	.78
	B8				.88	.83	.94	.88
	C1					.87	.89	.84
	C2						.86	.80
	C3							.88
	All asymmetries							.84
Older Men	B1	.85	.96	.92	.86	.72	.92	.87
	B4		.84	.95	.95	.76	.96	.89
	B7			.90	.84	.70	.90	.86
	B8				.95	.76	.98	.91
	C1					.80	.96	.89
	C2						.79	.76
	C3							.92
	All asymmetries							.87

also to be higher on the left, to rotate to the left, to present a greater anteroposterior tilt on the left, and to be accompanied by lateral prominence of the left femur.

The average correlation of skeletal asymmetries in Pattern I in each of the age-sex groups is as follows: in young women, .90; in young men, .85; in older women, .84; in older men, .87. In general the degree of average correlation tends to increase with age increment among men (.85 to .87) and to decrease with age increment among women (.90 to .84); in the younger group of subjects it tends to be greater among women (.90 versus .85) and in the older group it tends to be greater among men (.87 versus .84). These differences in correlation of asymmetries in the age-sex groups seem small, but it will be noted in each pattern which follows that there are age and sex differences similar to those shown in Pattern I. Their consistent occurrence indicates that the differences tend to be reliable.

The asymmetry in Pattern I maintaining an equal or higher average correlation with other asymmetries in the pattern in all four groups of subjects is C3, the lateral deviationof the head of the femur from the central vertical axis.

Pattern II
Coronal Rotation of the Pelvis and Femora

The intercorrelation of bilateral skeletal asymmetries in Pattern II in the age-sex groups is shown in Table XI, page 94. The asymmetries of this pattern occur at the sacral table (A2), the sacral wings (A1), the crests of the ilia (A3), the posterior inferior spines of the ilia (A4), the tuberosities of the ischia (A6), and the femoral heads at their superior borders (A5).

TABLE XI

Pattern II: Intercorrelation of Asymmetries Occurring with Coronal Rotation of the Pelvis and Femora

Group of Subjects		Intercorrelation of Asymmetries					Average r
		A2	A3	A4	A5	A6	
	A1	.88	.82	.72	.71	.68	.76
	A2		.77	.71	.70	.67	.75
Young Women	A3			.86	.91	.85	.84
	A4				.85	.85	.80
	A5					.89	.81
	A6						.79
	All asymmetries						.79
	A1	.88	.76	.75	.76	.71	.77
	A2		.68	.70	.69	.59	.71
Young Men	A3			.74	.85	.72	.75
	A4				.79	.70	.74
	A5					.76	.77
	A6						.70
	All asymmetries						.74
	A1	.90	.77	.70	.70	.76	.77
	A2		.73	.65	.64	.70	.72
Older Women	A3			.82	.91	.86	.82
	A4				.80	.79	.75
	A5					.88	.79
	A6						.80
	All asymmetries						.77
	A1	.88	.77	.71	.73	.72	.76
	A2		.83	.74	.75	.71	.78
Older Men	A3			.87	.93	.79	.84
	A4				.86	.78	.79
	A5					.80	.81
	A6						.76
	All asymmetries						.79

These asymmetries were produced experimentally with the inanimate skeletal structure by rotation of the pelvis and contacting femora in the coronal plane. Their measurements on the radiographs show lateral angulation of the pelvis and femora at the six places mentioned above. The positive intercorrelation of the asymmetries indicates that coronal rotation tends to occur simultaneously in the pelvis and in the femora to produce similar lateral angulation in these structures. Thus when the pelvis is higher on one side, the left femoral head will tend to be higher on the same side.

In each of the age-sex groups the average correlation of asymmetries in Pattern II is as follows: in young women, .79; in young men, .74; in older women, .77; in older men, .79. In general the average degree of correlation tends to increase with age increment among men (.74 to .79) and to decrease with age increment among women (.79 to .77); in the younger group of subjects it tends to be greater among women (.79 versus .74) and in the older group it tends to be greater among men (.79 versus .77). The association of degree of average correlation of asymmetries with age and sex in Pattern II tends to be the same as in Pattern I.

The asymmetry in Pattern II which maintains the highest average correlation with other asymmetries in three of the four groups is A3, lateral angulation of the pelvis at the crests of the ilia. In the young men's group A1 and A5 -- lateral angulation of the pelvis at the sacral table and at the posterior inferior spines of the ilia, respectively -- maintain the highest average correlation with other asymmetries.

Pattern III
Lateral and Rotatory Deviation in the Femora and Ilia

The intercorrelation of bilateral skeletal asymmetries in Pattern III in the age-sex groups is shown in Table XII, page 97.

Since measurements of the asymmetries of this pattern were taken diagonally across the surface of each ilium, the asymmetries of the ilia are included in the asymmetries of the femora. The latter occur at their heads (C8), their great trochanters (C7), and their small trochanters (C6).

The asymmetries in Pattern III were produced experimentally in inanimate pelvic and femoral skeletal structures by several different movements, as follows: rotation of the pelvis and femora in the coronal plane, rotation of the pelvis in the transverse plane, and asymmetrical rotation of the pelvis in the sagittal plane. The bilateral measurements of the asymmetries in Pattern III show differences in diagonal relationships of three parts of the femora to the posterior inferior spines of the ilia. The positive intercorrelation of the asymmetries indicates that coronal, horizontal, and bilaterally unequal rotation of the pelvis, and lateral movement of the femora tend to occur together to produce similar diagonal asymmetries in the bilateral position of the ilia and femora.

The average correlation of skeletal asymmetries in each of the age-sex groups is as follows: in young women, .72; in young men, .61; in older women, .71; in older men, .78. In general the degree of average correlation tends to increase with age increment among men (.61 to .78); to decrease with age increment among women (.72 to .71); in the younger group it tends to be greater among women (.72 versus .61), in the older group in tends to be greater among men (.78 versus .73).

The asymmetry showing the highest average correlation with other

TABLE XII

Pattern III: Intercorrelation of Asymmetries Occurring with Lateral and Rotatory Deviation in the Femora and Ilia

Group of Subjects	Intercorrelation of Asymmetries			Average r
		C7	C8	
Young Women	C6	.74	.75	.75
	C7		.67	.71
	C8			.71
	All asymmetries			.72
Young Men	C6	.63	.61	.62
	C7		.60	.62
	C8			.61
	All asymmetries			.61
Older Women	C6	.72	.71	.72
	C7		.70	.71
	C8			.71
	All asymmetries			.71
Older Men	C6	.75	.84	.80
	C7		.75	.75
	C8			.80
	All asymmetries			.78

asymmetries in Pattern III in the age-sex groups is C6, diagonal distance of the small trochanter from the posterior inferior spine of the ilium.

Pattern IV
Rotatory Deviation in the Anterior Arch of the Pelvis

The correlation of bilateral skeletal asymmetries in Pattern IV in each of the age-sex groups is shown in Table XIII. The asymmetries of this pattern (B5 and B6) occur in the anterior arch of the pelvis at the obturator foramina.

TABLE XIII

Pattern IV: Correlation of Asymmetries Occurring with Rotatory Deviation in the Anterior Arch of the Pelvis

	Young Women	Young Men	Older Women	Older Men
Asymmetry	B6	B6	B6	B6
B5	.77	.79	.71	.84

The asymmetries were produced experimentally by rotation of the inanimate pelvis in the horizontal plane and by bilateral difference in rotation of the pelvis in the sagittal plane. When the pelvis was rotated to the left side, the right obturator foramen showed a greater width than the left (B5); when the pelvis was rotated in a sagittal plane to a greater extent on the left side the right obturator foramen showed also a greater vertical depth (B6). The bilateral measurements show differences in vertical and horizontal relationships of the borders of the foramina, the greater measurement occurring on the side opposite the direction of the deviation. The positive correlation of these asymmetries indicates that a rotation of the pelvis to the left is accompanied by a greater anteroposterior tilt of the pelvis on the left to produce the appearance of increased width and depth of the right obturator foramen, and decreased width and depth of the left one.

In general the average degree of correlation of skeletal asymmetries in Pattern IV tends to increase with age increment among men (.79 to .84) and to decrease with age increment among women (.77 to .71); in both age groups it tends to be greater among men than among women (.79 versus .77, and .79 versus .84). The association of a greater degree of average correlation of asymmetries with men in the younger group is different from that indicated in previous patterns, but the difference is too small to be considered significant.

Since there are only two asymmetries in Pattern IV they cannot be contrasted in degree of correlation within the pattern in each age-sex group. In the summation, however, of the correlations of each of these asymmetries with all other skeletal asymmetries not in their pattern, B5 is higher than B6 in all four groups of subjects,* though B6 has the higher reliability (.66 versus .62).

Pattern V
Lateral and Rotatory Deviation in the Posterior Arch of the Pelvis and in the Femora

Table XIV, page 100, shows the correlation of bilateral asymmetries in Pattern V in each age-sex group. Since the measurements of the asymmetries of this pattern were taken diagonally across the surface of the ilium and the sacrum, the asymmetries of both the ilia and the sacrum were included in the asymmetries of the femora, which occurred at their heads (C10) and at their great trochanters (C9).

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* The summation of the correlations of each skeletal asymmetry with all other asymmetries is found in the Appendix, page 182.

The asymmetries in diagonal relationships were produced experimentally, with inanimate skeletal structures by several different movements, as follows: coronal rotation of the pelvis with the femora attached to it, rotation of the pelvis in the transverse plane, and asymmetrical rotation of the pelvis in the sagittal plane. Measurements of the asymmetries in Pattern V show differences in lateral diagonal relationships of the head and great trochanter of the femur to the posterior inferior spine of the far ilium. The positive correlation of the asymmetries indicates that coronal, horizontal, and bilaterally unequal anteroposterior rotation of the pelvis, and lateral movement of the femora occur together to produce diagonal asymmetry in the posterior arch of the pelvis and femora. Thus when the proximal portion of the left femur is prominent laterally, it tends also to be higher, the pelvis tends to be prominent and higher on the left, to rotate to the left, and to show a greater anteroposterior tilt on the left.

TABLE XIV

Pattern V: Correlation of Asymmetries Occurring with Lateral and Rotatory Deviation in the Posterior Arch of the Pelvis and in the Femora

	Young Women	Young Men	Older Women	Older Men
Asymmetry	C10	C10	C10	C10
C9	.80	.63	.82	.79

In general the correlation of asymmetries in Pattern V tends to increase with age increment among both men and women (.63 to .79, and .80 to .82, respectively); in both younger and older subjects it tends to be greater among women (.80 versus .63, and .82 versus .79, respectively).

The association of change in degree of average correlation with age increment in women, and with sex in the older group of subjects, is contrary to the association generally shown in previous patterns.

Since there are only two asymmetries in Pattern V, the summation of the correlations of each with all other skeletal asymmetries not in the pattern is contrasted. C9, the diagonal distance between the great trochanter and the far ilium, shows a slightly larger summation of correlations than C10, the diagonal distance between the femoral head and the far ilium, except in the group of older women. Of these two asymmetries C10 shows a higher reliability than C9 (.74 versus .64).

Pattern VI
Lateral Angulation of the Lumbar Spine

Table XV shows the correlation of bilateral skeletal asymmetries in Pattern VI in each of the age-sex groups. The asymmetries occur in the position of the fifth lumbar vertebra (D1) and in the position of the upper four lumbar vertebrae (D2 -- a summation of their horizontal asymmetry).

TABLE XV

Pattern VI: Correlation of Asymmetries Occurring with Lateral Angulation of the Lumbar Spine

	Young Women	Young Men	Older Women	Older Men
Asymmetry	D2	D2	D2	D2
D1	-.83	-.86	-.78	-.82

The asymmetries of Pattern VI were produced experimentally by coronal rotation of the inanimate pelvis as it supported the spinal column on its sacral table. The reaction in the spinal column to lateral tilting of the pelvis was coronal rotation of the fifth lumbar vertebra similar to that in the pelvis and lateral deviation of the first four lumbar vertebrae to the side opposite the high side of the pelvis and the fifth lumbar vertebra. The measurement of asymmetries on the radiographs showed lateral angulation of the fifth lumbar vertebra and horizontal deviation of the superimposed lumbar vertebrae. The negative correlation of the asymmetries indicates that lateral angulation tends to occur in the position of the entire lumbar spine.

In general the correlation of asymmetries in Pattern VI tends to decrease with age increment among both men and women (.86 to .82, and .83 to .78 respectively); in both the younger and older groups it tends to be greater among men (.86 versus .83, and .82 versus .78, respectively). The association of change in degree of correlation of asymmetries with age increment in men, and of greater degree of correlation of asymmetries among men in the younger group of subjects, is contrary to that shown generally in previous patterns.

Since there are only two asymmetries in Pattern VI, the summation of the correlations of each with all other skeletal asymmetries not in the pattern is contrasted. D1, lateral angulation of the fifth lumbar vertebra, shows a higher summation than D2, the summation of lateral deviation of the first four lumbar vertebrae, in all four groups of subjects. D1 also has a higher reliability than D2 (.92 versus .91).

Pattern VII
Coronal Rotation of the Shoulder Girdle and Upper Thorax

Table XVI, page 103, shows the intercorrelation of asymmetries in Pattern VII in each of the age-sex groups. The asymmetries of this

TABLE XVI

Pattern VII: Intercorrelation of Asymmetries Occurring with Coronal Rotation of the Shoulder Girdle and Upper Thorax

Group of Subjects	Intercorrelation of Asymmetries			Average r
		A9	A10	
Young Women	A8	.53	.46	.50
	A9		.41	.47
	A10			.44
	All asymmetries			.47
Young Men	A8	.46	.43	.45
	A9		.47	.47
	A10			.45
	All asymmetries			.45
Older Women	A8	.41	.50	.46
	A9		.36	.39
	A10			.43
	All asymmetries			.42
Older Men	A8	.44	.41	.43
	A9		.40	.42
	A10			.41
	All asymmetries			.42

pattern occur in the shoulder girdle at the scapular inferior angles (A8) and at the clavicles (A9), and in the upper thorax (A10).

These asymmetries were produced experimentally on inanimate skeletal structures by rotating the shoulder girdle and the upper thorax in a coronal plane. Bilateral measurement of these structures on the radiographs shows lateral angulation of the shoulder girdle and upper thorax. The positive intercorrelation of the asymmetries indicates that coronal rotation of the shoulder girdle and upper thorax tends to produce lateral angulation or tilting of the two structures in the same general direction. Thus when the scapular inferior angle is higher on one side, the clavicle and the upper thorax tend also to be higher on the same side. Although the degree of intercorrelation of asymmetries in Pattern VII is low in comparison with the degree of intercorrelation of asymmetries in other patterns, it is similarly low in all four groups of subjects, and each asymmetry within the pattern shows little or no correlation with other skeletal asymmetries not in the pattern (see Table VII, page 82).

The average correlation of skeletal asymmetries in each of the age and sex groups is as follows: in young women, .47; in young men, .45; in older women, .42; in older men, .42. In general the degree of average correlation tends to decrease with age increment in both men and women (.45 to .42, and .47 to .42, respectively); in the younger group of subjects it tends to be greater in women (.47 versus .45), in the older group it is the same. The association of age and sex with the asymmetries of Pattern VII tends to be different from that shown in other specific patterns in the following manner: the average correlation of asymmetries tends to decrease instead of increase with age increment in men, and they tend to be similar in degree in the older age-sex groups instead of greater in men than in women.

The asymmetry of Pattern VII which maintains the highest average correlation with other asymmetries in three of the age-sex groups is A8, lateral angulation of the scapular inferior angles. In the group of young men A9, lateral angulation of the clavicles, maintains the highest average correlation.

SUMMARY

Bilateral skeletal asymmetries occur in seven specific patterns in each of the age-sex groups. The deviations from bilateral symmetry which tend to occur together to produce a configuration of asymmetries in each specific pattern are as follows:

Pattern I. A blending of coronal, horizontal, and bilaterally unequal anteroposterior rotations of the pelvis tends to occur with lateral deviation of the femora to produce similar asymmetries in the bilateral position of various parts of the two structures. When the left femur in its proximal portion is prominent laterally it tends also to be higher, the pelvis is higher on the left, prominent to the left, rotates to the left, and tilts anteroposteriorly to a greater degree on the left. This same pattern of deviation tends to occur on the right side when the right femur in its proximal portion is prominent laterally.

Pattern II. Coronal rotation of the pelvis and femora tends to produce similar lateral angulation in the position of each. When the pelvis is higher on one side, the femur will tend to be higher also on the same side.

Pattern III. A blending of coronal, horizontal, and bilaterally unequal anteroposterior rotations of the pelvis tends to occur with lateral deviation of the femora to produce similar diagonal asymmetries in the bilateral position of various parts of the two structures. When the left femur in its proximal portion is prominent laterally it tends also to be higher, the pelvis is higher on the left, prominent to the left, rotates to the left, and tilts anteroposteriorly to a greater degree on the left. The same pattern of deviation tends to occur on the right side when the right femur in its proximal portion is prominent laterally.

Pattern IV. A blending of horizontal and bilaterally unequal anteroposterior rotations of the pelvis tends to occur to produce the appearance of similar bilateral asymmetries in horizontal and vertical relationships of the borders of the obturator foramina. When the pelvis rotates horizontally to the left it tends also to tilt anteroposteriorly to a greater degree on the left; when it rotates horizontally to the right, it tends also to tilt anteroposteriorly to a greater degree on the right.

Pattern V. A blending of coronal, horizontal and bilaterally unequal anteroposterior rotations of the pelvis tends to occur with lateral deviation of the femora to produce similar diagonal asymmetries in the bilateral position of the posterior arch of the pelvis and the femora. When the left femur in its proximal portion is prominent laterally it tends also to be higher, the pelvis tends to be prominent to the left, higher on the left, to rotate to the left, and to show greater anteroposterior tilt on the left. The same pattern of deviation tends to occur on the right when the right femur in its proximal portion is prominent laterally.

<u>Pattern VI</u>. Coronal rotation of the fifth lumbar vertebra is generally accompanied by lateral deviation of the first four lumbar vertebrae to produce lateral angulation of the entire lumbar spine. When the left side of the fifth lumbar vertebra is higher than the right side, angulation of the entire lumbar spine tends to occur to the right side of the central vertical axis. The same pattern of deviation tends to occur to the left when the fifth lumbar vertebra is higher on the right side.

<u>Pattern VII</u>. Coronal rotation of the shoulder girdle and upper thorax tends to occur to produce similar lateral angulation in each structure. When the scapular inferior angle is higher on the left, the clavicle and the upper thorax tend also to be higher on the left; when the scapular inferior angle is higher on the right, the clavicle and the upper thorax tend also to be higher on the right.

A comparison of the deviations producing the different specific patterns of asymmetry indicates that a similar combination or blending of rotatory deviations (coronal, horizontal and sagittal) produces Patterns I, III, IV, and V, and that only one main type of rotatory deviation (coronal) produces Patterns II, VI and VII. This will be given further analysis in the next chapter.

An increased degree of average correlation of asymmetries with age increment in men occurs in all patterns except VI and VII and a decreased degree with age increment in women occurs in all patterns except V. In the younger group of subjects women show a greater average degree of correlation of asymmetries in all patterns except IV and VI and in the older group of subjects men show a greater average degree of correlation in all patterns except V.

The configuration of asymmetries in Pattern I in each of the age-sex groups is more consistent than the configuration of asymmetries in any other pattern. This is indicated by the following: (1) its asymmetries maintain a higher average correlation -- .84 to .90 -- than that shown in any other pattern, (2) one asymmetry, CS, has the highest average correlation in each of the age-sex groups, and (3) the association of degree of correlation with age and sex is that which occurs in the majority of patterns. Pattern VII contrasts most strongly with other specific patterns in that its asymmetries show little or no correlation with the asymmetries of other patterns and the intercorrelation of its asymmetries is lower than the intercorrelation of the asymmetries in any other specific pattern.

CHAPTER V

THE GENERAL PATTERN OF BILATERAL ASYMMETRY IN SKELETAL ALIGNMENT

A general pattern of asymmetry in bilateral skeletal alignment is a configuration of patterns of skeletal relationships which tend to occur together each time an individual assumes a standing position with his weight distributed evenly between the feet. The general pattern, then, is determined by the intercorrelation of specific patterns of asymmetry in the various parts of the skeletal structure.

This chapter will present (1) the intercorrelation of the seven specific patterns of bilateral skeletal asymmetry in each of the age-sex groups and (2) the general pattern of asymmetry in skeletal alignment.

INTERCORRELATION OF SPECIFIC PATTERNS OF BILATERAL ASYMMETRY

The intercorrelation of the specific patterns of bilateral asymmetry in each of the four groups of subjects is shown in Table XVII, page 110. The intercorrelation of these patterns shows the following in each of the four groups of subjects:

1. Patterns I and II show the highest correlation of any of the patterns (.78, .77, .71, .81).
2. Pattern I shows the highest average correlation with all other patterns (.55, .49, .51, .61).
3. Pattern VII shows the lowest average correlation with all other patterns (.14, .06, .16, .10). Its highest correlation occurs with Pattern VI (-.33) in the older group of women.

TABLE XVII

Intercorrelation of Specific Patterns of Asymmetry in Each of the Age-Sex Groups

Subjects		II	III	IV	V	VI	VII	Average r	Average r*
Young Women	I	.78	.70	-.66	.69	-.34	.15	.55	.63
	II		.48	-.49	.19	-.67	.20	.47	.52
	III			-.50	.68	-.15	.17	.45	.50
	IV				-.53	.26	-.05	.42	.49
	V					.07	.05	.37	.43
	VI						-.19	.28	.30
	VII							.14	
	All patterns							.38	.48
Young Men	I	.77	.57	-.62	.60	-.35	-.04	.49	.58
	II		.36	-.34	.12	-.57	-.02	.36	.43
	III			-.37	.72	-.17	-.02	.37	.44
	IV				-.48	.16	-.07	.34	.37
	V					.00	-.07	.33	.38
	VI						-.11	.26	.25
	VII							.06	.
	All patterns							.32	.41
Older Women	I	.71	.61	-.76	.60	-.34	-.02	.51	.60
	II		.23	-.40	-.03	-.60	-.14	.35	.39
	III			-.27	.75	-.11	-.27	.37	.39
	IV				-.39	.23	-.03	.35	.41
	V					-.03	-.18	.33	.36
	VI						-.33	.27	.26
	VII							.16	
	All patterns							.33	.40
Older Men	I	.81	.72	-.70	.74	-.50	-.18	.61	.69
	II		.49	-.54	.34	-.70	-.07	.49	.57
	III			-.55	.83	-.36	-.13	.51	.60
	IV				-.54	.38	.01	.45	.54
	V					-.23	-.11	.47	.54
	VI						-.09	.38	.43
	VII							.10	
	All patterns							.43	.55

* Pattern VII is omitted from this average of correlations of asymmetries.

4. Pattern VI tends to have a negative correlation with all patterns except Pattern IV. Negative correlations of patterns indicates lateral opposition in the location of patterns of asymmetry, except in Pattern IV in which positive correlation indicates lateral opposition.* In view of this, Pattern V is in general the only pattern of lateral opposition or compensation for the deviations represented in all other patterns.

5. In general the association of age and sex with degree of intercorrelation of patterns of bilateral asymmetry is the following:

   a. The average degree of intercorrelation of patterns tends to decrease with age increment among women; among men, the reverse is true.

   b. In the younger group of subjects the average degree of intercorrelation is greater among women; in the older groups of subjects, the reverse is true.

   c. There is an increase in negative correlation of Patterns V and VI with age increment among women, that is, there is an increasing tendency toward lateral opposition in the deviations of the lumbar spine and the deviations of the shoulder girdle and upper thorax.

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* This is explained by the following: a plus asymmetry in the lumbar spine was produced experimentally by lateral deviation of the lumbar spine to the right side; a plus asymmetry in the obturator foramina was produced experimentally by horizontal rotation and greater anteroposterior tilt of the pelvis on the left (see page 29). Thus a positive correlation of these two patterns occurs only when the deviation producing the asymmetries in each occurred in lateral opposition.

6. A comparison of the degree of correlation between the different patterns in each of the age-sex groups indicates that patterns of asymmetry produced by similar types of deviation show a higher degree of correlation than patterns of asymmetry produced by different types of deviation.* The correlations of patterns of asymmetry produced by similar types of deviation are shown in Table XVIII, Group A and Group B, page 113. To indicate the contrast in degree of relationship when patterns produced by different types of deviation are correlated, and when patterns produced by similar type or types of deviations are correlated, Tables XVII and XVIII are summarized as follows:

	All patterns** Average r	Patterns I, III, IV, V Average r	Patterns II and VI Average r
Y.W.	.48	.63	.67
Y.M.	.41	.56	.57
O.W.	.40	.56	.60
O.M.	.55	.68	.70

THE GENERAL PATTERN OF ASYMMETRY IN BILATERAL SKELETAL ALIGNMENT

The general pattern of asymmetry in bilateral skeletal alignment is limited to Patterns I, II, and VI for the following reasons:

* A comparison of the type or types of deviation producing the asymmetries in each pattern showed that there was similarity of types of deviation in Patterns I, III, IV, and V, and in Patterns II, VI, and VII (see pages 105 to 107).

** Pattern VII is excluded because of its low correlation with the other patterns.

TABLE XVIII

Similarity of Relationship of Patterns When Those Produced by the Same Type of Deviation are Correlated

Subjects	Group A Intercorrelation of Patterns				Average r	Group B Correlation of Patterns	
		III	IV	V			VI
Young Women	I	.70	-.66	.69	.68	II	-.67
	III		-.50	.68	.63		
	IV			-.53	.56		
	V				.63		
	All patterns				.63		
Young Men	I	.57	-.62	.60	.60	II	-.57
	III		-.37	.72	.55		
	IV			-.48	.49		
	V				.60		
	All patterns				.56		
Older Women	I	.61	-.76	.60	.66	II	-.60
	III		-.27	.75	.54		
	IV			-.39	.47		
	V				.58		
	All patterns				.56		
Older Men	I	.72	-.70	.74	.72	II	-.70
	III		-.55	.83	.70		
	IV			-.54	.60		
	V				.70		
	All patterns				.68		

* Group A includes patterns produced by a blending of coronal, horizontal and sagittal rotations; Group B includes patterns produced by coronal rotation. Pattern VII is omitted because of its comparatively low correlation with all patterns.

The table should be read across as follows: Among young women, Patterns I, III, IV, and V which are each produced by a blending of coronal horizontal, and sagittal rotations in the skeletal structure show an average intercorrelation of .63; Patterns II and VI which are produced by coronal rotation in the skeletal structure show a correlation of -.67. Similarity in degree of relationship of patterns tends to occur when patterns produced by similar deviation are correlated.

1. Patterns III, IV, and V do not show asymmetry of any skeletal part, or any type of deviation producing asymmetries of skeletal parts that are not included in Pattern I. Furthermore, their asymmetries are less reliable than the asymmetries of Pattern I. Since these three patterns are fairly closely related to Pattern I, and less reliable than Pattern I, for simplicity in presentation of the general pattern, they are eliminated.
2. Pattern VII (asymmetry of the shoulder girdle and upper thorax) shows little or no relationship with any pattern in comparison with the relationship between other patterns.
3. The asymmetries of the thoracic and cervical regions of the spinal column show the lowest correlation with other asymmetries, and they do not occur in a pattern.
4. The reliability of the asymmetries occurring in Patterns I, II, and VI indicates that the deviations from symmetry in the pelvis, proximal femora, and lumbar spine tend to be consistent and hence are probably functional to a greater degree than those occurring in other skeletal parts. Their reliability is as follows:

   Asymmetries of Pattern I -- .73 to .88
   Asymmetries of Pattern II -- .91 to .98
   Asymmetries of Pattern VI -- .91 and .92

The units of the skeletal structure included in the general pattern are the pelvis, the proximal portion of the femora, and the lumbar spine. The intercorrelation of the specific patterns which enter into the general pattern is shown in Table XIX, page 115. In each of the four groups or subjects Pattern II shows the highest average correlation

TABLE XIX

Intercorrelation of Specific Patterns I, II, and VI
Which Form the General Pattern of Asymmetry
in Skeletal Alignment

Group of Subjects	Intercorrelation of Patterns			Average r
		II	VI	
Young Women	I	.78	-.34	.56
	II		-.67	.73
	VI			.51
	All patterns			.60
Young Men	I	.77	-.35	.56
	II		-.57	.67
	VI			.46
	All patterns			.60
Older Women	I	.71	-.34	.53
	II		-.60	.66
	VI			.47
	All patterns			.55
Older Men	I	.81	-.50	.66
	II		-.70	.76
	VI			.60
	All patterns			.67

with the other patterns (.73, .67, .66, .76). Patterns I and II consistently correlate more highly than any other two patterns (.78, .77, .71, .81). Both Pattern I and Pattern II occur in the pelvis and femora, but they are made up of asymmetries produced by different types of deviation at the joints.* Pattern VI which occurs in the lumbar spine shows a higher correlation with Pattern II than with Pattern I. Since this is true, it would seem that there tends to be a higher relationship between patterns of asymmetry occurring in different units of the skeletal structure when these patterns are produced by a similar type of deviation. Pattern VI and Pattern II are produced by coronal rotation (lateral angulation) of the lumbar spine and the pelvis, respectively.

The intercorrelation of all asymmetries entering into the general pattern are shown in Table XX, page 117. A study of this table shows that in general the greater the distance between the location of asymmetries of the skeletal structure the less the degree of relationship. In each of the age-sex groups, lateral deviation of the femur (expressed by C1, C2, and C3) is one of the asymmetries maintaining the highest average correlation with all other asymmetries in the general pattern. The question arises whether, in a large number of individuals, the femur is prominent on one side more often than it is prominent on the other side. It was found that, among the subjects of this study, in each age-sex group the femur showed lateral prominence about an equal number of times to the right and to the left sides.**

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* The asymmetries of Pattern I are produced by coronal rotation of the pelvis and femora; the asymmetries of Pattern II are produced by a blending of coronal, horizontal, and bilaterally different sagittal rotations of the pelvis and lateral deviation of the femora.

** See Appendix, page 184.

TABLE XX

Correlation of Asymmetries in the General Pattern in Each Age-Sex Group of Subjects

Subjects		Intercorrelation of Asymmetries														Aver
		A2	A3	A4	A5	A6	B1	B4	B7	B8	C1	C2	C3	D1	D2	
Y.W.	A1	.88	.82	.72	.71	.68	.42	.53	.47	.57	.60	.65	.59	.76	-.65	
Y.M.		.88	.76	.75	.76	.71	.43	.73	.49	.67	.73	.74	.70	.71	-.56	
O.W.		.90	.77	.70	.70	.76	.41	.64	.41	.62	.60	.56	.63	.76	-.57	
O.M.		.88	.77	.71	.73	.72	.54	.71	.56	.65	.69	.55	.69	.78	-.66	
Y.W.	A2		.77	.71	.70	.67	.43	.52	.46	.56	.59	.60	.59	.86	-.69	
Y.M.			.68	.70	.69	.59	.35	.64	.40	.56	.64	.65	.61	.78	-.66	
O.W.			.73	.65	.64	.70	.39	.57	.38	.56	.54	.51	.58	.83	-.70	
O.M.			.83	.74	.75	.71	.56	.72	.54	.69	.72	.60	.71	.82	-.71	
Y.W.	A3			.86	.91	.85	.66	.74	.67	.78	.81	.81	.79	.68	-.55	
Y.M.				.74	.85	.72	.49	.71	.50	.69	.74	.76	.72	.53	-.39	
O.W.				.82	.91	.86	.50	.76	.47	.73	.72	.70	.74	.57	-.45	
O.M.				.87	.93	.79	.71	.83	.68	.83	.86	.73	.85	.64	-.53	
Y.W.	A4				.85	.85	.64	.68	.72	.76	.78	.74	.77	.61	-.44	
Y.M.					.79	.70	.46	.63	.55	.66	.70	.72	.67	.54	-.37	
O.W.					.80	.79	.41	.63	.49	.62	.61	.56	.61	.43	-.34	
O.M.					.86	.78	.65	.77	.67	.78	.80	.65	.79	.57	-.47	
Y.W.	A5					.89	.73	.80	.72	.86	.87	.84	.85	.61	-.41	
Y.M.						.76	.57	.77	.57	.78	.80	.79	.79	.50	-.32	
O.W.						.88	.51	.75	.46	.76	.72	.68	.73	.50	-.35	
O.M.						.80	.73	.83	.68	.85	.86	.71	.85	.56	-.41	
Y.W.	A6						.63	.68	.64	.76	.77	.75	.75	.59	-.44	
Y.M.							.44	.65	.49	.62	.68	.67	.65	.49	-.31	
O.W.							.49	.68	.46	.73	.65	.60	.70	.57	-.37	
O.M.							.57	.69	.57	.68	.67	.56	.68	.63	-.57	
Y.W.	B1							.86	.90	.90	.84	.82	.90	.34	-.16	
Y.M.								.75	.90	.82	.76	.70	.84	.25	-.12	
O.W.								.82	.90	.88	.78	.74	.87	.27	-.19	
O.M.								.85	.96	.92	.86	.72	.92	.48	-.33	
Y.W.	B4								.85	.92	.90	.88	.93	.40	-.21	
Y.M.									.76	.90	.92	.88	.96	.49	-.31	
O.W.									.76	.94	.91	.85	.94	.42	-.30	
O.M.									.84	.95	.95	.76	.96	.63	-.45	
Y.W.	B7									.91	.85	.83	.90	.38	-.20	
Y.M.										.83	.76	.71	.84	.34	-.20	
O.W.										.82	.72	.67	.80	.25	-.21	
O.M.										.90	.84	.70	.90	.48	-.34	
Y.W.	B8										.95	.92	.98	.45	-.26	
Y.M.											.91	.85	.95	.44	-.25	
O.W.											.88	.83	.94	.42	-.28	
O.M.											.95	.76	.98	.56	-.38	

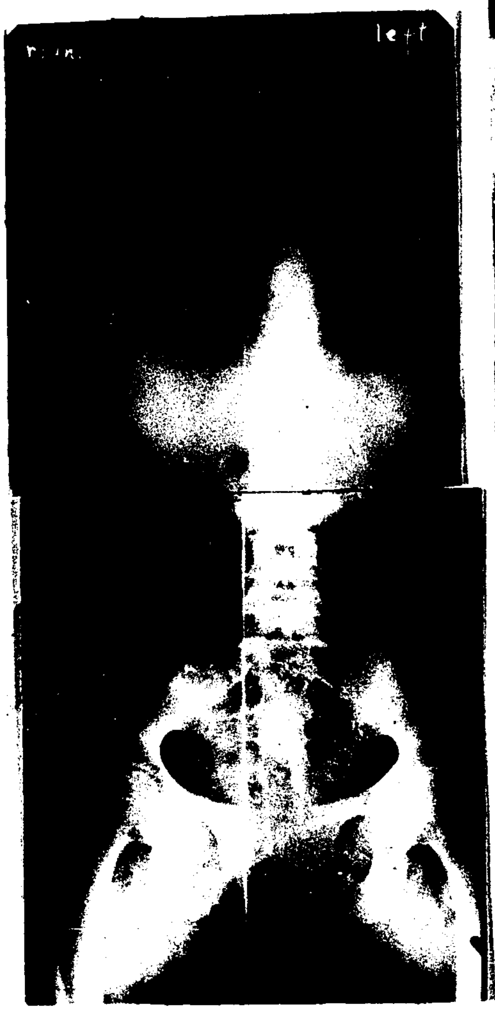
TABLE XX

Correlation of Asymmetries in the General Pattern in
Each Age-Sex Group of Subjects

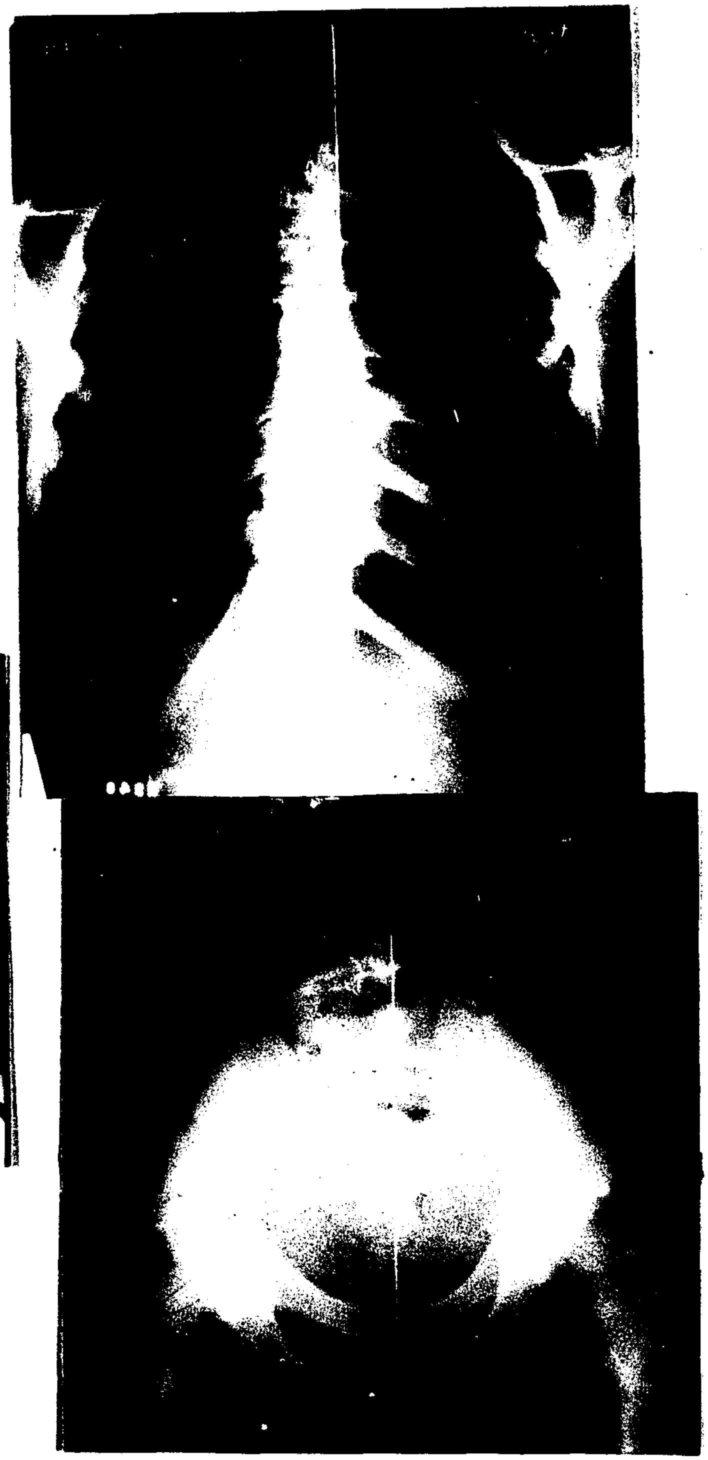
Subjects		Intercorrelation of Asymmetries														Average r
		A2	A3	A4	A5	A6	B1	B4	B7	B8	C1	C2	C3	D1	D2	
Y.W.	A1	.88	.82	.72	.71	.68	.42	.53	.47	.57	.60	.65	.59	.76	-.65	.65
Y.M.		.88	.76	.75	.76	.71	.43	.73	.49	.67	.73	.74	.70	.71	-.56	.69
O.W.		.90	.77	.70	.70	.76	.41	.64	.41	.62	.60	.56	.63	.76	-.57	.65
O.M.		.88	.77	.71	.73	.72	.54	.71	.56	.65	.69	.55	.69	.78	-.66	.69
Y.W.	A2		.77	.71	.70	.67	.43	.52	.46	.56	.59	.60	.59	.86	-.69	.65
Y.M.			.68	.70	.69	.59	.35	.64	.40	.56	.64	.65	.61	.78	-.66	.63
O.W.			.73	.65	.64	.70	.39	.57	.38	.56	.54	.51	.58	.83	-.70	.62
O.M.			.83	.74	.75	.71	.56	.72	.54	.69	.72	.60	.71	.82	-.71	.71
Y.W.	A3			.86	.91	.85	.66	.74	.67	.78	.81	.81	.79	.68	-.55	.76
Y.M.				.74	.85	.72	.49	.71	.50	.69	.74	.76	.72	.53	-.39	.66
O.W.				.82	.91	.86	.50	.76	.47	.73	.72	.70	.74	.57	-.45	.70
O.M.				.87	.93	.79	.71	.83	.68	.83	.86	.73	.85	.64	-.53	.78
Y.W.	A4				.85	.85	.64	.68	.72	.76	.78	.74	.77	.61	-.44	.72
Y.M.					.79	.70	.46	.63	.55	.66	.70	.72	.67	.54	-.37	.64
O.W.					.80	.79	.41	.63	.49	.62	.61	.56	.61	.43	-.34	.61
O.M.					.86	.78	.65	.77	.67	.78	.80	.65	.79	.57	-.47	.72
Y.W.	A5					.89	.73	.80	.72	.86	.87	.84	.85	.61	-.41	.77
Y.M.						.76	.57	.77	.57	.78	.80	.79	.79	.50	-.32	.70
O.W.						.88	.51	.75	.46	.76	.72	.68	.73	.50	-.35	.67
O.M.						.80	.73	.83	.68	.85	.86	.71	.85	.56	-.41	.75
Y.W.	A6						.63	.68	.64	.76	.77	.75	.75	.59	-.44	.71
Y.M.							.44	.65	.49	.62	.68	.67	.65	.49	-.31	.61
O.W.							.49	.68	.46	.73	.65	.60	.70	.57	-.37	.66
O.M.							.57	.69	.57	.68	.67	.56	.68	.63	-.57	.67
Y.W.	B1							.86	.90	.90	.84	.82	.90	.34	-.16	.66
Y.M.								.75	.90	.82	.76	.70	.84	.25	-.12	.56
O.W.								.82	.90	.88	.78	.74	.87	.27	-.19	.58
O.M.								.85	.96	.92	.86	.72	.92	.48	-.33	.70
Y.W.	B4								.85	.92	.90	.88	.93	.40	-.21	.71
Y.M.									.76	.90	.92	.88	.96	.49	-.31	.72
O.W.									.76	.94	.91	.85	.94	.42	-.30	.71
O.M.									.84	.95	.95	.76	.96	.63	-.45	.78
Y.W.	B7									.91	.85	.83	.90	.38	-.20	.68
Y.M.										.83	.76	.71	.84	.34	-.20	.60
O.W.										.82	.72	.67	.80	.25	-.21	.56
O.M.										.90	.84	.70	.90	.48	-.34	.69
Y.W.	B8										.95	.92	.98	.45	-.26	.76
Y.M.											.91	.85	.95	.44	-.25	.71
O.W.											.88	.83	.94	.42	-.28	.72
O.M.											.95	.76	.98	.56	-.38	.78

Y.M.		.79	.70	.46	.63	.55	.66	.70	.72	.67	.54	-.37	.6
O.W.		.80	.79	.41	.63	.49	.62	.61	.56	.61	.43	-.34	.6
O.M.		.86	.78	.65	.77	.67	.78	.80	.65	.79	.57	-.47	.7
Y.W.	A5		.89	.73	.80	.72	.86	.87	.84	.85	.61	-.41	.7
Y.M.			.76	.57	.77	.57	.78	.80	.79	.79	.50	-.32	.7
O.W.			.88	.51	.75	.46	.76	.72	.68	.73	.50	-.35	.6
O.M.			.80	.73	.83	.68	.85	.86	.71	.85	.56	-.41	.7
Y.W.	A6			.63	.68	.64	.76	.77	.75	.75	.59	-.44	.7
Y.M.				.44	.65	.49	.62	.68	.67	.65	.49	-.31	.6
O.W.				.49	.68	.46	.73	.65	.60	.70	.57	-.37	.6
O.M.				.57	.69	.57	.68	.67	.56	.68	.63	-.57	.6
Y.W.	B1				.86	.90	.90	.84	.82	.90	.34	-.16	.6
Y.M.					.75	.90	.82	.76	.70	.84	.25	-.12	.5
O.W.					.82	.90	.88	.78	.74	.87	.27	-.19	.5
O.M.					.85	.96	.92	.86	.72	.92	.48	-.33	.7
Y.W.	B4					.85	.92	.90	.88	.93	.40	-.21	.7
Y.M.						.76	.90	.92	.88	.96	.49	-.31	.7
O.W.						.76	.94	.91	.85	.94	.42	-.30	.7
O.M.						.84	.95	.95	.76	.96	.63	-.45	.7
Y.W.	B7						.91	.85	.83	.90	.38	-.20	.6
Y.M.							.83	.76	.71	.84	.34	-.20	.6
O.W.							.82	.72	.67	.80	.25	-.21	.5
O.M.							.90	.84	.70	.90	.48	-.34	.6
Y.W.	B8							.95	.92	.98	.45	-.26	.7
Y.M.								.91	.85	.95	.44	-.25	.7
O.W.								.88	.83	.94	.42	-.28	.7
O.M.								.95	.76	.98	.56	-.38	.7
Y.W.	C1								.95	.95	.45	-.27	.7
Y.M.									.96	.95	.48	-.31	.7
O.W.									.87	.89	.44	-.27	.6
O.M.									.80	.96	.59	-.43	.7
Y.W.	C2									.93	.49	-.33	.7
Y.M.										.90	.50	-.35	.7
O.W.										.86	.43	-.26	.6
O.M.										.79	.44	-.40	.6
Y.W.	C3										.47	-.29	.7
Y.M.											.47	-.29	.7
O.W.											.46	-.33	.7
O.M.											.58	-.42	.7
Y.W.	D1											-.83	.5
Y.M.												-.86	.5
O.W.												-.78	.5
O.M.												-.82	.6
Y.W.	D2												.4
Y.M.													.3
O.W.													.3
O.M.													.4

M.		.79	.70	.46	.63	.55	.66	.70	.72	.67	.54	-.37	.64
W.		.80	.79	.41	.63	.49	.62	.61	.56	.61	.43	-.34	.61
M.		.86	.78	.65	.77	.67	.78	.80	.65	.79	.57	-.47	.72
W.	A5		.89	.73	.80	.72	.86	.87	.84	.85	.61	-.41	.77
M.			.76	.57	.77	.57	.78	.80	.79	.79	.50	-.32	.70
W.			.88	.51	.75	.46	.76	.72	.68	.73	.50	-.35	.67
M.			.80	.73	.83	.68	.85	.86	.71	.85	.56	-.41	.75
.W.	A6			.63	.68	.64	.76	.77	.75	.75	.59	-.44	.71
.M.				.44	.65	.49	.62	.68	.67	.65	.49	-.31	.61
.W.				.49	.68	.46	.73	.65	.60	.70	.57	-.37	.66
.M.				.57	.69	.57	.68	.67	.56	.68	.63	-.57	.67
.W.	B1				.86	.90	.90	.84	.82	.90	.34	-.16	.66
.M.					.75	.90	.82	.76	.70	.84	.25	-.12	.56
.W.					.82	.90	.88	.78	.74	.87	.27	-.19	.58
.M.					.85	.96	.92	.86	.72	.92	.48	-.33	.70
.W.	B4					..85	.92	.90	.88	.93	.40	-.21	.71
.M.						.76	.90	.92	.88	.96	.49	-.31	.72
.W.						.76	.94	.91	.85	.94	.42	-.30	.71
.M.						.84	.95	.95	.76	.96	.63	-.45	.78
.W.	B7						.91	.85	.83	.90	.38	-.20	.68
.M.							.83	.76	.71	.84	.34	-.20	.60
.W.							.82	.72	.67	.80	.25	-.21	.56
.M.							.90	.84	.70	.90	.48	-.34	.69
.W.	B8							.95	.92	.98	.45	-.26	.76
.M.								.91	.85	.95	.44	-.25	.71
.W.								.88	.83	.94	.42	-.28	.72
.M.								.95	.76	.98	.56	-.38	.78
.W.	C1								.95	.95	.45	-.27	.76
.M.									.96	.95	.48	-.31	.74
.W.									.87	.89	.44	-.27	.69
.M.									.80	.96	.59	-.43	.78
.W.	C2									.93	.49	-.33	.75
.M.										.90	.50	-.35	.73
.W.										.86	.43	-.26	.65
.M.										.79	.44	-.40	.66
.W.	C3										.47	-.29	.76
.M.											.47	-.29	.74
.W.											.46	-.33	.72
.M.											.58	-.42	.79
.W.	D1											-.83	.57
.M.												-.86	.53
.W.												-.78	.51
.M.												-.82	.61
.W.	D2												.41
.M.													.38
.W.													.39
.M.													.49



A



B

Figure 14. Bilateral skeletal alignment. A is a radiograph of a skeletal structure which approximates bilateral symmetry; B is a radiograph which shows the general pattern of bilateral skeletal asymmetry. The subject of this radiograph swayed to the left in the interim between the exposure of the pelvic and thoracic x-ray films.

The asymmetries of the general pattern interpreted in terms of deviation of the skeletal structure show that the following relationships in asymmetrical alignment tend to occur. When the left ilium is higher than the right ilium, the pelvis tends to be prominent on the left, to rotate to the left, and to present a greater anteroposterior tilt on the left; the left femoral head is higher than the right, and the proximal portion of the left femur is prominent laterally; the lumbar spine deviates to the right of the central vertical axis. These asymmetries are shown in Figure 14B. The reverse tends to occur when the right ilium is higher than the left ilium.

The association of age and sex with degree of correlation in the general pattern of asymmetry is similar to that shown in the specific patterns of skeletal asymmetry; that is, the average correlation of asymmetries tends to decrease with age increment among women, to increase with age increment among men; in the younger group of subjects the average correlation of asymmetries is higher among women, in the older group it is higher among men.

<u>SUMMARY</u>

The general pattern of asymmetry in bilateral skeletal alignment is limited to the pelvis, the femora, and the lumbar portion of the spinal column. The correlation of the asymmetries of the thoracic and the cervical regions of the spinal column, of the scapular inferior angles and the clavicles of the shoulder girdle and of the upper thorax with other asymmetries is negligible in comparison with the correlation of asymmetries in the pelvis, the femora, and the lumbar spine.

In the general pattern, deviation in relation to the central vertical axis occurs on the same side in the pelvis and femora, but on the opposite side in the lumbar spine. It would seem that the only compensatory pattern of deviation which tends to have a degree of consistency in the subjects occurs in the lumbar spine and that there is no consistent compensation in the thoracic and the cervical regions of the spinal column or in the shoulder girdle.

Specific patterns of asymmetry in the general pattern of alignment show the highest correlations when they occur in the same units of the skeletal structure (Patterns I and II); when they occur in different units, patterns correlate most highly when they are produced by similar types of deviation (Patterns II and VI).

The association of age and sex with degree of correlation of asymmetries in the general pattern is the following: correlation of asymmetries tends to decrease with age increment among women, but to increase with age increment among men; in the younger group of subjects it tends to be higher among women, but in the older group of subjects, it tends to be higher among men.

The general pattern of alignment includes the following deviations of skeletal parts: when the pelvis is higher on the left side than it is on the right, it tends also to rotate to the left and to have a greater anteroposterior tilt on the left; the left femur is higher than the right and prominent laterally in its proximal portion; the lumbar spine deviates in the opposite direction, that is, to the right of the central vertical axis. When the pelvis is higher on the right side than on the left side, the opposite asymmetry in alignment tends to occur.

CHAPTER VI

THE ASSOCIATION OF BILATERAL SKELETAL ASYMMETRY WITH AGE, SEX, AND HANDEDNESS

The differences in degree of correlation of asymmetries were so similar for each of the four groups of subjects that the same specific patterns of asymmetry and the same general pattern of asymmetry occurred in all four groups of subjects. However, a comparison of degree of correlation of asymmetries in the four groups showed that both in specific patterns and in the general pattern there tends to be an association of age and sex with the degree of relationship between the asymmetries. For this reason, further study was made of differences in the asymmetries of the four age-sex groups.

In the study of correlation of asymmetries it was also found that there was little relationship between the asymmetry in the position of the shoulder girdle and the upper thorax (Pattern VI) and other skeletal asymmetries. Further study was made therefore to determine whether there was any relationship between the asymmetries of Pattern VI and the function of handedness.

The results of these further studies of asymmetries in the four groups of subjects and of the association of handedness to asymmetries will be shown in this chapter as follows:

1. The relationship between age in the sex groups and the degree of asymmetry

2. The relationship between sex in the age groups and the degree of asymmetry
3. The lateral location of asymmetries in the age-sex groups
4. Lateral curves of the spinal column in the age-sex groups
5. The relationship between handedness and the asymmetries of Pattern VI.

CHANGE IN DEGREE OF BILATERAL ASYMMETRY WITH AGE INCREMENT

Change in bilateral asymmetry with age increment in the sexes occurs in varying degree, particularly in those asymmetries which are not a part of the general pattern.

Change in Degree of Asymmetry with Age Increment Among Women

Table XXI shows that among women All skeletal asymmetries included in the general pattern tend to decrease in degree with age increment among women (see Table XXI, page 122). The chances in 100 that there is a true decrease range from 90 to 99.5.

Among the seventeen asymmetries not included in the general pattern, there are ten which tend to increase instead of decrease in degree of asymmetry. Of these only three tend to show a true increase, as follows: A8, lateral angulation of the shoulder girdle at the scapular inferior angles (97:100); C4, asymmetry in the relation of the greater trochanter to the latero-superior border of the acetabulum (93:100); and D3, lateral deviation of the thoracic spine (95:100).

TABLE XXI

Change in Degree of Skeletal Asymmetry with Age Increment Among Women

Asym.*	Pattern	Age Group	Mean	Critical Ratio	Chances[1] in 100	Change in Degree
A1**	II	Y.	20.45	1.6	94	decrease
		O.	16.86			
A2**	II	Y.	17.69	1.4	92	decrease
		O.	15.11			
A3**	II	Y.	18.97	1.6	94	decrease
		O.	15.85			
A4**	II	Y.	20.91	1.9	97	decrease
		O.	16.76			
A5**	II	Y.	15.74	2.0	98	decrease
		O.	12.45			
A6**	II	Y.	18.80	1.3	90	decrease
		O.	16.33			
A7		Y.	44.30	1.3	90	decrease
		O.	38.35			
A8	VII	Y.	30.70	1.9	97	increase
		O.	37.18			
A9	VII	Y.	25.29	1.0	84	decrease
		O.	22.61			
A10	VII	Y.	34.88	.4	65	increase
		O.	36.22			
B1**	I	Y.	14.16	1.6	94	decrease
		O.	12.11			
B2		Y.	9.58	2.4	99.2	decrease
		O.	7.51			
B3		Y.	5.58	.5	69	increase
		O.	7.51			
B4**	I	Y.	16.13	2.6	99.5	decrease
		O.	12.30			
B5	IV	Y.	8.79	.06	52	increase
		O.	8.85			
B6	IV	Y.	4.85	.7	76	increase
		O.	5.22			
B7**	I	Y.	20.55	2.6	99.5	decrease

A6**	II	Y. 18.80	O. 16.33	1.3	90	decrease
A7		Y. 44.30	O. 38.35	1.3	90	decrease
A8	VII	Y. 30.70	O. 37.18	1.9	97	increase
A9	VII	Y. 25.29	O. 22.61	1.0	84	decrease
A10	VII	Y. 34.88	O. 36.22	.4	65	increase
B1**	I	Y. 14.16	O. 12.11	1.6	94	decrease
B2		Y. 9.58	O. 7.51	2.4	99.2	decrease
B3		Y. 5.58	O. 7.51	.5	69	increase
B4**	I	Y. 16.13	O. 12.30	2.6	99.5	decrease
B5	IV	Y. 8.79	O. 8.85	.06	52	increase
B6	IV	Y. 4.85	O. 5.22	.7	76	increase
B7**	I	Y. 20.55	O. 15.45	2.6	99.5	decrease
B8**	I	Y. 13.99	O. 11.00	2.4	99.2	decrease
B9		Y. 5.32	O. 4.98	.6	73	decrease
C1**	I	Y. 19.81	O. 16.02	2.0	98	decrease
C2**	I	Y. 19.41	O. 16.40	1.7	96	decrease
C3**	I	Y. 20.29	O. 16.46	2.2	98.6	decrease
C4		Y. 5.10	O. 6.12	1.5	93	increase
C5		Y. 5.65	O. 5.99	.5	69	increase
C6	III	Y. 8.46	O. 8.50	.04	52	increase
C7	III	Y. 6.52	O. 5.96	.8	79	decrease
C8	III	Y. 5.63				

B8**	I	Y.	[illegible]	2.4	99.2	decrease
		O.	11.00			
B9		Y.	5.32	.6	73	decrease
		O.	4.98			
C1**	I	Y.	19.81	2.0	98	decrease
		O.	16.02			
C2**	I	Y.	19.41	1.7	96	decrease
		O.	16.40			
C3**	I	Y.	20.29	2.2	98.6	decrease
		O.	16.46			
C4		Y.	5.10	1.5	93	increase
		O.	6.12			
C5		Y.	5.65	.5	69	increase
		O.	5.99			
C6	III	Y.	8.46	.04	52	increase
		O.	8.50			
C7	III	Y.	6.52	.8	79	decrease
		O.	5.96			
C8	III	Y.	5.63	.5	69	decrease
		O.	5.29			
C9	V	Y.	8.60	.5	69	increase
		O.	9.05			
C10	V	Y.	9.30	.1	54	decrease
		O.	9.19			
D1**	VI	Y.	22.68	1.6	94	decrease
		O.	19.20			
D2**	VI	Y.	43.20	1.3	90	decrease
		OO.	37.43			
D3		Y.	156.75	1.6	95	increase
		O.	182.86			

* Asym. means asymmetry; O., older; Y., younger.

** Asymmetry occurring in the general pattern.

1. Garrett, op. cit., Table XIV, page 134

The table should be read across as follows: The asymmetry, A1, belonging to Pattern II of the general pattern has a mean of 20.45 in younger women and a mean of 16.86 in older women. The reliability of the difference between the measures with age increment, in terms of standard deviation of the difference, is 1.6. There are 94 chances in 100 that there is a true decrease in the asymmetry A1 -- lateral angulation of the wings of the sacrum -- with age increment in women.

Change in Degree of Asymmetry with Age Increment Among Men

With two exceptions asymmetries in the general pattern among men tend to increase in degree with age increment (see Table XXII, page 124). The chances that there is a true increase in degree of asymmetries are 90 or more in 100, except in A3 (62:100), in A4 (84:100), and in A5 (86:100). The asymmetries in the general pattern which tend to decrease in degree with age increment are: A6, lateral angulation of the pelvis at the tuberosities of the ischia, and D2, lateral deviation of the first four lumbar vertebrae. The chances that there is a true decrease in degree in these two asymmetries are 76 and 86, respectively, in 100.

Among the asymmetries not included in the general pattern, those which decrease rather than increase in degree according to the general tendency, are: A8, A9, A10, B6, C4, and D3. Of these asymmetries only three tend to show a true decrease: A10, lateral angulation of the upper thorax (94:100); B9, asymmetry in outward rotation of the femora (93:100); and D3, lateral deviation in the thoracic spine (99.7:100).

RELATIONSHIP BETWEEN SEX AND DEGREE OF BILATERAL ASYMMETRY

Differences in degree of bilateral asymmetry occurring with sex in the two age groups are found both in the general pattern of skeletal alignment and in individual bilateral asymmetries not included in the general pattern.

Relation Between Sex and Degree of Bilateral Asymmetry in Younger Subjects

The degree of asymmetry in the general pattern of alignment in the younger subjects tends to be greater among women than among

TABLE XXII

Change in Degree of Skeletal Asymmetry with Age Increment Among Men

A Asym.*	Pattern	Age Group	Mean	Critical Ratio	Chances in 100	Change in Degree
A1**	II	Y.	19.62	1.9	97	increase
		O.	23.75			
A2**	II	Y.	18.19	1.3	90	increase
		O.	20.65			
A3**	II	Y.	17.34	.3	62	increase
		O.	17.90			
A4**	II	Y.	18.69	1.0	84	increase
		O.	20.45			
A5**	II	Y.	13.74	1.1	86	increase
		O.	15.40			
A6**	II	Y.	20.05	.7	76	decrease
		O.	18.60			
A7		Y.	39.34	.09	54	increase
		O.	39.70			
A8	VII	Y.	29.56	.02	50	decrease
		O.	29.50			
A9	VII	Y.	22.72	.9	82	decrease
		O.	20.95			
A10	VII	Y.	33.79	1.6	94	decrease
		O.	28.95			
B1**	I	Y.	12.48	2.5	99.4	increase
		O.	15.58			
B2		Y.	9.71	.3	62	decrease
		O.	9.43			
B3		Y.	6.98	.04	52	increase
		O.	7.01			
B4**	I	Y.	12.29	2.1	98	increase
		O.	15.19			
B5	IV	Y.	8.06	.1	54	increase
		O.	8.19			
B6	IV	Y.	6.54	.6	73	decrease
		O.	6.14			
B7**	I	Y.	18.95	2.5	99.4	increase

[illegible]		O. 7.01	[illegible]	[illegible]	
B4**	I	Y. 12.29 / O. 15.19	2.1	98	increase
B5	IV	Y. 8.06 / O. 8.19	.1	54	increase
B6	IV	Y. 6.54 / O. 6.14	.6	73	decrease
B7**	I	Y. 18.95 / O. 24.03	2.5	99.4	increase
B8**	I	Y. 10.91 / O. 13.73	2.3	98.99	increase
B9		Y. 7.53 / O. 6.54	1.5	93	decrease
C1**	I	Y. 17.55 / O. 20.83	1.8	96	increase
C2**	I	Y. 17.62 / O. 20.86	1.7	96	increase
C3**	I	Y. 17.01 / O. 21.13	2.2	98.6	increase
C4		Y. 7.76 / O. 7.61	.2	58	decrease
C5		Y. 6.23 / O. 6.57	.6	73	increase
C6	III	Y. 9.27 / O. 10.88	1.6	94	increase
C7	III	Y. 7.09 / O. 7.20	.2	58	increase
C8	III	Y. 5.22 / O. 5.81	1.1	86	increase
C9	V	Y. 9.92 / O. 11.24	1.4	92	increase
C10	V	Y. 8.90 / O. 10.23	1.5	93	increase
D1**	VI	Y. 19.89 / O. 23.80	1.8	96	increase
D2**	VI	Y. 41.76 / O. 37.71	1.1	86	decrease
D3		Y. 188.19 / O. 141.51	2.8	99.7	decrease

* Asym. means asymmetry; Y., younger; O., older.

** Asymmetry occurring in the general pattern.

		O.	24.03			
B8**	I	Y.	10.91	2.3	98.99	increase
		O.	13.73			
B9		Y.	7.53	1.5	93	decrease
		O.	6.54			
C1**	I	Y.	17.55	1.8	96	increase
		O.	20.83			
C2**	I	Y.	17.62	1.7	96	increase
		O.	20.86			
C3**	I	Y.	17.01	2.2	98.6	increase
		O.	21.13			
C4		Y.	7.76	.2	58	decrease
		O.	7.61			
C5		Y.	6.23	.6	73	increase
		O.	6.57			
C6	III	Y.	9.27	1.6	94	increase
		O.	10.88			
C7	III	Y.	7.09	.2	58	increase
		O.	7.20			
C8	III	Y.	5.22	1.1	86	increase
		O.	5.81			
C9	V	Y.	9.92	1.4	92	increase
		O.	11.24			
C10	V	Y.	8.90	1.5	93	increase
		O.	10.23			
D1**	VI	Y.	19.89	1.8	96	increase
		O.	23.80			
D2**	VI	Y.	41.76	1.1	86	decrease
		O.	37.71			
D3		Y.	188.19	2.8	99.7	decrease
		O.	141.51			

* Asym. means asymmetry; Y., younger; O., older.

** Asymmetry occurring in the general pattern.

The table should be read across as follows: The asymmetry, A1, belonging to Pattern II of the general pattern, has a mean of 19.62 among the younger men and a mean of 23.75 among the older men. The reliability of the difference between the measures with age increment, in terms of the standard deviation of the difference, is 1.9. There are 97 chances in 100 that there is a true increase in the asymmetry A1 -- lateral angulation of the wings of the sacrum -- with age increment in men.

men (see Table XXIII, page 126). However, the chances that this difference will occur in the younger sex groups are in general less than the chances of change in degree of asymmetry with age increment in each sex. Two asymmetries in the general pattern show a slight tendency to be greater in degree among men than among women. These are A2, lateral angulation of the tuberosities of the ischia (79:100).

Of those asymmetries not in the general pattern, five show a marked tendency to be greater in degree among men than among women. These are B3, horizontal asymmetry of the ilia at the level of their anterior inferior spines (98:100); B6, vertical distance asymmetry in the appearance of the obturator foramina (99.8:100); B9, asymmetry in the outward rotation of the femora (100:100); C4, asymmetry in the location of the great trochanters in relation to the latero-superior borders of the acetabula (100:100); and D3, lateral deviation of the thoracic spine (94:100).

Relation Between Sex and Degree of Bilateral Asymmetry in Older Subjects

The degree of asymmetry in the general pattern of skeletal alignment in older subjects tends to be greater among men than among women (see Table XXIV, page 127). This tendency is marked in all asymmetries except D2, lateral deviation of the first four lumbar vertebrae. The chances that this asymmetry will be greater in degree among men than among women are only 54 in 100.

Of those asymmetries not in the general pattern, five show a tendency to be greater among women than among men. This tendency is marked, however, in only three of these asymmetries, as follows:

TABLE XXIII

Relationship of Degree of Skeletal Asymmetry and Sex Among the Younger Subjects

Asym.*	Pattern	Sex Group	Mean	Critical Ratio	Chances in 100	Sex with Greater Asymmetry
A1**	II	W.	20.45	.5	69	women
		M.	19.62			
A2**	II	W.	17.69	.3	62	men
		M.	18.19			
A3**	II	W.	18.97	1.0	84	women
		M.	17.34			
A4**	II	W.	20.91	1.2	88	women
		M.	18.60			
A5**	II	W.	15.74	1.4	85	women
		M.	13.74			
A6**	II	W.	18.80	.8	79	men
		M.	20.05			
A7		W.	44.30	1.3	90	women
		M.	39.34			
A8	VII	W.	30.70	.4	65	women
		M.	29.56			
A9	VII	W.	25.29	1.2	88	women
		M.	22.72			
A10	VII	W.	34.88	.4	65	women
		M.	33.79			
B1**	I	W.	14.16	1.4	85	women
		M.	12.48			
B2		W.	9.58	.2	58	men
		M.	9.71			
B3		W.	5.58	2.1	98	men
		M.	6.98			
B4**	I	W.	16.13	.9	99.8	women
		M.	12.29			
B5	IV	W.	8.79	.8	79	women
		M.	8.06			
B6	IV	W.	4.85	2.9	99.8	men
		M.	6.54			
B7**	I	W.	20.55	.9	82	women
		M.	18.95			
		W.	13.99			

		M. 33.79			
B1**	I	W. 14.16 / M. 12.48	1.4	85	women
B2		W. 9.58 / M. 9.71	.2	58	men
B3		W. 5.58 / M. 6.98	2.1	98	men
B4**	I	W. 16.13 / M. 12.29	.9	99.8	women
B5	IV	W. 8.79 / M. 8.06	.8	79	women
B6	IV	W. 4.85 / M. 6.54	2.9	99.8	men
B7**	I	W. 20.55 / M. 18.95	.9	82	women
B8**	I	W. 13.99 / M. 10.91	2.8	99.7	women
B9		W. 5.32 / M. 7.53	3.8	100	men
C1**	I	W. 19.81 / M. 17.55	1.3	90	women
C2**	I	W. 19.41 / M. 17.62	1.1	86	women
C3**	I	W. 20.29 / M. 17.01	2.0	98	women
C4		W. 5.10 / M. 7.76	4.3	100	men
C5		W. 5.65 / M. 6.23	1.0	84	men
C6	III	W. 8.46 / M. 9.27	1.0	84	men
C7	III	W. 6.52 / M. 7.09	.9	82	men
C8	III	W. 5.63 / M. 5.22	.8	79	women
C9	V	W. 8.60 / M. 9.92	1.6	85	men
C10	V	W. 9.30 / M. 8.90	.5	69	women
D1**	VI	W. 22.68 / M. 19.89	1.3	90	women
D2**	VI	W. 43.20 / M. 41.76	.4	65	women
D3		W. 156.75	1.6	94	men

[illegible]	[illegible]		M. 10.91	2.8	99.7	women
B9		W. 5.32	M. 7.53	3.8	100	men
C1**	I	W. 19.81	M. 17.55	1.3	90	women
C2**	I	W. 19.41	M. 17.62	1.1	86	women
C3**	I	W. 20.29	M. 17.01	2.0	98	women
C4		W. 5.10	M. 7.76	4.3	100	men
C5		W. 5.65	M. 6.23	1.0	84	men
C6	III	W. 8.46	M. 9.27	1.0	84	men
C7	III	W. 6.52	M. 7.09	.9	82	men
C8	III	W. 5.63	M. 5.22	.8	79	women
C9	V	W. 8.60	M. 9.92	1.6	85	men
C10	V	W. 9.30	M. 8.90	.5	69	women
D1**	VI	W. 22.68	M. 19.89	1.3	90	women
D2**	VI	W. 43.20	M. 41.76	.4	65	women
D3		W. 156.75	M. 198.19	1.6	94	men

* Asym. means asymmetry; W., women; M., men.

** Asymmetry occurring in the general pattern.

The table should be read across as follows: The asymmetry, A1, belonging to Pattern II of the general pattern of skeletal alignment, has a mean of 20.45 in younger women and a mean of 19.62 in younger men. The reliability of the difference between the measures in sex among younger subjects, in terms of the standard deviation of the difference, is .5. There are 69 chances in 100 that there is a greater degree of the asymmetry A1 -- lateral angulation of the wings of the sacrum -- in young women than in young men.

TABLE XXIV

Relationship of Degree of Skeletal Asymmetry and Sex Among the Older Subjects

Asym.*	Pattern	Sex Group	Mean	Critical Ratio	Chances in 100	Sex with Greater Asymmetry
A1**	II	W. M.	16.86 23.75	2.8	99.74	Men
A2**	II	W. M.	15.11 20.65	2.7	99.7	men
A3**	II	W. M.	15.85 17.90	2.8	99.74	men
A4**	II	W. M.	16.76 20.45	1.7	96	men
A5**	II	W. M.	12.45 15.40	1.7	96	men
A6**	II	W. M.	16.33 18.60	1.0	84	men
A7		W. M.	38.35 39.70	.3	62	men
A8	VII	W. M.	37.18 29.50	2.1	98	women
A9	VII	W. M.	22.61 20.95	.7	76	women
A10	VII	W. M.	36.22 28.95	2.0	98	women
B1**	I	W. M.	12.11 15.58	2.6	99.5	men
B2		W. M.	7.51 9.43	2.0	98	men
B3		W. M.	5.98 7.01	1.3	90	men
B4**	I	W. M.	12.30 15.19	1.8	96	men
B5	IV	W. MM.	8.85 8.19	.7	76	women
B6	IV	W. M.	5.22 6.14	1.6	94	men
B7**	I	W. M.	15.45 [illegible]	3.9	100	men

A10	VII	M. 28.95	W. 12.11	2.0	98	women
B1**	I	M. 15.58	W. 7.51	2.6	99.5	men
B2		M. 9.43	W. 5.98	2.0	98	men
B3		M. 7.01	W. 12.30	1.3	90	men
B4**	I	M. 15.19	W. 8.85	1.8	96	men
B5	IV	MM. 8.19	W. 5.22	.7	76	women
B6	IV	M. 6.14	W. 15.45	1.6	94	men
B7**	I	M. 24.03	W. 11.00	3.9	100	men
B8**	I	M. 13.73	W. 4.98	2.1	98	men
B9		M. 6.54	W. 16.02	2.4	99.2	men
C1**	I	M. 20.82	W. 16.40	2.3	98.9	men
C2**	I	M. 20.86	W. 16.46	2.2	98.6	men
C3**	I	M. 21.13	W. 6.11	2.3	98.9	men
C4		M. 7.61	W. 5.99	1.9	97	men
C5		M. 6.57	W. 8.50	.9	82	men
C6	III	M. 10.88	W. 5.96	2.2	98.6	men
C7	III	M. 7.20	W. 5.29	1.6	94	men
C8	III	M. 5.81	W. 9.05	.8	79	men
C9	V	M.* 11.24	W. 9.19	2.0	98	men
C10	V	M. 10.23	W. 19.20	1.0	84	men
D1**	VI	M. 23.80	W. 37.43	2.0	98	men
D2**	VI	M. 37.71	W. 182.86	.1	54	men

		M. 24.03			
B8**	I	W. 11.00 M. 13.73	2.1	98	men
B9		W. 4.98 M. 6.54	2.4	99.2	men
C1**	I	W. 16.02 M. 20.82	2.3	98.9	men
C2**	I	W. 16.40 M. 20.86	2.2	98.6	men
C3**	I	W. 16.46 M. 21.13	2.3	98.9	men
C4		W. 6.11 M. 7.61	1.9	97	men
C5		W. 5.99 M. 6.57	.9	82	men
C6	III	W. 8.50 M. 10.88	2.2	98.6	men
C7	III	W. 5.96 M. 7.20	1.6	94	men
C8	III	W. 5.29 M. 5.81	.8	79	men
C9	V	W. 9.05 M.** 11.24	2.0	98	men
C10	V	W. 9.19 M. 10.23	1.0	84	men
D1**	VI	W. 19.20 M. 23.80	2.0	98	men
D2**	VI	W. 37.43 M. 37.71	.1	54	men
D3		W. 182.86 M. 141.51	2.4	99.2	women

* Asym. means asymmetry; W., women; M., men.

** Asymmetry occurring in the general pattern.

The table should be read across as follows: The asymmetry, A1, belonging to Pattern II of the general pattern of skeletal alignment, has a mean of 16.86 in older women and a mean of 23.75 in older men. The reliability of the difference between the measures in sex among older subjects, in terms of the standard deviation of the difference, is 2.8. There are 99.74 chances in 100 that there is a greater degree of the asymmetry A1 -- lateral angulation of the wings of the sacrum -- in older men than in older women.

A8, lateral angulation of the scapular inferior angles (98:100); A10, lateral angulation of the upper thorax (98:100); and D3, lateral deviation of the thoracic spine (99.2:100).

Summary of Skeletal Asymmetry in Relation to Age and Sex

In general skeletal asymmetry is associated with age and sex in the following manner:

a. Correlation of asymmetries and degree of asymmetry decreases with age increment among women; it increases with age increment among men.

b. Correlation of asymmetries and degree of asymmetry is greater in the younger group among women; in the older group it is greater among men.

This association of degree of asymmetries with age and sex is consistent in all asymmetries of the general pattern except A2, A6, and D2. The chances in 100 that these will differ are not very marked. Among those asymmetries not in the general pattern A7, C8, and C10 constantly show the same association with age and sex as the asymmetries of the general pattern. Among other asymmetries not in the general pattern there is a varying association of their degree with age and sex.

LATERAL LOCATION OF ASYMMETRIES IN THE AGE-SEX GROUPS

The asymmetries which show the most marked tendency to occur more frequently on one side of the structure than on the other side* in the subjects of this study are those in the shoulder girdle and upper thorax

* For lateral location of the skeletal asymmetries in each of the age-sex groups of subjects, see Appendix, Table XXXVII, page 184.

(A8, A9, A10). The more frequent appearance of these asymmetries on the left side of the structure will be discussed in relation to handedness.

The remaining asymmetries tend to be fairly similar in right- and left-sided distribution in three of the age-sex groups: young women, older women, and older men, with the exception of B3, the horizontal distance asymmetry in the appearance of the surface of the ilium just above the acetabulum. In each of the four groups of subjects B3 occurs more frequently on the right side.

In the group of young men the asymmetries tend to be more unequal in their lateral distribution than in any of the other groups of subjects. This inequality in distribution is shown particularly in lateral angulation asymmetries in the pelvis -- A3, A4, A6, and A7 -- which occur more frequently on the left side; in lateral deviation of the thoracic region of the spinal column (D3) to the right side; and in asymmetries B1, C4, C6, C9, and C10, which occur more frequently on the right side. These latter asymmetries indicate mainly horizontal rotation and lateral deviation in the pelvis only, or in the pelvis and femora combined.

LATERAL CURVES OF THE SPINAL COLUMN IN THE AGE-SEX GROUPS

An analysis of the lateral curves of the spinal column in the subjects of this study shows that in one-third, or more, of the subjects in each age-sex group the spinal column deviates to one side of the central vertical axis and does not return to, or recross it (see Table XXV, page 130). A greater percentage of the younger than of the older subjects show one lateral curve only of the spinal column (42.1 and 45.6 versus 30.0 and 31.0), a greater percentage of the older than of the younger subjects show two lateral curves (25.5 and 21.0 versus 20.7 and 17.6),

TABLE XXV

Lateral Curves of the Spinal Column in the Age-Sex Group

	Percentage of varying number of lateral curves					Lateral Curves in Consecutive: First		Second		
Groups	None	One	Two	Three	Four	Av.* degree	Av. N. of V.	Av. degree	Av. N. of V.	de
Y.W.	33.9	42.1	20.7	3.3		7.28	8.6	5.87	7.7	9.
Y.M.	33.5	45.6	17.6	3.3		6.26	8.1	6.06	8.3	6.
O.W.	38.3	33.0	25.5	3.2		6.73	7.3	6.66	8.6	6.
O.M.	37.0	31.0	21.0	7.0	4.0	5.42	6.5	5.50	6.8	5.

* Av. means average; N., number; V., vertebrae; Y.W., young women; Y.M., young me
older men.

The table is read across as follows: Among young women the spinal column deviat
percent of the subjects and does not return to or recross the axis; in 42.1 per
lateral curve; in 20.7 per cent there are two lateral curves, in 3.3 per cent t
None of the young women in this study have four lateral curves. The first late
7.28 degrees with 8.6 vertebrae in the curve; the second, an angulation of 5.87
the third, an angulation of 9.62 degrees with an average of 8.5 vertebrae in th

TABLE XXV

Lateral Curves of the Spinal Column in the Age-Sex Groups

of varying ateral curves			Lateral Curves in Consecutive Order from Pelvis							
			First		Second		Third		Fourth	
o	Three	Four	Av.* degree	Av. N. of V.	Av. degree	Av. N. of V.	Av. degree	Av. N. of V.	Av. v degree	Av. N. of V.
.7	3.3		7.28	8.6	5.87	7.7	9.62	8.5		
.6	3.3		6.26	8.1	6.06	8.3	6.75	5.8		
.5	3.2		6.73	7.3	6.66	8.6	6.16	5.3		
.0	7.0	4.0	5.42	6.5	5.50	6.8	5.95	8.1	2.75	3.8

., number; V., vertebrae; Y.W., young women; Y.M., young men; O.W., older women; O.M.,

ross as follows: Among young women the spinal column deviates from the central axis in 33.9
cts and does not return to or recross the axis; in 42.1 per cent of the subjects there is one
.7 per cent there are two lateral curves, in 3.3 per cent there are three lateral curves.
men in this study have four lateral curves. The first lateral curve shows an angulation of
6 vertebrae in the curve; the second, an angulation of 5.87 with 7.7 vertebrae in the curve;
tion of 9.62 degrees with an average of 8.5 vertebrae in the curve.

a greater percentage of the older men than of any other group show three lateral curves, and only in older group of men were there any subjects with four lateral curves.

The first,* second, and third lateral curves of the spinal column, when they appear in the subjects of this study, tend to be similar both in their average degree of angulation and in the average number of vertebrae in each curve. The fourth curve in the older group of men tends to contain fewer vertebrae and to be less marked in its degree of angulation than any of the first three curves.

The various statistical treatments of the deviations of the spinal column indicate that no specific pattern of alignment of the spinal column as a whole occurs in the subjects of this study, but that the alignment of the spinal column, even though it is consistently similar over a period of time in each subject, is largely individual.

HANDEDNESS AND ASYMMETRY IN THE SHOULDER GIRDLE AND UPPER THORAX

The bilateral asymmetries of the shoulder girdle and upper thorax**-- Pattern VI and the first four thoracic vertebrae -- seem to occur independent of all other skeletal asymmetries, also they tend to differ from other bilateral asymmetries. Their independence and difference have been noted, as follows:

1. There is little or no relation between the asymmetries of

* The first curve is the one nearest the pelvis; the second, third, and fourth curves follow in order of increasing distance from the pelvis.

** The term "upper thorax" refers to the first two ribs. In this chapter the first four thoracic vertebrae are given specific consideration, but are consistently designated as the upper thoracic spine to avoid confusion in meaning with the upper thorax.

Pattern VI and other skeletal asymmetries.*

2. There is little or no relation of the asymmetry of the thoracic spine as a whole** with other asymmetries, except with the first four lumbar vertebrae. The correlations of the thoracic spine (D3) with the lumbar spine (D2) in each of the age and sex groups is .57, .56, .53, and .53.* The positive relationship indicates that the asymmetry of the thoracic spine tends to occur on the same side as the asymmetry of the lumbar spine.

3. Pattern VI shows no relation to other specific patterns of asymmetry, with one possible exception, namely, for the older group of women the correlation of Pattern VI and Pattern V is -.33.***

4. The association of age and sex with the asymmetries of Pattern VI tends to be the reverse of that shown with the asymmetries in the general pattern.

Nine of the 497 subjects reported ambidexterity. However, it was found on investigation that each of these subjects tended to be ambidextrous in only one skill -- writing -- and that otherwise their handedness was specific. These subjects were considered therefore right- or left-handed according to the hand used in a greater number of activities. The percentage of right-handed subjects varied in the age and sex groups as follows: in young women, 100 per cent; in young men, 88 per cent; in

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* See Table VII, page 82.

** The correlation of the asymmetry of the upper thoracic spine with other asymmetries was not computed. In view of the relation between the slant of the upper thoracic spine and the asymmetries of Pattern VI, it is probably true that there is less correlation between the upper thoracic spine and other skeletal asymmetries than between the entire thoracic spine and other asymmetries.

*** See Table XVII, page 110.

older women, 93 per cent; in older men, 96 per cent.

A large percentage in all four groups of subjects, whether right- or left-handed, tend to have a greater height on the left side of the shoulder girdle and upper thorax than on the right, that is, the asymmetry tends to occur on the left side (see Table XXVI, page 134). Similarly, the upper thoracic spine tends to deviate consistently to the same side whether the subjects are right- or left-handed, but its deviation is on the right, that is, a gradual slant to the right from the vertical. The percentage of subjects with left asymmetry of the shoulder girdle and upper thorax is greater in all four groups when the subjects are right-handed than when they are left-handed, but this percentage decreases when the subjects are left-handed. This difference does not occur in the asymmetry of the upper thoracic spine (see percentage columns, Table XXVI, page 134).

In the different groups of subjects the degree of asymmetry occurring on the left with right-handedness is greater than the degree of asymmetry occurring on the right with right-handedness. This is true also when subjects are left-handed, with one exception -- the asymmetry of the scapular inferior angle (A8) in the group of older men. In this group the degree of left asymmetry of the scapular inferior angles occurring with right-handedness is one and six-tenths times the degree of right asymmetry with right-handedness; the degree of right asymmetry of the scapular inferior angles occurring with left-handedness is three and two-tenths times the degree of left asymmetry with left-handedness. It was found that older men have in general the most marked degree of skeletal asymmetry of any group. In this one asymmetry of the scapular inferior angle there seems to be a definite relationship with handedness, that is, A8, Angulation of the Scapular Inferior Angles

Handed- ness	N.*	Percen- tage	Group	Left high: Percen- tage	Left high: Av. Asym.	Right high: Percen- tage	Right high: Av. Asym.	Even: Percen- tage	Dif. Asym.	Degree paris
	121	100	Y.W.	80	-35.41	13	17.50	7	-17.91	L. 2.
Right	161	88	Y.M.	79	-33.34	15	17.50	6	-15.84	L. 1.
	87	93	O.W.	89	-43.73	10	22.22	1	-21.51	L. 1.
	96	96	O.M.	80	-34.61	13	12.50	7.	-22.11	L. 1.
	0		Y.W.							
Left	21	12	Y.M.	57	-21.25	43	20.55	0	.70	L. 1.
	7	7	O.W.	57	-38.75	29	12.50	14	-26.25	L. 3.
	4	4	O.M.	75	-21.66	25	70.00	0	48.34	R. 3.

* N. means number; Av., average; Dif., difference; Asym., asymmetry; V., vertebrae;
Asym. indicates that the asymmetry occurs on the left side, whereas no sign indi

The table should be read across as follows: Of 121 young women, 100 per cent are
lar inferior angle is higher on the left than on the right side, its average asy
angle is higher on the right than on the left side, its average asymmetry being
are even. The difference between the asymmetry when it occurs on the left side
in these right-handed subjects asymmetry in the scapular inferior angles is grea
ness. Comparing the degree of asymmetry on the two sides, the left is two times
Vertebrae are read in like manner.

TABLE XXVI

The Relation of Asymmetries of the Shoulder Girdle and Upper Thorax to Handedness

apular Inferior Angles				A9, Angulation of the Clavicles						
	Even			Left high		Right high		Even		
. m.	Percentage	Dif. Asym.	Degree Comparison	Percentage	Av. Asym.	Percentage	Av. Asym.	Percentage	Dif. Asym.	Degree Comparison
.50	7	-17.91	L. 2.0 x R.	81	-29.38	8	18.00	11	-11.38	L. 1.6 x R.
.50	6	-15.84	L. 1.9 x R.	81	-28.34	11	13.61	8	-14.73	L. 1.9 x R.
.22	1	-21.51	L. 1.9 x R.	78	-26.10	17	16.33	5	- 9.77	L. 1.6 x R.
.50	7.	-22.11	L. 1.6 x R.	85	-22.07	13	12.91	2	- 9.16	L. 1.7 x R.
.55	0	.70	L. 1.03x R.	62	-25.77	19	12.50	19	-13.27	L. 2.0 x R.
.50	14	-26.25	L. 3.1 x R.	71	-19.00	29	5.00	0	-14.00	L. 3.8 x R.
.00	0	48.34	R. 3.2 x L.	50	-50.00	50	10.00	0	-40.00	L. 5.0 x R.

, asymmetry; V., vertebrae; L., left; R., right; a minus sign before the number appearing under
side, whereas no sign indicates that it occurs on the right side.

; women, 100 per cent are right-handed. In 80 per cent of these right-handed subjects the scap-
ight side, its average asymmetry being -35.41; in 13 per cent of the subjects the scapular infer-
average asymmetry being 17.50; and in 7 per cent of the subjects the scapular inferior angles
; occurs on the left side and when it occurs on the right side is -17.91. This indicates that
r inferior angles is greater when it occurs on the left side, that is, in opposition to handed-
les, the left is two times that on the right. A9, A10, and the Slant of the Upper Thoracic

ABLE XXVI

houlder Girdle and Upper Thorax to Handedness

	.9, Angulation of the Clavicles					A10, Angulation of the Upper Thorax					
	Right high		Even			Left high		Right high		Even	
.	Percentage	Av. Asym.	Percentage	Dif. Asym.	Degree Comparison	Percentage	Av. Asym.	Percentage	Av. Asym.	Percentage	Dif. Asym.
B	8	18.00	11	-11.38	L. 1.6 x R.	73	-40.17	23	24.46	4	-15.71
4	11	13.61	8	-14.73	L. 1.9 x R.	79	-39.64	16	22.40	5	-17.24
D	17	16.33	5	- 9.77	L. 1.6 x R.	67	-44.54	29	24.60	5	-19.94
7	13	12.91	2	- 9.16	L. 1.7 x R.	73	-33.64	23	21.59	4	-12.05
7	19	12.50	19	-13.27	L. 2.0 x R.	48	-34.00	43	23.88	9	-10.12
D	29	5.00	0	-14.00	L. 3.8 x R.	71	-35.00	29	15.00	0	-20.00
D	50	10.00	0	-40.00	L. 5.0 x R.	50	-20.00	50	12.50	0	- 7.50

a minus sign before the number appearing under
the right side.

r cent of these right-handed subjects the scap-
13 per cent of the subjects the scapular infer-
t of the subjects the scapular inferior angles
ne right side is -17.91. This indicates that
ne left side, that is, in opposition to handed-
, A10, and the Slant of the Upper Thoracic

A10, Angulation of the Upper Thorax							Slant, Upper Thoracic V.		
Left high		Right high		Even			Left	Right	Vertical
Percentage	Av. Asym.	Percentage	Av. Asym.	Percentage	Dif. Asym.	Degree Comparison	Percentage	Percentage	Percentage
73	-40.17	23	24.46	4	-15.71	L. 1.6 x R.	20	78	2
79	-39.64	16	22.40	5	-17.24	L. 1.8 x R.	19	79	2
67	-44.54	29	24.60	5	-19.94	L. 1.8 x R.	27	69	4
73	-33.64	23	21.59	4	-12.05	L. 1.6 x R.	27	72	1
48	-34.00	43	23.88	9	-10.12	L. 1.4 x R.	15	80	5
71	-35.00	29	15.00	0	-20.00	L. 2.3 x R.	49	71	0
50	-20.00	50	12.50	0	- 7.50	L. 1.5 x R.	25	75	0

the asymmetry occurs in opposition to handedness.

The relation between asymmetry of the upper thoracic spine and handedness is similar but opposite to the relation between the asymmetries of the shoulder girdle and upper thorax and handedness (see Table XXVII, page 136).

In a greater percentage of subjects in each group the upper thoracic spine slants to the right (see column 3, Table XXVII, page 136). The greater percentage of subjects tends to have a left asymmetry of the shoulder girdle, whether the upper thoracic spine slants to the right, to the left, or is perpendicular. This percentage is greater when the upper thoracic spine slants to the right than when it slants to the left (compare the two percentage columns under Angulation of Shoulder Girdle).

When the upper thoracic spine slants to the right the greater percentage of subjects have a left asymmetry in the upper thorax (see the two percentage columns under Angulation of Upper Thorax) and the asymmetry is greater in degree on the left than on the right. When the upper thoracic spine slants to the left the greater percentage of subjects have a right asymmetry in the upper thorax and the asymmetry is greater in degree on the right than on the left, except in the group of older men.

A comparison of the shoulder girdle asymmetry occurring with different slants of the upper thoracic spine and the upper thoracic asymmetry occurring with different slants of the upper thoracic spine shows that the asymmetries of the shoulder girdle and upper thoracic spine are much less closely related than asymmetries of the upper thorax and the upper thoracic spine.

TABLE XXVII

The Relation Between the Slant of the Upper Thoracic Sp
Asymmetries of the Shoulder Girdle and Upper Tho

Upper Thoracic Spine Slant	N.*	Percentage	Group	Angulation of Shoulder Girdle (A8 and A9) Left high Percentage	Av. Asym.	Right high Percentage	Av. Asym.	Degree Comparison	A L Perc tag
	95	78	Y.W.	94	-31.51	5**	9.40	L. 3.4 x R.	96
	144	80	Y.M.	86	-28.1[illegible]	13	10.84	L. 2.6 x R.	84
Right	65	70	O.W.	94	-32.80	1	3.00	L.10.9 x R.	82
	73	73	O.M.	91	-28.00	8	6.17	L. 4.5 x R.	91
	24	20	Y.W.	67	-16.12	29	13.00	L. 1.2 x R.	21
	33	17	Y.M.	61	-21.45	36	11.25	L. 1.9 x R.	42
Left	25	28	O.W.	68	-24.82	32	20.25	L. 1.2 x R.	36
	26	26	O.M.	65	-21.18	27	11.42	L. 1.9 x R.	19
	2	2	Y.W.	1	-20.00	1	5.00		50
Vertical	5	3	Y.M.	5	-44.80	0			40
	4	2	O.W.	4	-22.25	0			25
	1	1	O.M.	1	-10.00	0			100

* N. means number; Av., average; Asym., asymmetry; L., left; R., right; the minu
Asym. indicates that the asymmetry occurs on the left side, whereas no sigh ir

** When, in reference to either the shoulder girdle or the upper thorax, the summ
and the percentage with right high is not 100, the difference is the percentag
the skeletal part concerned.

The table should be read across as follows: Among 78 per cent of the young wom
right. This is accompanied by a high left shoulder girdle among 94 per cent c
metry of 31.51, and a high right shoulder girdle among 5 per cent of the subje
The degree of asymmetry on the left is 3.4 times the degree of asymmetry on th
thoracic spine in these subjects is also accompanied by a high left upper thor
an average asymmetry of 41.70 and a high right upper thorax among 10 percent o
of 19.44. The degree of asymmetry on the left is 2.1 times the degree of asym

TABLE XXVII

Relation Between the Slant of the Upper Thoracic Spine and the Asymmetries of the Shoulder Girdle and Upper Thorax

Angulation of Shoulder Girdle (A8 and A9)					Angulation of Upper Thorax (A10)				
Left high		Right high			Left high		Right high		
ercen-tage	Av. Asym.	Percen-tage	Av. Asym.	Degree Com-parison	Percen-tage	Av. Asym.	Percen-tage	Av. Asym.	Degree Com-parison
94	-31.51	5**	9.40	L. 3.4 x R.	96	-41.70	10	19.44	L. 2.1 x R.
86	-28.1[illegible]	13	10.84	L. 2.6 x R.	84	-41.27	11	[illegible]5.33	L. 1.2 x R.
94	-32.80	1	3.00	L.10.9 x R.	82	-48.30	17	17.72	L. 2.7 x R.
91	-28.00	8	6.17	L. 4.5 x R.	91	-33.71	9	21.18	L. 1.6 x R.
67	-16.12	29	13.00	L. 1.2 x R.	21	-17.00	75	26.94	R. 1.6 x L.
61	-21.45	36	11.25	L. 1.9 x R.	42	-21.07	52	21.76	R. 1.03x L.
68	-24.82	32	20.25	L. 1.2 x R.	36	-20.55	60	28.66	R. 1.4 x L.
65	-21.18	27	11.42	L. 1.9 x R.	19	-32.00	66	21.18	L. 1.5 x R.
1	-20.00	1	5.00		50	-30.00	50	25.00	
5	-44.80	0			40	-25.00	40	25.00	
4	-22.25	0			25	-15.00	25	20.00	
1	-10.00	0			100	-10.00	0		

ge; Asym., asymmetry; L., left; R., right; the minus sigh before the number appearing under ymmetry occurs on the left side, whereas no sigh indicates it occurs on the right side.

r the shoulder girdle or the upper thorax, the summation of the percentage with left high ht high is not 100, the difference is the percentage of subjects with no asymmetry of .

ross as follows: Among 78 per cent of the young women the upper thoracic spine slants to the by a high left shoulder girdle among 94 per cent of these subjects with an average asym- right shoulder girdle among 5 per cent of the subjects with an average asymmetry of 9.40. the left is 3.4 times the degree of asymmetry on the right. The right slant of the upper jects is also accompanied by a high left upper thorax among 96 per cent of the subjects with 70 and a high right upper thorax among 10 percent of the subjects with an average asymmetry ymmetry on the left is 2.1 times the degree of asymmetry on the right.

Summary of Asymmetry of Shoulder Girdle and Upper Thorax in Relation to Handedness

There is no marked relationship in the subjects of this study between handedness and the asymmetries of the shoulder girdle, the upper thorax, and the upper thoracic spine. However, there is a tendency for asymmetry of the shoulder girdle and upper thorax to occur in opposition to handedness, and for the asymmetry of the upper thoracic spine to occur on the same side with handedness. This association of asymmetry with handedness is shown by a decrease in the number of left asymmetries and an increase in the number of right asymmetries with left-handedness in comparison with those occurring with right-handedness. However, the number of right asymmetries occurring with left-handedness is not as great as the number of left asymmetries occurring with right-handedness. In the group of older men a definite relationship tends to occur between the asymmetry of the scapular inferior angles and handedness, namely, when subjects are right-handed the left scapular inferior angle tends to be higher than the right, and when subjects are left-handed the right scapular inferior angle tends to be higher than the left.

It may be noted also in the subjects of this study that among the asymmetries of the upper part of the skeletal structure the lateral slant of the upper thoracic spine is more closely related to the lateral angulation of the upper thorax than it is to the lateral angulation of the shoulder girdle (compare columns of Degree Comparison, Table XXVII, page 136). The asymmetries of these two skeletal parts tend to occur fairly consistently on opposite sides of the structure.

SUMMARY

In general skeletal asymmetry is related to age and sex as follows: (a) correlation of asymmetries and degree of asymmetries decrease with age increment among women, they increase with age increment among men; (b) correlation of asymmetries and degree of asymmetries are greater among women than among men in the younger group of subjects, in the older group the reverse tends to be true.

The frequency in location of asymmetries on the right side in comparison with their frequency in location on the left side is fairly similar in each of the age-sex groups of subjects, with a few exceptions. In each age-sex group the asymmetries of the shoulder girdle and upper thorax occur more often on the left side, and B3, the appearance of horizontal asymmetry of the surface of the ilium just above the acetabulum, tends to occur more frequently on the right side. In the younger men there is more inequality in lateral distribution of asymmetries than in any other group. This is shown particularly in lateral angulation of the pelvis on the left, and in horizontal rotation and lateral deviations of the pelvis only and of the pelvis and femora on the right.

The alignment of the spinal column, even though it tends to be consistently similar in any one subject over a period of time, is largely individual. In approximately one-third of the subjects the spinal column deviates to one side of the axis and does not return to or recross it. When the spinal column returns to or recrosses the axis, the following tends to be true in the subjects of this study; there are more younger than older subjects with only one lateral curve, more older than younger subjects with two lateral curves, more older men than any other age-sex

subjects with three lateral curves, and older men only with four lateral curves. In the first, second, and third lateral curves in each age-sex group the average degree of angulation and the average number of vertebrae in the curves are similar. The fourth curve in the group of older men tends to contain fewer vertebrae and to show less angulation than any other curves.

The asymmetries of the shoulder girdle, the upper thorax, and the upper thoracic spine seem to occur quite independent of the other asymmetries of the skeletal structure. Of these asymmetries the slant of the upper thoracic spine and the angulation of the upper thorax are most closely related, as follows: when the upper thoracic spine slants to one side, the upper thorax tends to be higher on the opposite side. The association of these asymmetries with age and sex tends in general to be the reverse of the association of the majority of the asymmetries with age and sex, namely, these asymmetries tend to increase with age increment among women and to decrease with age increment among men; they tend to be greater among men than among women in the younger group of subjects, and to be greater among women than among men in the older group of subjects.

The tendency for the asymmetries of the shoulder girdle and the upper thorax to be related to handedness is not sufficiently marked for the relationship to be stated as a generalization for all subjects regardless of age and sex. Such relationship as does occur may be stated as follows: when subjects are right-handed the shoulder girdle and the upper thorax show a marked tendency to be higher on the left than on the right and the upper thoracic spine to slant to the right rather than to the left; but when subjects are left-handed the shoulder girdle and the upper thorax show only a slight tendency to be higher on the right than on the left and the upper thoracic spine to slant to the left rather than to the right. However, among older men the association of handedness with one skeletal asymmetry, that of the scapular inferior angles, may be stated as a generalization, as follows: when the subjects are right-handed the scapular inferior angle tends to be higher on the left than on the right; when subjects are left-handed the scapular inferior angle tends to be higher on the right than on the left.

CHAPTER VII

GENERAL SUMMARY

It was the purpose of this study to attempt (1) to determine by measurement some of the bilateral asymmetries in the alignment of the skeletal framework when subjects stand with the weight equally distributed between the feet and (2) to determine the relationship between these asymmetries.

PROCEDURE

Two radiographs were taken of 516 subjects in the Department of Physical Education and Health in the School of Education of New York University. One radiograph included the proximal portion of the femora, the pelvis, and the lumbar spine; the other included the thorax, the shoulder girdle, and a portion of the cervical spine. Thirty of the subjects were radiographed at two different times under identical conditions for the purpose of establishing reliability of the bilateral asymmetries.

A study of the radiographs of sixty subjects chosen at random was made in conjunction with inanimate skeletal structures. The inanimate skeletal structures were manipulated experimentally to produce asymmetries in them comparable to those in the radiographs. Direction, type, and plane of movement used to produce the various asymmetries, and possible points of reference for measurement were noted. The information gained from this experimental study served as the basis of interpretation of the measured asymmetries.

The radiographs of the above-mentioned subjects were used experimentally also to develop the measures. Fifty-five bilateral measurements were tried. Fifteen of these were excluded on the basis of gross error, five on the basis of reliability below .60, and three on the basis of intercorrelation. Ten of the final measurements were taken horizontally,* eight diagonally, two vertically, and twelve by angulation. All measurements were taken bilaterally except those on the vertebrae and the pubic symphysis. The distribution of the measurements in the various units of the skeletal structure was as follows; thirteen in the pelvis only, five in the femora only, eight in the pelvis and femora, seventeen to twenty-five in the spinal column, two in the shoulder girdle, and one in the upper thorax.

Approximately 35,000 measurements were made on the radiographs of 516 subjects.

ORGANIZATION AND ANALYSIS OF DATA

The subjects were divided into four groups according to age and sex. Subjects over forty-two years and subjects under seventeen years were eliminated because of the small number above and below these ages. This reduced the number of subjects used in the final study from 516 to 497.

Reliability was computed on the asymmetries measured on the first and second sets of radiographs of thirty of the subjects taken at two different times. The means and sigmas of asymmetries of these thirty subjects were later compared with those of each of the four groups of sub-

* The measurements in the spinal column, with the exception of angulation of lateral curve, were taken on each vertebra.

jects to determine whether there was similarity among them.

The skeletal asymmetries were determined from the bilateral measurements on all the radiographs and their correlations were computed for each of the four groups of subjects. The four sets of correlations were consistently similar, and the relative value of correlation within each set of data indicated that asymmetries could be grouped according to degree of correlation.

On the basis of arbitrarily established criteria specific patterns of intercorrelation were constructed from the average correlation of each of the asymmetries in the age-sex groups, then these patterns were built for each of the four groups separately and again subjected to the test of the criteria.

The specific patterns of asymmetry were intercorrelated to determine the general pattern of asymmetry in skeletal alignment.

To determine the association of age and sex with the various skeletal asymmetries the significant differences between degree of asymmetry in the age-sex groups were computed, the lateral distribution of the asymmetries in each of the age-sex groups was determined, and the lateral curves of the spinal column were analyzed in each of the age-sex groups. Finally the asymmetries of the shoulder girdle and the upper thorax were studied in relation to handedness.

CONCLUSIONS

Bilateral asymmetry was discovered in all of the 497 subjects studied. Although occasionally there was symmetry in the location of lateral identical parts according to one type of measurement, this was never true when the parts were subjected to another type of measurement.

The reliability, or extent to which the bilateral asymmetries may be measured consistently and therefore be considered habitual and functional, ranged from .60 to .98. The top of the sacrum is the most stable in its position of any skeletal part, its reliability being .98. Reliability of all other asymmetries tend in general to decrease as (a) the distance of the deviating part from the top of the sacrum and from the central vertical axis increases and/or (b) as the number of joints and area of skeletal structure between the deviating part and the sacrum increases. The maintenance of equilibrium in the standing position is accompanied by movement in varying direction, but direction of movement is not necessarily related to asymmetrical position of the supporting femora.

Seven different patterns of bilateral skeletal asymmetry were found in the alignment of the skeletal structure. These patterns were named according to their location and the type or types of deviation producing their asymmetries:

Pattern I:	Lateral and Rotatory Deviation in the Pelvis and Femora
Pattern II:	Coronal Rotation of the Pelvis and Femora
Pattern III:	Lateral and Rotatory Deviation in the Femora and Ilia.
Pattern IV:	Rotatory Deviation in the Anterior Arch of the Pelvis
Pattern V:	Lateral and Rotatory Deviation in the Posterior Arch of the Pelvis and in the Femora
Pattern VI:	Lateral Angulation of the Lumbar Spine
Pattern VII:	Coronal Rotation of the Shoulder Girdle and Upper Thorax

On the basis of the preliminary study of the radiographs in conjunction with inanimate skeletal structures, the following interpretation of the patterns of bilateral skeletal asymmetry is made.

Patterns I, III, and V indicate that lateral and rotatory deviations of the pelvis and femora tend to occur together. Pattern IV indicates that rotatory deviations occur together in the pelvis. The asymmetries in each of these four patterns are as follows: Patterns III and V are composed of diagonal asymmetries of the femora and specific parts of the pelvis; Pattern IV is composed of horizontal and vertical asymmetry of the anterior arch of the pelvis; and Pattern I is composed of horizontal asymmetries of the femora, and horizontal and vertical asymmetries of the pelvis. Since the interpretation of Patterns I, III, IV, and V are quite similar, the only difference being that Patterns III, IV and V include smaller portions of the pelvis and femora, the interpretation of Pattern I only is given here.

Pattern I indicates that a blending of coronal, horizontal, and bilaterally unequal anteroposterior rotations of the pelvis tends to occur with lateral deviation of the femora on the same side of the structure. When the left femur in its proximal portion is prominent laterally, it tends also to be higher, the pelvis is higher on the left, prominent to the left, rotates to the left, and tilts anteroposteriorly to a greater degree on the left. These deviations tend to occur together on the opposite side of the skeletal structure when the right femur in its proximal portion is prominent laterally.

Pattern II indicates that coronal rotation of the pelvis and femora tends to produce similar lateral angulation in the position of each structure. When the pelvis is higher on one side, the femur will tendalso to be higher on the same side.

Pattern VI indicates that lateral angulation of the fifth lumbar vertebra is accompanied in general by lateral deviation of the first four lumbar vertebrae in the direction of the low side of the fifth lumbar vertebra.

Pattern VII indicates that similar lateral angulations of the shoulder girdle and upper thorax tend to occur together to produce a greater height in each on the same side of the skeletal structure.

The general pattern of skeletal alignment was determined by an analysis of the intercorrelation of the specific patterns of asymmetry, the deviations which tend to produce each of these patterns, the units of structure involved in them, and the specific location of the asymmetries of the various patterns within the different units of the skeletal structure. Since several of the patterns of asymmetry are located in the region of the pelvis and femora, an analysis was made to determine whether some of the patterns are fairly closely related and whether one or two might therefore represent an adequate and perhaps more reliable picture of the asymmetry of the pelvis.

The intercorrelation of patterns indicated the following: Patterns I and II maintain the highest relationship of any two patterns; Pattern I shows the highest relationship of any one pattern with all other patterns; Pattern VII shows little or no relation with any other pattern.

The intercorrelation of specific patterns of asymmetry shows further those patterns in which asymmetries are produced by deviations of similar type have a greater degree of intercorrelation than those in which asymmetries are produced by deviations dissimilar in type. The one exception to this is Pattern VII, which shows little or no correlation with any pattern. Patterns in which the asymmetries are produced by a blending of rotations of the skeletal structure in the different planes of the body (I, III, IV, V) show an average intercorrelation of .56 to .68 in the age-sex groups; patterns in which the asymmetries are produced by coronal rotation (II and VI) show a correlation of .57 to .70 in the age-sex groups; and patterns in which the asymmetries are produced by different types of deviation (excluding VII) show an average intercorrelation of .32 to .43 in the age-sex groups.

The above analysis of the patterns indicates that Patterns III, IV, and V are fairly closely related to Pattern I in that they are produced by the same types of deviation, are located in the same skeletal units (the only difference being that Patterns III, IV, and V include a lesser portion of the pelvis, or of the pelvis and femora), and the specific points of reference used on the deviating parts for their measurements are the same in each of these patterns. Since there is this relationship between these four patterns and since Pattern I shows both a higher correlation with other patterns and a greater reliability of its asymmetries, this pattern enters the general pattern to the exclusion of the other three.

Patterns II and VI are the only other patterns whose correlation indicates that they tend to occur consistently with Pattern I. The general pattern of asymmetry, therefore, is formed by specific patterns I, II and VI. These patterns tend to occur together fairly consistently in the subjects of this study.

The interpretation of the general pattern in terms of deviation of the skeletal structure from symmetrical alignment indicates that coronal, horizontal, and bilaterally different sagittal rotations in the pelvis, and lateral deviation in the femora and in the lumbar spine tend to occur as one deviation to produce bilateral asymmetry in horizontal and vertical relationships of these skeletal parts. The general pattern of alighment tends to occur as follows: when the left ilium is higher than the right ilium, the pelvis tends to be prominent to the left, to rotate to the left, and to present a greater anteroposterior tilt on the left; the left femoral head is higher than the right and the proximal portion of the left femur is prominent laterally; the lumbar spine deviates to the right of the central vertical axis. The converse tends to occur when the right ilium is higher than the left ilium.

In general the association of age, sex and handedness with skeletal asymmetry in the subjects of this study is as follows:

a. Age -- Correlation of asymmetries and degree of asymmetry tend to decrease with age increment among women; they tend to increase with age increment among men.

b. Sex -- Correlation of asymmetries and degree of asymmetry tends to be greater among the women than among men between the ages of seventeen and twenty-two; they are greater among men than among women between the ages of twenty-three and forty-two. In the subjects of this study it would seem that the association of the degree of asymmetry with sex tends to be the reverse in older subjects of what it is in younger subjects.

c. Handedness -- When subjects are right-handed there is a marked tendency for the left shoulder girdle and upper thorax to be higher than the right and for the upper thoracic spine to slant to the right; when subjects are left-handed there is a similar tendency in asymmetry, but the proportion of subjects who follow this tendency is much less than in right-handedness. In the older group of men there tends to be a definite relation between handedness and the angulation of the scapular inferior angles, that is, right-handedness is accompanied by a higher left scapular inferior angle; left-handedness is accompanied by a higher right scapular inferior angle.

A fairly similar distribution of the skeletal asymmetries on the right and the left sides occurs in three of the age-sex groups of subjects (young women, older women, older men), with a few exceptions. In the younger men there is more inequality of lateral distribution of asymmetries than in any other group. This is shown particularly in lateral angulation of the ilia and the tuberosities of the pelvis which occurs approximately twice on the left to once on the right; and in horizontal rotation and lateral deviations of the pelvis only, and of the pelvis and femora, which again occurs in about the ratio of two to one, but more often on the right side.

In all groups the asymmetries of the shoulder girdle and upper thorax occur approximately three and five-tenths to five times as often on the left side as on the right side. The appearance of horizontal asymmetry of the ilium just above the acetabulum also tends to occur more often on one side -- the right. The ratio of its lateral distribution is about once on the left to two or three times on the right.

No pattern of asymmetry was found in the alignment of the spinal column as a whole. Although the asymmetries of its vertebrae tend to be fairly consistent over a period of time in any one person, the relationship of the various asymmetries of the vertebrae seem to be largely individual in the subjects of this study. It was found, however, that in one-third or more of the subjects of each age-sex group the spinal column deviates to one side of the axis and does not return to or recross it. In the remainder of the subjects the following tends to be true in relation to lateral curves: there are more younger than older subjects with only one lateral curve; more older than younger subjects with two lateral curves; more older men than any other age-sex subjects with three lateral curves, and older men only with four lateral curves. In the latter only four per cent show a fourth lateral curve. In the first, second, and third lateral curves in each age-sex group the average degree of angulation and the average number of vertebrae in the curves are similar. The fourth curve in the group of older men tends to contain fewer vertebrae and to show less angulation than any other curves.

CHAPTER VIII

INTERPRETATIONS AND IMPLICATIONS

In the alignment of any structure for equilibrium in relation to the pull of gravity the base of the structure and the distribution of weight in relation to the center of the base are of fundamental importance. In the human being the main units of weight of the body are the head, the thorax, and the pelvis, connected by the spinal column. These parts are considered the main units because they are indispensable to a continuation of life. The upper and lower extremities function for movement of the body and for manipulation of objects in the external world. The extremities and the main units of the structure are integrated in function by means of the nervous systems. In addition to this point of view the assumptions that are stated in Chapter I serve as a basis of interpretation of the results of the study of alignment of the skeletal structure.

It was found that the sacrum is the most stable in its position of any part of the structure, and that stability tends to decrease as the parts of the structure increase in distance from the sacrum. Since the center of gravity is located in the region of the sacrum[1] it would seem that the pelvis should be considered as the true base of the structure and that the distance of parts of the structure from the center of gravity is one of the factors influencing consistency in the relationships of

1. Arthur Steindler, Mechanics of Normal and Pathological Locomotion in Man, Chapter IV.

parts of the structure to each other and to the pelvis as the base of the structure.

The marked tendency of the body to shift its position in relation to a plumb line and the consistency of the occurrence of asymmetries and patterns of asymmetry despite the sway of the body indicates first, that posture is dynamic, not static; second, that there are asymmetries that are habitual and functional in the kinetics of the body; and third, that there is a postural pattern and not "postures" in the body. This leads us to question the ability of any person to voluntarily assume a "good posture." Positions of the body may be assumed at the will of the individual, but each position will undoubtedly be influenced by, and in accord with, the postural pattern which the individual has.

Patterns of Alignment

The tendency of asymmetries to occur in functional patterns indicates that there are deviations from symmetrical weight distribution that occur similarly in many people. On the other hand, there are asymmetries in weight distribution which are also functional, but which do not occur in a pattern with other asymmetries. Such asymmetries indicate individual and unpredictable differences in the habitual relationships which may occur in any one person, or in other words, in the postural pattern of the individual. Specific patterns of alignment of the body may be interpreted in a number of ways, as follows: (a) stress experienced in the bony structure when its alignment is habitually asymmetrical, (b) habit patterns of bilaterally different neuromuscular action which tend to persist in the kinetics of the body, (c) patterns of hypertonicity in muscles produced by a continually uneven action of muscles around the joints in maintaining the equilibrium of the structure, and (d) patterns of limitation in the movement allowed in the joints of the structure, that is, patterns of limitation of the rhythmic flow of action and reaction in the movement of the body.

The basis of interpretation of each pattern of bilateral asymmetry in alignment will be the relative position of the bilateral axes of weight thrust from joint to joint through the portion of the structure included in the pattern. These axes are established by the relative position of proximal and distal joints which, in turn, is indicated by the asymmetries of the pattern.

For clarity of presentation of the implications of patterns of asymmetry it will be arbitrarily assumed that the asymmetries of Patterns I, II, III, IV, V and VII occur on the left side and that the asymmetries of Pattern VI occur on the right side.* It should be noted that interpretation of the patterns can be made only in terms of the relative position of identical lateral parts of the structure, as follows:

<u>Pattern I: Lateral and Rotatory Deviation in the Pelvis and Femora.</u> The asymmetries of this pattern indicate that the axis of the thrust of superimposed weight will not be centered in the sacral table, and that the amount of weight transferred through the right and left halves of the pelvis will not be equal. Assuming that the pattern occurs on the left side of the structure there will be a tendency for the right half of the structure not only to carry the greater amount of weight but to carry it closer to the central axis of the structure.

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* This relative lateral distribution of the patterns is in general in accord with the intercorrelations of patterns, however, Patterns I, II, III, IV, and V are apt to appear as many times on the right side as on the left side when the entire group of subjects of this study is considered. Only Pattern VII appears in unequal lateral distribution, that is, more frequently on the left.

The proximal end of the bilateral axes of weight thrust through the pelvis will be at a common point in the sacral table, the distal end of each axis will be at the head of the femur on its side, but the two will not be similarly located in the femoral heads. The distal end of the axis of weight thrust on the left, in comparison with that on the right, will tend to be higher, more posterior, and more lateral. The pressure of weight therefore tends to be forward and inward on the right in comparison with the pressure of weight backward and outward on the left. This difference in direction of lateral weight thrust indicates that a twisting or torsion stress tends to occur in addition to compression stress.

The pattern of action in muscles and hence of developed hypertonicity is in general as follows: the muscles on the back and to the outside of the femoral joint on the left will tend to be in concentric contraction in the maintenance of equilibrium, the muscles on the front and the inside of the left femoral joint will tend to be in eccentric contraction as they automatically resist the forward and outward pressure of weight which is not adequately supported at the head of the femur. The tendency toward hyperextension in the left femoral joint and contraction of the gluteus maximus will promote "tendon action" of the rectus femoris to assist the iliofemoral ligament in the protection of the front of the joint.[1] The action of muscles around the right femoral joint will be more balanced than the action of muscles around the left femoral joint. No statement can be advanced in regard to the comparative action of the outward rotators of the femur on the right and left sides for the reason that greater outward rotation in one femur, though a reliable asymmetry,

1. Wilhelmine G. Wright, Muscle Function, pages 8 to 19.

did not occur in any pattern of asymmetry. There will be varying degrees in the relative action of the muscles on the right and the left side of the pelvis and the proximal femora, but with evidence of a pattern of torsion stress it would seem that there is a potential condition in the inequality of weight distribution and of muscle action for the precipitation of such difficulties as sacroiliac strain and sciatica, whether these conditions occur with sudden exertion in the muscalature of the body, with continued muscular strain in maintenance of equilibrium in a poorly aligned structure, or with infection in the body.

There tends to be greater limitation of flexion and adduction in the left than in the right femoral joint. Concomitant with this, there will tend to be a greater amount of muscular work in all action of the left femoral joint than in action of the right femoral joint. Which joint will experience the greater limitation in inward rotation cannot be stated since outward rotation is not a component of any pattern. When the <u>action</u> of support of weight on the left femoral head is farther from the central vertical axis of the structure than the <u>action</u> of support of weight on the right femoral head, it may logically be expected that in general <u>reaction</u> at some level in the upper structure will tend to occur farther to the right of the central vertical axis than to the left.

<u>Pattern II: Coronal Rotation of the Pelvis and Femora.</u> The lateral angulation asymmetries in this pattern again indicate that the axis of the thrust of superimposed weight will not be centered in the sacral table, and that the amount of weight transferred into the pelvis will be greater on the right side than on the left side, assuming that the lateral tilt of the pelvis raises the left side. The weight on the right side of the pelvis will be supported closer to the central vertical axis than that on the left side.

Assuming that it is possible for the bilateral axes of weight thrust to occur in the same coronal plane,* the proximal end of these axes will occur at a common point in the sacral table, the distal end of the left axis will be farther from the central vertical axis and in a higher transverse plane than the right. When the base of support of weight at the left femoral joint is higher than the base of support of weight at the right femoral joint there will be a tendency for weight to slide to the right, that is, shear stress will occur in the bony structure of the pelvis and the proximal femora.

The pattern of action in muscles and hence of their developed hypertonicity in the kinetics of this region of the body is as follows. Lateral muscles on the pelvis and proximal femur on the left will tend to be in a pattern of concentric contraction. Again there will tend to be a greater amount of muscular work put forth in the function of the left femur than in the function of the right femur in the support and movement of weight. The action of weight support on the left femur will be farther from the center of the structure than the action of support of weight on the right, and the reaction at some level of the upper structure will be farther to the right of the center of the structure than to the left. Adduction in the left femoral joint will tend to be more limited than in the right femoral joint, moreover, due to the synergistic action[1] of the tensor fasciae lata in movements of flexion of the thigh, as flexion

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* Pattern I shows that the bilateral axes will not occur in the same coronal plane; the tendency for asymmetries occurring with lateral angulation to maintain a higher degree of correlation among themselves than with other skeletal asymmetries indicates that lateral angulation of the pelvis and femora is probably a dominent type of deviation in these structures.

1. Ibid., pages 116 to 153.

is increased there will be a tendency for the left knee to gradually assume a more lateral position in relation to the left femoral joint.

Pattern III: Lateral and Rotatory Deviation in the Femora and Ilia. This pattern is fairly closely related to Pattern I though more limited in area of the skeletal structure. The proximal ends of the bilateral axes of weight thrust are at the level of the posterior inferior spines of the ilia. The asymmetrical alignment of the bilateral axes in Pattern I indicates that the proximal ends of the bilateral axes in Pattern III will not be in the same relationship to the central vertical axis of the structure. The distal ends of the bilateral axes will be in the same location as the distal ends of the bilateral axes of Pattern I since the points of reference on the femora are the same. The asymmetries of Pattern III indicate that the bilateral thrust of weight into the shafts of the femora will be similar to that in Pattern I. For this reason further analysis will not be given for Pattern III since in general it will be similar to that for Pattern I.

Pattern IV: Rotatory Deviation in the Anterior Arch of the Pelvis. The proximal location of the axes of weight thrust of this pattern will be located at the pubic symphysis. In the bilaterally symmetrical structure these lateral axes would undoubtedly be continuous from one femoral joint to the other. The asymmetries of Pattern IV, however, indicate that the medial end of the left axis will be more forward and lower than the right axis of weight thrust. The medial ends of both axes will be to the left of the central vertical axis. The lateral ends of the two axes have a common location with the distal ends of the bilateral axes of Pattern I. There tends to be torsion stress at the pubic symphysis and in the anterior arch of the pelvis, as indicated by the asymmetries of the pattern. Further analysis of this pattern would be similar to that for Pattern I since the asymmetries and the deviations producing the asymmetries of the two are similar.

Pattern V: Lateral and Rotatory Deviation in the Posterior Arch of the Pelvis and in the Femora. This pattern, as well as Patterns III and IV, are closely related to Pattern I. The proximal end of the left axis of weight thrust is at the right posterior inferior spine of the ilium, and the proximal end of the left axis of weight thrust is at the left posterior inferior spine of the ilium. Whereas Pattern IV indicated torsion in the anterior arch of the pelvis and Pattern I indicated torsion in the pelvis as a whole, this pattern emphasizes torsion stress in the posterior arch of the pelvis. Analysis of muscle action and of limitation of movement are similar to that made for Pattern I.

Pattern VI: Lateral Angulation of the Lumbar Spine. Lateral deviations in the vertebrae of the lumbar spine may become progressively greater as the distance of vertebrae from the sacrum increases, or they may first become greater and then less. The treatment of the asymmetries of this pattern did not distinguish between the two types of deviation; it showed only that the position of the vertebrae of the lumbar spine tends to be lateral to the central vertical axis. Analysis of the two general types of deviation will be different. When the deviations of the vertebrae become greater as they increase in distance from the sacrum the axis of weight thrust will be at an angle with the sacral table. In this situation there is a tendency for shear stress to occur in addition to compression stress throughout the bodies of the vertebrae and at the intervertebral articulations. Assuming that the lumbar spine deviates to the right the effort to maintain equilibrium of the slanting structure will produce in both surface and deep muscles on the left an eccentric contraction to resist the tendency of the lumbar spine to sag farther to the right with the pull of gravity. Although the muscles at the right of the lumbar spine will work little, if any, in the maintenance of the equilibrium of this slanting structure in the upright position, the distance between their origins and insertions is lessened by the lateral slant of the spine and their contraction in movement of the structure as a whole will tend to be continuously detrimental to the alignment of the spine. Lateral bending to the right in the region of the lumbar spine will not only be easier to accomplish than lateral bending to the left, but it can be produced in greater degree than on the left.

When the alignment of the lumbar vertebrae tends to assume the form of a lateral curve, bending stress is experienced in this portion of the structure. It is granted by engineers that bending stress in a column for the support of weight is the most detrimental of any stress. The muscle action in the bending lumbar spine is different from that in the slanting lumbar spine. Assuming that the convexity of the lateral curve occurs on the right, muscles at the base of the lumbar spine on the left will be in eccentric contraction, at the convexity of the curve eccentric contraction will occur in the muscles on the right side. Lateral bending in the direction of the convexity of the curve will be limited, and efforts to accomplish such bending will tend to produce the bending sought in other regions of the spine instead of at the convexity of the curve.

<u>Pattern VII</u>: <u>Coronal Rotation of the Shoulder Girdle and the Upper Thorax</u>. The junction of the shoulder girdle with the thorax is at the top of the sternum -- the sternoclavicular joint. The low correlation of the asymmetries in this pattern indicates that there are undoubtedly other functional types of deviation in addition to lateral

angulation in the shoulder girdle, also that the relationship of the types of deviation tends to be highly individual. It was shown that the asymmetry in the shoulder girdle and upper thorax is associated to some degree with handedness. The fact that the asymmetries of the shoulder girdle and upper thorax are not associated with asymmetries in the rest of the structure, and the fact that the shoulder girdle is a superimposed weight and has no part in the support of "dead load"[1] of the structure itself, seem to be an indication that reaction to emotional strain such as worry and fear occurs more in the musculature around the shoulder girdle than in any other part of the structure. No attempt will be made to analyze muscle action around the shoulder girdle since the correlation of asymmetries in this region is too low to indicate any marked degree of similarity in subjects. It can be stated generally that the upper fibers of the trapezius on the side of the higher shoulder will tend to be in greater concentric contraction than those on the left. The stress experienced in the bony structure in this region is undoubtedly torsion stress, particularly at the sternoclavicular joint.

The General Pattern of Bilateral Asymmetry. The general pattern includes the asymmetries of Patterns I, II, and VI. This pattern occurs in the regions of the pelvis, the proximal femora, and the lumbar spine, that is, in the central part of the structure as a whole. It would seem that asymmetries of the structure above this area, although reliable and therefore probably functional, are highly individual. The general pattern indicates that a prediction of the position of the shoulder girdle cannot be made from the asymmetries occurring in the pelvis, and vice versa;

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1. Walter Binger, What Engineers Do, page 228.

it also indicates that the asymmetries in the pelvis are not to be considered indicative of the lateral deviation or the lateral curves which may occur in the spine above its lumbar region. Whether asymmetries in the alignment of the structure below its central portion tend to be as individual as asymmetries above the central portion cannot be determined from this study. They can be determined, however, by relating the contour of the body of the subjects of this study to their discovered skeletal alignment.

The dominant stresses experienced in the bony structure in addition to compression stress in the general pattern tend to occur as follows: shear or bending stress in the lumbar spine and torsion stress in the pelvis and femora.

When the left pelvis and the left femur are prominent laterally in the general pattern, and the lumbar spine presents a right lateral curve, the following hypertonicity in muscle action tends to occur: eccentric contraction on the right at the level of the convexity of the lateral lumbar curve, eccentric contraction at the base of the lumbar spine on the left, concentric contraction in the vertical muscles on the outside and back of the left femoral joint, and eccentric contraction in the muscles on the front and inside of the left femoral joint. When the right pelvis and right femur are prominent laterally and the lumbar spine presents a left lateral curve, the location of hypertonic muscle action will be similar to that above, but will occur on sides in opposition to those stated above.

The general analysis of muscle action has been made on the basis of deviations which tend to occur habitually in the central part of the structure. It should be remembered, however, that neither the general pattern of asymmetry in the alignment of the skeletal structure in all of its details, nor the analysis of muscle action will apply to any one individual, even though it tends to be true in general for a large number of individuals.

Association of Age and Sex with Skeletal Asymmetries

In the younger subjects asymmetries are more marked in degree and more highly associated in women than in men; in the older subjects the reverse tends to be true. In women there tends to be a decrease in degree of asymmetry and in correlation of asymmetries with age increment; in men, the reverse tends to be true.

Structural differences in the sexes may be a factor which contributes to the more marked degree of asymmetry in young women than in young men. In women a decrease in the amount and intensity of physical activity with age increment may be a contributing factor to the decrease both in degree of asymmetry and in interrelationship of asymmetries. In men perhaps a continuation of physical activity, both in work and play, at least to the age of forty, tends to increase both the degree of skeletal asymmetries and their interrelationship.

Recommendations

This investigation holds that posture education should not only produce change for better alignment, but it should promote a greater degree of ease in everyday activities, and more rhythm and flexibility in movement. The outcomes of the study indicate that bilateral asymmetry in the skeletal alignment is reliable, and therefore probably habitual and functional. In view of this, and in view of the fact that balance and movement of the body are largely automatic, it is suggested that the following practices should be subjected to critical evaluation:

a. Posture cues, such as head up, stretch tall, shoulder blades back, tuck the pelvis under, walk with the weight toward the outside of the foot, to mention only a few

b. Lateral bending, hanging and stretching as means of reducing lateral curvature of the spine

c. The need of teaching any muscle action, other than that requested by the student, as a means of changing the student's posture (This does not refer to the teacher's needed knowledge of muscle action.)

d. The concept of relaxation as a "letting go" process -- a process of doing less and less of muscle work

e. The use of formalized exercises for parts of the body, either for benefit to posture or for physiological benefit

f. The use of standards of posture which present supposedly ideal contours of the body, even though these may be set up for different types of individuals

g. Emphasis on strengthening the extensor muscles of the body to attain a better posture

h. Grading posture.

The investigator offers the following suggestions for theory and practice in all teaching which deals with the kinetics of the body:

a. Place emphasis on a functional knowledge of the skeletal framework and its relationships, rather than a rote memory of anatomy. Thinking in relation to any difficulties in posture or in the acquisition of skills should invariably proceed from knowledge and observation of the supporting skeletal structure and its interrelationships. This is fundamental to the analysis of muscle action.

b. Relate the analysis of muscle action around any joint to the muscle action needed in the rest of the body to maintain equilibrium while the joint is in motion. When this is tried it becomes evident that the continually changing coordination in muscle action is beyond the comprehension of the human mind, also that organizing categorically according to function tends to limit the concept of the function of the body as a whole.

c. A longitudinal view of the life of the individual should be considered in all posture and activity teaching. Posture teaching should reduce strain, recondition neuromuscular responses to stimuli, help the individual to recognize and interpret strain, and then know what to do about it. Posture teaching at any age level should be of such nature that it will be of even greater benefit as the student grows older.

d. Activity teaching which imposes on the individual techniques of movement should aim, at the same time, to change neuro-muscular habit patterns for greater ease in these techniques.

CHAPTER IX

RESEARCH PROBLEMS

The correlations of bilateral asymmetries measured in the investigator's study should be subjected to factor analysis. The patterns of asymmetry were constructed on the basis of degree of intercorrelation of asymmetries. A factor analysis would undoubtedly show the order of influence of types of deviation at the joints in the various asymmetries. The results would supply the basis of grouping asymmetries into patterns. With such treatment the patterns of asymmetry would no doubt be somewhat different from those found by the investigator.

The data for the investigator's study was collected with the idea of making its results more practical in the school situation by further research. Therefore, photographs and radiographs of the subjects were taken at the same time. A study relating the bilateral contour of the body to bilateral alignment of the supporting framework is now in progress.*

Measurement of rotation in the spinal column was not undertaken in the investigator's study. Observation of the vertebrae of the spinal column during the study and measurement of the radiographs led the investigator to believe that some of the generalizations made in regard to the spinal column by Lovett and others through their studies of the structurally handicapped are not applicable to the so-called normal individual. A study of the relation of rotation of the vertebrae to their lateral de-

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* This study is being conducted by Goddard Du Bois.

viation should be made.*

The various relationships of the ribs to the vertebrae at their costovertebral joints in the radiographs used by the investigator in the present study suggests the need of a study of flexibility of movement of the ribs for breathing in relation to vital capacity. The muscle-bound thorax undoubtedly interferes with full flexibility of the ribs and with even use of the diaphragm in breathing.

A study similar to that of the investigator should be made on the anteroposterior alignment of the skeletal structure. It is suggested that anteroposterior relationships of the structure may be measured in reference to a vertical line through the center of the femoral joint where the weight of the upper structure is transferred into the lower extremities. However, the present study shows that the centers of the femoral joints are probably not in the same coronal plane. For this reason, the line of gravity, if it could be determined for each person at the time his radiographs are taken, would no doubt be a better vertical for use as a reference in taking anteroposterior measurements. If photographs of the subjects are taken at the same time, the contour of the body could then be related to the alignment of the supporting skeletal structure, and the results of the study made more practical for the school situation.

It is doubtful whether posture teaching of any kind is justified if it does not do more than contribute to what might seem to be a better alignment of the body. It would seem that posture teaching should enable the individual to live with greater ease and poise, less fatigue, and less

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* This study is being undertaken by Ellen Neall Duvall.

expenditure of energy in one's daily activities. For this reason the investigator would like to have the results of teaching procedure subjected, not only to measurement, but to testing to determine what changes, if any, occur in energy consumption, at least in some of the fundamental activities such as sitting, standing, walking, and stair climbing.*

Posture teaching should result not only in better alignment, but in more complete movement in the joints without strain, and with a minimum of distortion in the integrated relation of the head, the thorax, and the pelvis. A means should be found of testing the results of posture teaching on flexibility throughout the body. Objective records of subjects in positions which test flexibility, particularly at the femoral, theknee, and the angle joints, might be made both before and after a period of posture instruction. The positions being tested should be in accord with the architecture of joints and the action of both ligaments and two-joint muscles. A comparison of these records through measurement of relationships in the body would undoubtedly indicate whether positions requiring flexibility could be assumed with less distortion in the body after a period of posture teaching.

It is granted in general that there is change in the form of bone as a result of uneven pressure of the body weight on the skeletal structure. Furthermore, many people consider that after they are adult it is doubtful whether posture teaching can help them. The accuracy of this belief should be subjected to study. One means of testing whether posture can be changed, particularly after growth is completed, would be to study

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* Harriet Graham of Teachers College, Columbia University, is conducting a study which is attempting to relate the difference in energy consumption in the lying and standing positions to bilateral and to anteroposterior alignment of the body.

the effects, if any, of change in posture on cell arrangement in the bones. Such a study would necessarily require a number of years.

A study should be made of the flow of movement in the body in the reactionary distribution of weight as the lower extremities alternately support the body in walking. Such a study could be made on both the bilateral and the anteroposterior reaction in the body. The findings could then be related to the distribution of weight in the standing position. This would be one means of testing the extent to which neuromuscular habits used to maintain the equilibrium of the body in a standing position would influence the rhythmic flow of action through the body in movement. The most objective study of this type would be one which collected its data from moving pictures of radiographic or fluorscopic type.

There is need of a study which will help to evolve teaching procedures which are in accord with principles of general education and which more adequately meet the needs of the present industrial era.

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A P P E N D I X

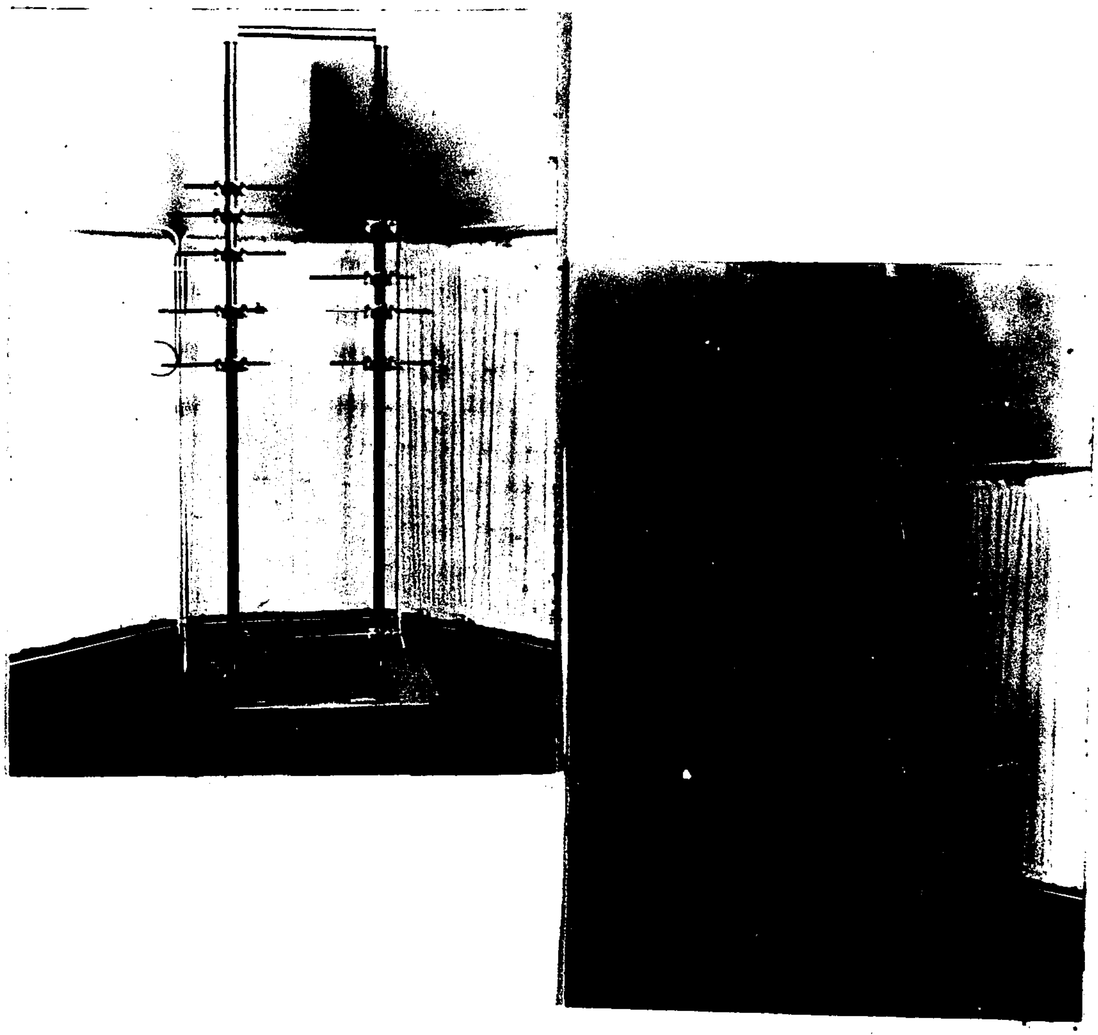

Figure 15. The Posturimeter. Designed and used by the American Child Health Association in the School Health Study.

DD

Information Sheet

Please fill in the following with information requested.

Photograph number ________________ (leave blank) Radiograph number ________________ (leave blank)

Name ____
last name first name

Address (local) ____ Tele. No. __________

(home) ____

Age ______ Height ________________ Present weight ________________

What sports or activities have you engaged in the most? ________________

____

Handedness: Right ______ Left ______

What accidents, injuries, or sprains have you had? ________________

____

Do you have any backache between the shoulders? ______ in the middle back? ____

in the lower back? _____. Do you have any pain in your feet? ____ legs? ______

What diseases have you had? ____

____

Did any complications follow these diseases, as kidney? ________ eye? ______

ear? ________ muscle paralysis? ________ or otherwise? ________________

What operations have you had? ____

Is your vision normal? _____ Do you wear glasses? ____ all the time? ________

part of the time? _______ Do the glasses correct your difficulty? ________

Is your hearing normal; in the right ear? ______ left ear? ______________

When you are worried or emotionally upset, do you feel muscular or physical tension? _______ Where? ________________________________

Do you have headaches? ________ What seems to be the cause? ______________

Do you consider your posture good? ______ Check the following things in reference to your posture: Toe in? ____ Toe out? ____ Pronated feet? _____ Hyperextended knees? _____ Relaxed knees? ____ Hollow lower back? ____ Flat lower back? _______ Straight middle back? _______ Rounded middle back? _____ Round shoulders? ____

Pelvis sagging down in front? _____ Forward head? _____

Write your idea of a good posture. Use the other side of this sheet if necessary.

Directions to Subjects for Preparation for Radiographs and Photographs

Please take off everything except your shoes. Have these ready to remove later. Put on the white robe and tie it at the waist-line. Bring your information blank which you have filled out with you.

STATISTICAL TECHNIQUES

1. Computational expression of the Pearson Product-Moment formula:

$$r_{xy} = \frac{\frac{\Sigma xy}{N} - \frac{\Sigma x}{N} \times \frac{\Sigma y}{N}}{\sqrt{\frac{\Sigma (x)^2}{N} - (M_x)^2}\sqrt{\frac{\Sigma (y)^2}{N} - (M_y)^2}}$$

In which $M_x = \frac{\Sigma x}{N}$, and $M_y = \frac{\Sigma y}{N}$

To determine the correctness of data to be used in the correlation formula, the following formulae were used:

$$\Sigma x + \Sigma y = \Sigma (x+y)$$

$$x^2 + y^2 + 2(\Sigma xy) = \Sigma (x+y)^2$$

2. Correlation of sums of scores

The computational expression of the formula for the correlation of two variables with two variables is the following:

$$r_{(x+y)(z+w)} = \frac{r_{xz}\sigma_x\sigma_z + r_{xw}\sigma_x\sigma_w + r_{yz}\sigma_y\sigma_z + r_{yw}\sigma_y\sigma_w}{\sqrt{\sigma_x^2 + \sigma_y^2 + 2r_{xy}\sigma_x\sigma_y}\sqrt{\sigma_z^2 + \sigma_w^2 + 2r_{zw}\sigma_z\sigma_w}}$$

3. Computational expression of the formula used to compute sigma of the asymmetries, regardless of signs, follows:

$$\sigma_x = \sqrt{\frac{\Sigma x^2}{N} - Mx^2}$$

4. Computational expression of the formula used to compute the significant difference of the means of the asymmetries:

$$\text{Sig. diff.}_{(M_x - M_y)} = \frac{M_x - M_y}{\sqrt{\frac{\sigma_x^2}{N} - \frac{\sigma_y^2}{N}}}$$

TABLE XXVIII

Sample of Recorded Measurements

X-Ray Number	27F		23F		214F		201F		192F	
Key	Left	Rt.	Left	Rt.	Left	Rt.	Left	Rt.	Left	Rt.
A1	90.5		89.0		87.5		86.5		89.0	
A2	90.0		89.0		87.5		89.5		91.0	
A3	89.5		89.0		86.5		87.5		90.0	
A4	90.0		89.5		87.5		90.0		91.5	
A5	89.5		90.0		87.5		89.5		89.5	
A6	91.0		89.5		88.0		90.5		90.5	
A7	63.0	62.5	51.0	55.5	63.0	56.5	69.0	59.5	58.5	52.0
A8	86.5		88.0		86.0		85.0		86.0	
A9	86.0		86.5		84.0		86.5		86.0	
A10	84.5		88.5		88.5		89.5		88.5	
B1	9.6	7.2	6.1	5.1	5.9	4.4	7.0	8.7	6.8	5.8
B2	11.2	9.0	10.3	9.6	11.7	10.5	8.6	10.0	10.6	9.8
B3	10.6	10.8	10.5	9.8	9.2	9.0	10.1	11.4	10.8	10.7
B4	17.0	13.6	15.8	14.3	15.5	12.9	13.3	15.4	15.6	14.5
B5	5.9	5.4	5.0	5.5	4.0	4.7	7.1	5.8	4.3	4.3
B6	4.6	3.9	4.8	5.2	3.7	4.1	5.8	5.2	3.6	2.9
B7	16.5	13.8	14.2	12.9	13.9	10.5	13.7	16.1	17.6	17.5
B8	2.4		1.2		2.6			1.6	1.1	
B9	13.9	14.5	11.4	11.9	12.4	11.2	14.8	13.4	14.9	14.4
C1	26.9	22.3	22.0	20.8	23.8	19.3	22.8	24.0	23.8	22.6
C2	34.1	29.9	27.2	25.9	29.6	25.3	30.1	31.3	30.5	28.8
C3	20.8	16.3	16.5	14.7	17.6	14.9	15.5	18.6	16.7	15.6
C4	9.9	9.1	6.1	6.6	7.5	6.8	8.8	9.1	9.8	9.8
C5	14.4	13.6	11.1	11.9	13.7	13.3	14.4	15.0	14.9	14.8
C6	27.5	26.3	22.5	22.3	21.4	19.6	24.8	26.0	27.2	27.3
C7	27.2	26.4	24.1	24.3	23.3	22.0	25.8	26.8	28.9	29.4
C8	14.7	13.4	12.8	12.5	10.6	10.1	12.9	14.0	14.4	15.1
C9	45.7	44.0	39.6	39.3	41.4	39.5	42.1	42.7	44.5	43.6
C10	31.9	29.7	28.2	27.5	29.2	28.4	27.8	29.5	29.7	29.4
D1	92.5		87.0		90.0		89.5		91.0	
4L	1.2			.4	0	0		.2	1.1	
3L	1.4			.8		.5		.5	1.3	
2L	1.5			1.2		.8		1.0	1.4	
1L	1.2			1.7		1.2		1.1	1.7	
12T	1.0			1.4		.9		1.0	1.5	
11T	.9			1.3		.7		.5	1.5	
10T	.7			1.2		.5		.3	1.6	
9T	.7			1.3		.3	..3		1.6	
8T	.7			1.5		.4	.2		1.5	
7T	.7			1.7		.5	.1		1.3	
6T	.6			1.9		.5	.1		1.0	
5T	.6			1.9		.5		.4	.7	
4T	.3			1.8		.7		.5	.6	
3T	0	0		1.8		.9		.6	.5	
2T	0	0		1.7		1.2		.7	.4	
1T		.4		2.0		1.5		.8	.4	

Key	Left	Rt.	Left	Rt.	Left	Rt.	Left	Rt.	Left	Rt.
A1	90.5		89.0		87.5		86.5		89.0	
A2	90.0		89.0		87.5		89.5		91.0	
A3	89.5		89.0		86.5		87.5		90.0	
A4	90.0		89.5		87.5		90.0		91.5	
A5	89.5		90.0		87.5		89.5		89.5	
A6	91.0		89.5		88.0		90.5		90.5	
A7	63.0	62.5	51.0	55.5	63.0	56.5	69.0	59.5	58.5	52.0
A8	86.5		88.0		86.0		85.0		86.0	
A9	86.0		86.5		84.0		86.5		86.0	
A10	84.5		88.5		88.5		89.5		88.5	
B1	9.6	7.2	6.1	5.1	5.9	4.4	7.0	8.7	6.8	5.8
B2	11.2	9.0	10.3	9.6	11.7	10.5	8.6	10.0	10.6	9.8
B3	10.6	10.8	10.5	9.8	9.2	9.0	10.1	11.4	10.8	10.7
B4	17.0	13.6	15.8	14.3	15.5	12.9	13.3	15.4	15.6	14.5
B5	5.9	5.4	5.0	5.5	4.0	4.7	7.1	5.8	4.3	4.3
B6	4.6	3.9	4.8	5.2	3.7	4.1	5.8	5.2	3.6	2.9
B7	16.5	13.8	14.2	12.9	13.9	10.5	13.7	16.1	17.6	18.5
B8	2.4		1.2		2.6			1.6	1.1	
B9	13.9	14.5	11.4	11.9	12.4	11.2	14.8	13.4	14.9	14.4
C1	26.9	22.3	22.0	20.8	23.8	19.3	22.8	24.0	23.8	22.6
C2	34.1	29.9	27.2	25.9	29.6	25.3	30.1	31.3	30.5	28.8
C3	20.8	16.3	16.5	14.7	17.6	14.9	15.5	18.6	16.7	15.6
C4	9.9	9.1	6.1	6.6	7.5	6.8	8.8	9.1	9.8	9.8
C5	14.4	13.6	11.1	11.9	13.7	13.3	14.4	15.0	14.9	14.8
C6	27.5	26.3	22.5	22.3	21.4	19.6	24.8	26.0	27.2	27.3
C7	27.2	26.4	24.1	24.3	23.3	22.0	25.8	26.8	28.9	29.4
C8	14.7	13.4	12.8	12.5	10.6	10.1	12.9	14.0	14.4	15.1
C9	45.7	44.0	39.6	39.3	41.4	39.5	42.1	42.7	44.5	43.6
C10	31.9	29.7	28.2	27.5	29.2	28.4	27.8	29.5	29.7	29.4
D1	92.5		87.0		90.0		89.5		91.0	
4L	1.2			.4	0	0		.2	1.1	
3L	1.4			.8		.5		.5	1.3	
2L	1.5			1.2		.8		1.0	1.4	
1L	1.2			1.7		1.2		1.1	1.7	
12T	1.0			1.4		.9		1.0	1.5	
11T	.9			1.3		.7		.5	1.5	
10T	.7			1.2		.5		.3	1.6	
9T	.7			1.3		.3	..3		1.6	
8T	.7			1.5		.4	.2		1.5	
7T	.7			1.7		.5	.1		1.3	
6T	.6			1.9		.5	.1		1.0	
5T	.6			1.9		.5		.4	.7	
4T	.3			1.8		.7		.5	.6	
3T	0	0		1.8		.9		.6	.5	
2T	0	0		1.7		1.2		.7	.4	
1T		.4		2.0		1.5		.8	.4	
7C		.7		1.9		1.8		.9	.3	
6C		.8		1.9		2.1			.3	
5C		1.0		1.9		2.3			.3	
4C		1.2		1.8		2.7				
3C		1.3		1.8		3.1				
2C				1.8						
1C				1.8						

TABLE XXIX

Sample Record of Asymmetries Determined from Measurements Taken on the Radiographs of the Subjects

Radiograph Number	27F*	23F	214F	201F	192F
Asymmetry					
A1	8	-10	-25	-35	-10
A2	0	-10	-25	- 5	10
A3	- 5	-10	-35	-25	0
A4	0	- 5	-25	0	15
A5	- 5	0	-25	- 5	- 5
A6	10	- 5	-20	5	5
A7	- 5	45	-65	-95	-65
A8	-35	-20	-40	-50	-40
A9	-40	-35	-60	-35	-40
A10	-55	-15	-15	- 5	-15
B1	-24	-10	-15	17	- 4
B2	-22	- 7	-12	14	- 8
B3	2	- 7	- 2	13	- 1
B4	-34	-15	-26	21	-11
B5	- 5	5	7	-13	0
B6	- 7	4	4	- 6	- 7
B7	-27	-13	-34	24	- 1
B8	-24	-12	-26	16	-11
B9	6	5	-12	-14	- 5
C1	-46	-12	-45	12	-12
C2	-42	-13	-43	12	-17
C3	-45	-18	-27	31	-11
C4	- 8	5	- 7	3	0
C5	- 8	8	- 4	6	- 1
C6	-12	- 2	-18	12	1
C7	- 8	2	-13	10	5
C8	-13	- 3	- 5	11	7
C9	-17	- 3	-19	6	- 9
C10	-22	- 7	- 8	17	- 3
D1**	25	-30	0	- 5	10

* The radiograph numbers are the same as those of the subjects whose measurements are given in Table XXVIII.

** With the exception of D1, the asymmetries of the vertebrae of the spinal column may be read directly from the original measurements given in Table XXVIII.

TABLE XXX

Frequency Distribution of 516 Subjects According to Age and Sex

Age	Number of Women	Number of Men	Total
8	1	0	1
15	1	0	1
16	4	2	6
17	19	8	27
18	21	19	40
19	27	50	77
20	26	42	68
21	17	29	46
22	8	32	40
23	6	20	26
24	8	16	24
25	5	9	14
26	6	10	16
27	9	4	13
28	1	2	3
29	3	7	10
30	3	2	5
31	3	3	6
32	3	1	4
33	7	5	12
34	10	3	13
35	5	4	9
36	4	0	4
37	4	1	5
38	7	5	12
39	3	2	5
40	2	4	6
41	5	2	7
42	1	3	4
43	1	0	1
44	1	0	1
45	2	0	2
46	2	0	2
47	1	1	2
48	1	0	1
56	1	0	1
60	1	0	1
Total	229	287	516

The table (line 4) should be read across as follows: Among the subjects 17 years of age there were nineteen women and eight men, making a total of twenty-seven subjects at this age level.

TABLE X

Average Intercorrelation of Asymmetrie

Asym.*	A2	A3	A4	A5	A6	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6
A1	.89	.78	.72	.73	.72	.37	.09	.09	.09	.45	.67	.01	.65	-.39	-.32
A2		.75	.70	.70	.67	.37	.08	.09	.11	.43	.62	.04	.61	-.35	-.30
A3			.82	.90	.81	.52	.03	.05	.05	.59	.73	.06	.76	-.44	-.24
A4				.83	.78	.39	.01	.02	.01	.54	.65	.02	.68	-.43	-.28
A5					.83	.51	.02	.02	.01	.64	.72	.04	.79	-.46	-.22
A6						.30	.07	.06	-.03	.53	.65	.06	.68	-.53	-.41
A7							-.04	-.01	.05	.11	.44	-.47	.33	.23	.37
A8								.46	.45	-.02	.01	.10	-.02	-.09	-.06
A9									.41	-.01	.04	.09	.01	-.09	-.05
A10										-.05	.04	.03	-.02	.04	.03
B1											.38	.39	.82	-.71	-.50
B2												-.07	.74	-.28	-.18
B3													.16	-.55	-.55
B4														-.60	-.41
B5															.78
B6															
B7															
B8															
B9															
C1															
C2															
C3															
C4															
C5															
C6															
C7															
C8															
C9															
C10															
D1															
D2															

* Asym. means asymmetry.

TABLE XXXII

...lation of Asymmetries in Four Age-Sex Groups of Subjects

B3	B4	B5	B6	B7	B8	B9	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	D1	D2	D3
.01	.65	-.39	-.32	.48	.63	.00	.66	.63	.65	.35	.39	.35	.27	.27	.13	.08	.75	-.61	-.20
.04	.61	-.35	-.30	.45	.59	.01	.62	.59	.62	.33	.41	.30	.26	.25	.14	.09	.82	-.69	-.24
.06	.76	-.44	-.24	.58	.75	-.02	.78	.75	.78	.48	.48	.45	.24	.30	.22	.19	.61	-.48	-.16
.02	.68	-.43	-.28	.61	.70	-.06	.75	.67	.71	.36	.39	.48	.41	.46	.11	.11	.54	-.41	-.11
.04	.79	-.46	-.22	.61	.81	-.10	.81	.76	.81	.43	.44	.39	.15	.21	.19	.21	.54	-.37	-.08
.06	.68	-.53	-.41	.54	.70	-.09	.67	.65	.70	.33	.37	.35	.16	.16	.11	.12	.57	-.42	-.12
-.47	.33	.23	.37	.06	.26	.15	.38	.36	.28	.54	.38	.11	-.01	.14	.02	-.08	.27	-.26	-.08
.10	-.02	-.09	-.06	.00	.01	-.07	-.03	-.06	-.01	-.12	-.04	-.09	-.06	-.07	-.09	-.05	.12	-.09	-.04
.09	.01	-.09	-.05	-.01	.01	.02	.01	-.02	.01	-.01	.00	-.02	-.03	-.06	-.03	-.04	.10	-.15	-.05
.03	-.02	.04	.03	-.03	-.01	.03	-.01	-.07	-.01	-.03	-.04	-.04	-.03	-.01	-.05	-.06	.19	-.16	-.07
.39	.82	-.71	-.50	.92	.88	-.27	.81	.72	.88	.21	.17	.75	.43	.63	.65	.83	.34	-.20	-.07
-.07	.74	-.28	-.18	.39	.67	-.05	.73	.67	.73	.37	.40	.23	.10	.13	.03	.02	.05	-.39	-.11
	.16	-.55	-.55	.44	.30	-.20	.18	.13	.27	-.30	-.21	.33	.24	.29	.33	.47	.02	.02	.33
		-.60	-.41	.80	.93	-.18	.92	.84	.95	.33	.34	.60	.32	.48	.46	.55	.49	-.32	-.06
			.78	-.76	-.71	.25	-.58	-.50	-.65	.03	-.27	-.47	-.27	-.33	-.40	-.55	-.32	.18	.09
				-.60	-.48	.19	-.38	-.32	-.46	.15	.04	-.38	-.29	-.32	-.30	-.42	-.29	.21	.13
					.87	-.26	.79	.73	.86	.15	.19	.73	.49	.67	.59	.75	.36	-.24	-.07
						-.22	.92	.84	.96	.27	.30	.63	.35	.51	.48	.61	.47	-.29	-.07
							-.03	.11	-.21	.57	.19	.30	.23	-.13	.34	-.29	.03	-.03	.00
								.90	.94	.40	.34	.66	.41	.50	.52	.53	.49	-.32	-.08
									.87	.50	.38	.70	.39	.45	.57	.49	.47	-.33	-.08
										.33	.35	.65	.36	.53	.50	.62	.50	-.33	-.08
											.65	.54	.33	.20	.43	.05	.29	-.22	-.08
												.32	.53	.19	.18	.04	.31	-.24	-.0[illegible]
													.71	.73	.86	.67	.28	-.18	-.06
														.68	.54	.39	.17	-.11	.0[illegible]
															.55	.66	.18	-.15	-.1[illegible]
																.76	.11	-.05	-.04
																	.06	.01	-.0[illegible]
																		-.82	-.2[illegible]
																			.5[illegible]

TABLE XXXII

Classification of Average Correlation of Skeletal Asymmetries
According to Ten-Degree Range

Asym.*	.90	Asym.	.80 to .90	Asym.	.70 to .80	Asym.	.60 to .70	Asym.	.50 to .60	Asym.	.40 to .50
A3A5	.90	A1A2	.89	A1A3	.78	A1B2	.67	A2B8	.59	A1B1	.45
B1B7	.92	A2D1	.82	A1A4	.72	A1B4	.65	A2C2	.59	A1B7	.48
B4B8	.93	A3A4	.82	A1A5	.73	A1B8	.63	A3A7	.52	A2B1	.43
B4C1	.92	A3A6	.81	A1A6	.72	A1C1	.66	A3B1	.59	A2B7	.45
B4C3	.95	A4A5	.83	A1D1	.75	A1C2	.63	A3B7	.58	A2C5	.41
B8C1	.92	A5A6	.83	A2A3	.75	A1C3	.65	A4B1	.54	A3B5	.44
B8C3	.96	A5B8	.81	A2A4	.70	A1D2	.61	A4D1	.54	A3C4	.48
C1C2	.90	A5C1	.81	A2A5	.70	A2A6	.67	AA5A7	.51	A3C5	.48
C1C3	.94	A5C3	.81	A3B2	.73	A2B2	.62	A5D1	.54	A3C6	.45
		B1B4	.82	A3B4	.76	A2B4	.61	A6B1	.53	A3D2	.48
		B1B8	.88	A3B8	.75	A2C1	.62	A6B5	.53	A4B5	.43
		B1C1	.81	A3C1	.78	A2C3	.62	A6B7	.54	A4C6	.48
		B1C3	.88	A3C2	.75	A2D2	.69	A6D1	.57	A4C7	.41
		B1C10	.83	A3C3	.78	A3D1	.61	A7C4	.54	A4C8	.46
		B4B7	.80	A4A6	.78	A4B2	.65	B1B6	.50	A4D2	.41
		B4C2	.84	A4B8	.70	A4B4	.68	B3B5	.55	A5B5	.46
		B7B8	.87	A4C1	.75	A4B7	.61	B3B6	.55	A5C4	.43
		B7C3	.86	A4C3	.71	A4C3	.67	B4C10	.55	A5C5	.44
		B8C2	.84	A5B2	.72	A5B1	.64	B5C1	.58	A6B6	.41
		C2C3	.87	A5B4	.79	A5B7	.61	B5C2	.50	A6D2	.42
		C6C9	.86	A5C2	.76	A6B2	.65	B5C10	.55	A7B2	.44
		D1D2	.82	A6B8	.70	A6B4	.68	B7C9	.59	A7B3	.47
				A6C3	.70	A6C1	.67	B8C8	.51	A8A9	.46
				B1B5	.71	A6C2	.65	B9C4	.57	A8A10	.45
				B1C2	.72	B1C8	.63	C1C8	.50	A9A10	.41
				B1C6	.75	B1C9	.65	C1C9	.52	B1C7	.43
				B2B4	.74	B2B8	.67	C1C10	.53	B2C5	.40
				B2C1	.73	B2C2	.67	C2C4	.50	B3B7	.44
				B2C3	.73	B4B5	.60	C2C9	.57	B3C10	.47
				B5B6	.78	B4C6	.60	C3C8	.53	B4B6	.41
				B5B7	.76	B5C3	.65	C3C9	.50	B4C8	.48
				B5B8	.71	B6B7	.60	C3D1	.50	B4C9	.46
				B7C1	.79	B7C8	.67	C4C6	.54	B4D1	.49
				B7C2	.73	B8C6	.63	C5C7	.53	B5C8	.47
				B7C6	.73	B8C10	.61	C7C9	.54	B5C9	.40
				B7C10	.75	C1C6	.66	C8C9	.55	B6B8	.48
				C2C6	.70	C3C6	.65	D1D3	.55	B6C3	.46
				C6C7	.71	C3C10	.62			B6C10	.42
				C6C8	.73	C4C5	.65			B7C7	.49
				C9C10	.76	C6C10	.67			B9C9	.48
						C7C8	.68			B8D1	.47
						C8C10	.66			C1C4	.40
										C1C7	.41
										C1D1	.49
										C2C8	.45
										C2C10	.49
										C2D1	.47
										C4C9	.43

TABLE XXXIII

Average Degree of Asymmetry in Each Age-Sex Group of Subjects - Regardless of Side of Asymmetry

Asymmetry	Young Women	Young Men	Older Women	Older Men
A1	20.45	19.62	16.86	23.75
A2	17.69	18.19	15.11	20.65
A3	18.97	17.34	15.85	17.90
A4	20.91	18.60	16.76	20.45
A5	15.74	13.74	12.45	15.40
A6	18.80	20.05	16.33	18.60
A7	44.30	39.34	38.35	39.70
A8	30.70	29.56	37.18	29.50
A9	25.29	22.72	22.61	20.95
A10	34.88	33.79	36.22	28.95
B1	14.16	12.48	12.11	15.58
B2	9.58	9.71	7.51	9.43
B3	5.58	6.98	5.98	7.01
B4	16.13	12.29	12.30	15.19
B5	8.79	8.06	8.85	8.19
B6	4.85	6.54	5.22	6.14
B7	20.55	18.95	15.45	24.03
B8	13.99	10.91	11.00	13.73
B9	5.32	7.53	4.98	6.54
C1	19.81	17.55	16.02	20.83
C2	19.41	17.62	16.40	20.86
C3	20.29	17.01	16.48	21.13
C4	5.10	7.76	6.12	7.61
C5	5.65	6.23	5.99	6.57
C6	8.46	9.27	8.50	10.88
C7	6.52	7.09	5.96	7.20
C8	5.63	5.22	5.29	5.81
C9	8.60	9.92	9.05	11.24
C10	9.30	8.90	9.19	10.23
D1	22.68	19.89	19.20	23.80
D2	43.20	41.76	37.43	37.71
D3	156.75	188.20	183.86	141.51

TABLE XXXIV

Reliability of Skeletal Asymmetries with Means and Standard Dev
in the First and Second Radiographs of Thirty Subjects U
Reliability, and Means and Standard Deviations of .
in the Radiographs of the Four Groups of Sub

	.Z........	....	MEANS	....	....	....	....	......	
Number of Subjects	30	30	30	121	182	94	100	30	
Asymmetry	r	x	y	Y.W.	Y.M.	O.W.	O.M.	x	
	.98								
A1	.98	- 4.29	- 2.86	.21	- 2.69	- 1.97	- 6.65	30.31	
A2	.95	- 8.66	- 8.00	- 1.40	- 4.01	- 1.81	- 6.95	24.21	
A3	.95	- 9.46	- 7.68	- 4.34	- 6.29	- 2.02	- 6.60	21.26	
A4	.95	- 5.17	- 6.00	- 2.48	- 6.07	- 1.76	- 5.65	23.22	
A5	.93	- 6.83	- 4.17	- 3.51	- 2.58	- 1.28	- 2.50	17.53	
A6	.91	- 8.00	- 6.83	- 3.10	- 6.15	- 1.44	- 5.60	23.00	
A7	.84	-29.00	-10.17	-19.83	-15.93	- 8.78	- 8.20	43.99	
A8	.83	-28.00	-22.33	-26.07	-21.59	-32.29	-25.10	42.26	
A9	.71	-19.00	-19.67	-22.31	-19.48	-17.18	-17.25	20.70	
A10	.88	-13.50	-12.33	-23.55	-25.27	-22.50	-18.95	34.80	
B1	.73	7.66	2.04	1.50	2.65	.06	1.78	15.2	
B2	.92	- 2.57	- 1.20	- .14	- .17	1.02	- 1.27	11.87	
B3	.60	6.83	1.80	2.39	3.98	1.51	3.47	8.03	
B4	.86	2.60	.13	- .12	- .19	- .60	- 1.39	19.12	
B5	.62	- 5.40	- 1.40	- 1.42	- 2.05	- .91	- 2.05	9.40	
B6	.66	- 3.36	- .63	- 1.28	- 1.74	- .88	- 2.44	6.55	
B7	.77	10.62	3.21	- 1.02	.99	- 2.17	- .33	22.2	
B8	.78	2.50	- 1.13	- .55	.01	.06	- .65	15.16	
B9	.73	- .61	- 1.55	.15	.32	- .30	.38	7.6	
C1	.81	- 1.70	- 4.60	- 1.56	- .38	- .70	- 1.19	23.40	
C2	.85	- .44	- 4.56	- .50	1.20	- .79	- 2.42	20.95	
C3	.88	4.23	- .70	5.4	1.96	1.31	- .05	23.09	
C4	.91	.56	- .06	1.12	1.57	1.63	1.25	9.78	
C5	.86	- 2.07	- 1.23	.17	.36	1.20	.77	8.35	
C6	.82	9.06	2.38	1.83	2.84	1.16	1.90	11.07	
C7	.83	2.60	- .17	.93	.09	- .09	.16	7.78	
C8	.77	4.03	1.30	.49	.20	- .14	.41	5.44	
C9	.64	9.44	3.88	1.61	3.98	1.12	2.88	8.44	
C10	.74	8.77	2.63	1.58	3.59	1.26	3.37	9.30	
D1	.92	- .17	3.38	5.41	1.87	2.39	- 1.10	27.67	
D2	.91	18.36	9.87	-14.09	1.98	- 9.06	2.81	27.44	
D3	.83	58.17	8.30	- .39	40.79	-24.12	35.47	221.6	25

r is the reliability of the asymmetry; x, the asymmetry on the first radiographs
on the second radiographs of 30 subjects; Y.W. means young women; Y.M., young mer
men.

TABLE XXXIV

ity of Skeletal Asymmetries with Means and Standard Deviations of Asymmetries
n the First and Second Radiographs of Thirty Subjects Used to Determine
Reliability, and Means and Standard Deviations of Asymmetries
in the Radiographs of the Four Groups of Subjects

MEANS					STANDARD DEVIATIONS					
30	121	182	94	100	30	30	121	182	94	100
y	Y.W.	Y.M.	O.W.	O.M.	x	y	Y.W.	Y.M.	O.W.	O.M.
- 2.86	.21	- 2.69	- 1.97	- 6.65	30.31	31.23	26.5	24.4	22.8	29.8
- 8.00	- 1.40	- 4.01	- 1.81	- 6.95	24.21	25.31	23.4	22.6	19.6	25.4
- 7.68	- 4.34	- 6.29	- 2.02	- 6.60	21.26	20.24	23.2	21.2	21.3	21.8
- 6.00	- 2.48	- 6.07	- 1.76	- 5.65	23.22	25.17	27.2	22.8	21.9	25.2
- 4.17	- 3.51	- 2.58	- 1.28	- 2.50	17.53	17.65	19.9	17.7	17.0	19.7
- 6.83	- 3.10	- 6.15	- 1.44	- 5.60	23.00	24.91	23.3	24.8	22.5	24.1
-10.17	-19.83	-15.93	- 8.78	- 8.20	43.99	51.46	51.4	48.3	50.3	50.1
-22.33	-26.07	-21.59	-32.29	-25.10	42.26	31.90	27.6	31.3	32.2	29.6
-19.67	-22.31	-19.48	-17.18	-17.25	20.70	19.00	22.3	20.2	24.0	19.9
-12.33	-23.55	-25.27	-22.50	-18.95	34.80	31.60	35.6	33.7	39.2	31.7
2.04	1.50	2.65	.06	1.78	15.2	14.7	17.6	15.1	14.5	18.8
- 1.20	- .14	- .17	1.02	- 1.27	11.87	10.95	11.4	12.2	9.9	11.6
1.80	2.39	3.98	1.51	3.47	8.03	7.04	7.7	8.0	7.6	8.6
.13	- .12	- .19	- .60	- 1.39	19.12	19.54	19.8	15.8	16.0	19.1
- 1.40	- 1.42	- 2.05	- .91	- 2.05	9.40	9.03	11.4	10.5	10.9	10.2
- .63	- 1.28	- 1.74	- .88	- 2.44	6.55	7.67	6.4	8.6	6.2	7.4
3.21	- 1.02	.99	- 2.17	- .33	22.2	23.6	25.8	23.8	20.0	29.7
- 1.13	- .55	.01	.06	- .65	15.16	14.97	17.2	13.9	13.6	17.2
- 1.55	.15	.32	- .30	.38	7.6	6.8	6.7	9.6	6.6	8.2
- 4.60	- 1.56	- .38	- .70	- 1.19	23.40	21.80	24.8	22.1	21.0	25.8
- 4.56	- .50	1.20	- .79	- 2.42	20.95	21.67	23.7	22.4	20.6	25.9
- .70	5.4	1.96	1.31	- .05	23.09	22.16	24.8	21.4	20.2	26.6
- .06	1.12	1.57	1.63	1.25	9.78	7.75	6.9	9.7	7.7	9.5
- 1.23	.17	.36	1.20	.77	8.35	6.30	7.4	8.0	7.5	8.0
2.38	1.83	2.84	1.16	1.90	11.07	11.62	10.3	11.4	10.9	13.5
- .17	.93	.09	- .09	.16	7.78	7.87	8.3	9.1	7.9	9.1
1.30	.49	.20	- .14	.41	5.44	6.86	7.5	6.7	7.0	7.3
3.88	1.61	3.98	1.12	2.88	8.44	11.17	10.8	11.8	11.7	13.1
2.63	1.58	3.59	1.26	3.37	9.30	9.79	11.3	10.6	11.2	13.2
3.38	5.41	1.87	2.39	- 1.10	27.67	31.42	28.3	26.3	23.7	29.7
9.87	-14.09	1.98	- 9.06	2.81	27.44	30.96	51.9	53.9	48.5	47.3
8.30	- .39	40.79	-24.12	35.47	221.6	253.4	199.6	237.8	215.6	183.7

he asymmetry; x, the asymmetry on the first radiographs of 30 subjects; y, the asymmetry
of 30 subjects; Y.W. means young women; Y.M., young men; O.W., older women; O.M., older

TABLE XXXV

Summation of the Correlations of Each Bilateral Skeletal Asymmetry with all Other Asymmetries in Each of the Age-Sex Groups of Subjects

Asymmetry	Young Women	Young Men	Older Women	Older Men
A1	13568	13653	12202	14551
A2	13550	12424	12230	14880
A3	16260	13213	13694	16720
A4	15760	12990	12020	15570
A5	16230	13580	12661	15810
A6	15120	11584	12510	14270
A7	8501	7530	7630	8630
A8	3750	2890	4320	3210
A9	4401	2390	3600	3344
A10	4120	2363	4220	4370
B1	15800	13330	14210	17070
B2	13214	11170	11244	12330
B3	6602	6522	7110	6770
B4	16070	14920	15240	17770
B5	12842	10750	10680	14210
B6	9970	9370	8250	11714
B7	16390	13890	13570	17170
B8	17340	15010	15460	17940
B9	5202	5810	4604	4491
C1	17190	15620	15020	17950
C2	17130	15960	14670	15310
C3	17560	15660	15650	16790
C4	9340	9110	9680	10090
C5	7782	7520	9450	10520
C6	14402	12003	12490	15380
C7	9380	7500	8394	11590
C8	11340	9170	8395	13120
C9	9920	8760	9064	12430
C10	10833	8864	8942	12840
D1	11543	10450	10264	13270
D2	8830	7870	8480	10940
D3	3884	2343	2794	4680

TABLE XXXVI

Correlations of Asymmetries Within the Various Groups of Asymmetries (Patterns) with Other Skeletal Asymmetries

Group A (Pattern I)

	B1	B4	B7	B8	C1	C2	C3
A1	.45	.65	.48	.63	.66	.63	.65
A2	.43	.61	.45	.59	.62	.59	.62
A3	.59	.76	.58	.75	.78	.75	.78
A4	.54	.68	.61	.70	.75	.67	.71
A5	.64	.79	.61	.81	.81	.76	.81
A6	.53	.68	.54	.70	.67	.65	.70
A7	.11	.33	.06	.26	.38	.36	.28
A8	.02	.02	.00	.01	.03	.06	.01
A9	.01	.01	.01	.01	.01	.02	.01
A10	.05	.02	.03	.01	.01	.08	.01
B2	.38	.74	.39	.67	.73	.67	.73
B3	.39	.16	.44	.30	.18	.13	.27
B5	.71	.60	.76	.71	.37	.50	.65
B6	.50	.41	.60	.48	.38	.32	.46
B9	.27	.18	.26	.22	.03	.11	.21
C4	.31	.33	.15	.27	.40	.50	.33
C5	.17	.34	.19	.30	.34	.38	.35
C6	.75	.60	.73	.63	.66	.70	.65
C7	.43	.32	.49	.35	.41	.39	.36
C8	.63	.48	.67	.51	.60	.45	.53
C9	.65	.46	.59	.48	.52	.57	.50
C10	.83	.55	.75	.61	.53	.49	.62
D1	.34	.49	.36	.47	.49	.47	.50
D2	.20	.32	.24	.29	.32	.33	.33
D3	.07	.06	.07	.07	.08	.08	.08
Av.	.40	.42	.40	.43	.43	.43	.43

Group B (Pattern II)

	A1	A2	A3	A4	A5	A6
A7	.37	.37	.52	.39	.51	.30
A8	.09	.08	.03	.01	.02	.07
A9	.09	.09	.05	.02	.02	.06
A10	.09	.11	.05	.01	.01	.03
B1	.45	.43	.59	.54	.64	.53
B2	.67	.62	.73	.65	.72	.65
B3	.01	.04	.06	.02	.04	.06
B4	.65	.61	.76	.68	.79	.68
B5	.39	.35	.44	.43	.46	.53
B6	.32	.30	.24	.28	.22	.41
B7	.48	.45	.58	.61	.61	.54
B8	.63	.59	.75	.70	.81	.70
B9	.00	.01	.02	.06	.10	.09
C1	.66	.62	.78	.75	.81	.67
C2	.63	.59	.75	.67	.76	.65
C3	.65	.62	.78	.71	.81	.70
C4	.35	.33	.48	.36	.43	.33
C5	.39	.41	.48	.39	.44	.37
C6	.35	.30	.45	.48	.39	.35
C7	.27	.26	.24	.41	.15	.16
C8	.27	.25	.30	.46	.21	.16
C9	.13	.14	.22	.11	.19	.11
C10	.06	.09	.19	.11	.21	.12
D1	.75	.82	.61	.54	.54	.57
D2	.61	.69	.48	.41	.37	.42
D3	.20	.24	.16	.11	.08	.10
Av.	.37	.36	.41	.38	.40	.36

Group C (Pattern III)

	C6	C7	C8
A1	.35	.27	.27
A2	.30	.26	.25
A3	.45	.24	.30
A4	.48	.41	.46
A5	.39	.15	.21
A6	.35	.16	.16
A7	.11	.01	.14
A8	.09	.06	.07
A9	.02	.03	.06
A10	.04	.03	.01
B1	.75	.43	.63
B2	.23	.10	.13
B3	.33	.24	.29
B4	.60	.32	.48
B5	.47	.27	.33
B6	.38	.39	.32
B7	.73	.49	.67

Group D (Pattern IV)

	B5	B6
A1	.39	.32
A2	.35	.30
A3	.44	.24
A4	.43	.28
A5	.46	.22
A6	.53	.41
A7	.23	.37
A8	.09	.06
A9	.09	.09
A10	.04	.03
B1	.71	.50
B2	.28	.18
B3	.55	.55
B4	.60	.41
B7	.76	.60
B8	.71	.48
B9	.25	.19

Group F (Pattern V)

	C9	C10
A1	.13	.08
A2	.14	.09
A3	.22	.19
A4	.11	.11
A5	.19	.21
A6	.11	.12
A7	.02	.08
A8	.09	.05
A9	.03	.04
A10	.05	.06
B1	.65	.83
B2	.03	.02
B3	.33	.47
B4	.46	.55
B5	.40	.55
B6	.30	.42
B7	.59	.75

Av. .40 .42 .40 .43 .43 .43 .43

Av. .37 .36 .41 .38 .40 .36

Group C (Pattern III)

	C6	C7	C8
A1	.35	.27	.27
A2	.30	.26	.25
A3	.45	.24	.30
A4	.48	.41	.46
A5	.39	.15	.21
A6	.35	.16	.16
A7	.11	.01	.14
A8	.09	.06	.07
A9	.02	.03	.06
A10	.04	.03	.01
B1	.75	.43	.63
B2	.23	.10	.13
B3	.33	.24	.29
B4	.60	.32	.48
B5	.47	.27	.33
B6	.38	.39	.32
B7	.73	.49	.67
B8	.63	.35	.51
B9	.30	.23	.13
C1	.66	.41	.50
C2	.70	.39	.45
C3	.65	.36	.53
C4	.54	.33	.20
C5	.32	.53	.19
C9	.86	.54	.55
C10	.67	.37	.66
D1	.28	.19	.18
D2	.18	.11	.15
D3	.06	.01	.10
Av.	.41	.41	.31

Group D (Pattern IV)

	B5	B6
A1	.39	.32
A2	.35	.30
A3	.44	.24
A4	.43	.28
A5	.46	.22
A6	.53	.41
A7	.23	.37
A8	.09	.06
A9	.09	.09
A10	.04	.03
B1	.71	.50
B2	.28	.18
B3	.55	.55
B4	.60	.41
B7	.76	.60
B8	.71	.48
B9	.25	.19
C1	.58	.38
C2	.50	.32
C3	.64	.46
C4	.03	.15
C5	.27	.04
C6	.47	.38
C7	.27	.29
C8	.33	.32
C9	.40	.30
C10	.55	.42
D1	.32	.29
D2	.18	.21
D3	.09	.13
Av.	.39	.30

Group F (Pattern V)

	C9	C10
A1	.13	.08
A2	.14	.09
A3	.22	.19
A4	.11	.11
A5	.19	.21
A6	.11	.12
A7	.02	.08
A8	.09	.05
A9	.03	.04
A10	.05	.06
B1	.65	.83
B2	.03	.02
B3	.33	.47
B4	.46	.55
B5	.40	.55
B6	.30	.42
B7	.59	.75
B8	.48	.61
B9	.34	.29
C1	.52	.53
C2	.57	.49
C3	.50	.62
C4	.43	.05
C5	.18	.04
C6	.86	.67
C7	.54	.39
C8	.55	.66
D1	.11	.06
D2	.05	.01
D3	.04	.01
Av.	.30	.30

Group E (Pattern VI)

	D1	D2
A1	.75	.61
A2	.82	.69
A3	.61	.48
A4	.54	.41
A5	.54	.37
A6	.57	.42
A7	.27	.26
A8	.12	.09
A9	.10	.15
A10	.19	.16
B1	.34	.20
B2	.05	.39
B3	.02	.02
B4	.49	.32
B5	.32	.18
B6	.29	.21
B7	.36	.24
B8	.47	.29
B9	.03	.03
C1	.49	.32
C2	.47	.33

Group G (Pattern VII)

	A8	A9	A10
A1	.09	.09	.09
A2	.08	.09	.11
A3	.03	.05	.05
A4	.01	.02	.01
A5	.02	.02	.01
A6	.07	.06	.03
A7	.04	.01	.05
B1	.02	.01	.05
B2	.01	.04	.04
B3	.10	.09	.03
B4	.02	.01	.02
B5	.09	.09	.04
B6	.06	.05	.03
B7	.00	.01	.03
B8	.01	.01	.01
B9	.07	.02	.03
C1	.03	.01	.01
C2	.06	.02	.07
C3	.01	.01	.01
C4	.12	.01	.03
C5	.04	.00	.04

B2	.23	.10	.13
B3	.33	.24	.29
B4	.60	.32	.48
B5	.47	.27	.33
B6	.38	.39	.32
B7	.73	.49	.67
B8	.63	.35	.51
B9	.30	.23	.13
C1	.66	.41	.50
C2	.70	.39	.45
C3	.65	.36	.53
C4	.54	.33	.20
C5	.32	.53	.19
C9	.86	.54	.55
C10	.67	.37	.66
D1	.28	.19	.18
D2	.18	.11	.15
D3	.06	.01	.10
Av.	.41	.41	.31

B2	.28	.18
B3	.55	.55
B4	.60	.41
B7	.76	.60
B8	.71	.48
B9	.25	.19
C1	.58	.38
C2	.50	.32
C3	.64	.46
C4	.03	.15
C5	.27	.04
C6	.47	.38
C7	.27	.29
C8	.33	.32
C9	.40	.30
C10	.55	.42
D1	.32	.29
D2	.18	.21
D3	.09	.13
Av.	.39	.30

B2	.03	.02
B3	.33	.47
B4	.46	.55
B5	.40	.55
B6	.30	.42
B7	.59	.75
B8	.48	.61
B9	.34	.29
C1	.52	.53
C2	.57	.49
C3	.50	.62
C4	.43	.05
C5	.18	.04
C6	.86	.67
C7	.54	.39
C8	.55	.66
D1	.11	.06
D2	.05	.01
D3	.04	.01
Av.	.30	.30

Group E (Pattern VI)

	D1	D2
A1	.75	.61
A2	.82	.69
A3	.61	.48
A4	.54	.41
A5	.54	.37
A6	.57	.42
A7	.27	.26
A8	.12	.09
A9	.10	.15
A10	.19	.16
B1	.34	.20
B2	.05	.39
B3	.02	.02
B4	.49	.32
B5	.32	.18
B6	.29	.21
B7	.36	.24
B8	.47	.29
B9	.03	.03
C1	.49	.32
C2	.47	.33
C3	.50	.33
C4	.29	.22
C5	.31	.24
C6	.28	.18
C7	.17	.11
C8	.18	.15
C9	.11	.05
C10	.06	.01
D3	.21	.55
Av.	.33	.27

Group G (Pattern VII)

	A8	A9	A10
A1	.09	.09	.09
A2	.08	.09	.11
A3	.03	.05	.05
A4	.01	.02	.01
A5	.02	.02	.01
A6	.07	.06	.03
A7	.04	.01	.05
B1	.02	.01	.05
B2	.01	.04	.04
B3	.10	.09	.03
B4	.02	.01	.02
B5	.09	.09	.04
B6	.06	.05	.03
B7	.00	.01	.03
B8	.01	.01	.01
B9	.07	.02	.03
C1	.03	.01	.01
C2	.06	.02	.07
C3	.01	.01	.01
C4	.12	.01	.03
C5	.04	.00	.04
C6	.09	.02	.04
C7	.06	.03	.03
C8	.07	.06	.01
C9	.09	.03	.05
C10	.05	.04	.06
D1	.12	.10	.19
D2	.09	.15	.16
D3	.04	.05	.07
Av.	.05	.04	.05

TABLE XXXVII

The Lateral Location of the Skeletal Asymmetries in Each of the Age-Sex Groups of Subjects

Specific Pattern	Asymmetry	Young Women (121)* -** + o	Young Men (182) - + o	Older Women (97) - + o	Older Men (100) - + o
I	B1	61: 58: 2	77:101: 4	43: 50: 1	48: 50: 2
I	B4	59: 62: 0	88: 90: 4	45: 44: 5	52: 44: 4
I	B7	67: 52: 2	79: 98: 5	40: 52: 2	50: 48: 2
I	B8	63: 54: 4	89: 84: 9	43: 50: 1	47: 47: 6
I	C1	63: 55: 3	91: 88: 3	38: 53: 3	53: 44: 3
I	C2	63: 58: 0	87: 93: 2	41: 51: 2	52: 47: 1
I	C3	59: 60: 2	87: 91: 4	40: 52: 2	48: 50: 2
II	A1	47: 60:14	93: 69:20	39: 41:14	53: 40: 7
II	A2	53: 53:15	99: 63:20	42: 42:10	55: 37: 8
II	A3	68: 43:10	102: 67:13	43: 39:12	55: 33:12
II	A4	60: 47:14	102: 60:20	44: 42: 8	53: 42: 5
II	A5	64: 41:16	96: 65:21	42: 42:10	48: 41:11
II	A6	65: 48: 8	107: 62:13	48: 38: 8	56: 30:14
III	C6	53: 63: 5	68:108: 6	39: 54: 1	45: 53: 2
III	C7	56: 61: 4	80: 91:11	42: 44: 8	48: 48: 4
III	C8	60: 52: 9	82: 91: 9	47: 42: 5	46: 47: 7
IV	B5	62: 53: 8	93: 77:12	49: 39: 6	52: 42: 6
IV	B6	61: 52: 8	96: 72:14	50: 38: 6	57: 36: 7
V	C9	48: 64: 9	65:110: 7	40: 48: 6	39: 58: 3
V	C10	55: 64: 2	64:112: 6	40: 48: 6	41: 56: 3
VI	D1	40: 72: 9	82: 84:16	36: 50: 8	51: 44: 5
VI	D2	77: 43: 1	88: 93: 1	55: 38: 1	47: 50: 3
VII	A8	97: 16: 8	134: 38:10	79: 12: 3	78: 13: 9
VII	A9	98: 10:13	144: 22:16	73: 17: 4	78: 14: 8
VII	A10	88: 28: 5	138: 34:10	63: 27: 4	72: 24: 4
	A7	79: 37: 5	105: 71: 6	49: 42: 3	56: 43: 1
	B2	62: 57: 2	95: 84: 3	43: 45: 6	53: 43: 4
	B3	42: 73: 6	43:126:13	33: 54: 7	26: 65: 9
	B9	47: 62:12	80: 96: 6	41: 45: 8	47: 47: 6
	C4	49: 59:13	76:100: 6	34: 57: 3	45: 53: 2
	C5	57: 55: 9	81: 90:11	42: 49: 3	39: 52: 9
	D3	67: 54: 0	75:106: 1	50: 44: 0	42: 58: 0

* The number of subjects is stated under each group.

** Minus (-) means the asymmetry occurs on the left side; plus (+), the asymmetry occurs on the right side; zero (o), there is no asymmetry.