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HINGE POINTS
OF
THE HUMAN BODY

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This sixth quarterly report consists of three short monthly summaries of work covering the months of April, May, and June of 1953, plus certain annotations which indicate the current status of the research under Contract AF 18(600)-43.

REPORT ON WORK DURING APRIL

The April research effort was furthered by approximately 930 hours of time by research assistants, 56 hours of secretarial and artist help, and work by the principal investigator. The chief activities consisted of:

1. Over 100 hours (ordinarily involving two research assistants' labor) were devoted to data gathering on living subjects.
2. Data processing on various schedules of work on living subjects continued.
3. An accelerated program of work on localizing of joint centers of extremity joints was under way in April and will continue through May.
4. The new setup for determining data on sagittal-plane force diagrams of the body for various postures was assembled for initial studies.
5. Two cadavers were dismembered and mechanical data on body segments were obtained.

During May the basic data gathering on living subjects will be pushed to completion and a further emphasis will be put on data processing.

REPORT ON WORK DURING MAY

During May the work by the principal investigator was augmented by approximately 640 hours of research-assistant and 75 hours of secretarial help. Principal work of the month consisted of:

1. An intensive period devoted to data gathering on living models (almost 160 hours). Some 29 men were used in completing routine procedures or in repetitions where earlier records had not been technically satisfactory. This work completed the record-taking on 40 selected subjects. Such records provide much of the basic data of this investigation.
2. A systematic processing of data on five or six topics including work on hand and foot kinetotopes, shoulder and hip axes, and body volume distributions was emphasized.
3. Work on locating the paths of the instantaneous joint centers for functional conditions of joint action was continued and accelerated.

Data processing will be the major activity for June and the later summer months. Work on body posture in relation to force-diagrams of the body will get fully underway. A change to summer personnel involving full-time project work for the principal investigator and less part-time help begins in June. If personnel may be budgeted, joint work should continue.

REPORT ON WORK DURING JUNE

After the 15th of the month, the principal investigator and Dr. George Gaughran, associate, contributed full time to the project. Total research work amounted to 710 hours and this was supplemented by 122 hours of an illustrator's time and 118 hours of secretarial help. The major activities of the month consisted of:

1. An intensive period of data processing on foot-range patterns and the preparation of a manuscript draft and illustrations. Twenty selected subjects formed the present study sample, but for the final report data at hand on an additional twenty subjects will be included.

2. About 30 hours of model time were devoted to the completion of scheduled work on the routine study sample and to supplemental observations that aid interpretation during the present analytical period.
3. Considerable work was devoted to summarizing records on functional locating of hip and shoulder axes.
4. Work continued on equipment improvements, on tests, and on data gathering for the analysis of action-and-reaction sagittal-plane forces exerted by the body in the seated position.

Work on axes of cadaver limb joints was suspended pending the possibility of obtaining further help. During July, data processing and writing will continue as major activities, together with continued work on the force-diagram study.

ANNOTATIONS

1. The basic schedule of data gathering on some 40 living subjects was completed during this period. For more than 12 months, series of records were gathered on the subjects dealing with body measurements of various kinds: anthropometry, determination of regional body volumes, and measurements of joint ranges. In addition measurements of pelvic and thoracic tilt in seated postures were made. Functional data on locating shoulder and hip axes and studies of the work space for the hand and foot in different end-member orientations were also followed intensively. Early in the data-gathering period some 20 or 25 hours of subject time were required but, during the later period under consideration, the time was often below 15 hours. Assistants ordinarily worked in teams of two or three in the gathering of data.

The study sample included 7 extremely rotund body types and at least 10 extremely thin builds and a similar sample of extremely muscular types. Ten median types corresponding in body build with the more common physiques of the fighter-pilot group of the Air Force were used. Numerical data and hundreds of photographic records, including motion pictures, are at hand for analysis. Preliminary checks on the quality of the records have been made as well as various repetitions, so that the great bulk of our data should now be reliable.

2. Over the past few months, many of the photographic records have been measured and tabulated. Certain of the more elaborate data schedules, such as the regional body volume data and the foot-space records, have been partly developed. Half of the sample dealing with the work space of the foot has now been summarized and a manuscript draft has been written. Records on the work space for the hand also have received much attention.

3. Photographic records on the functional localization of a common shoulder axis for the seated subject have been traced for all subjects and the moving paths of instantaneous centers of rotation have been plotted. These records are currently under study. Similar data on the hip axis for the seated subject are slightly less advanced. Individual patterns of shoulder movement differ greatly and the variables due to several degrees of joint freedom, to mass differences, to muscle forces, to speed of movement, and to action-recoil patterns require evaluation.

4. The mechanical data based on cadaver dismemberment that have been obtained earlier were augmented in April by two unpreserved bodies. It is at present very difficult to obtain enough cadavers for class dissection at this University. If this situation is eased and if it is possible to arrange for short-time medical-student help, it may be feasible to supplement our records by data from one or two additional bodies. Since this, however, is not certain, it may be necessary to limit the sample to the several bodies on which we presently have data in our files.

5. It is known that the body can exert certain magnitudes of force; with electromyography it should be possible to analyze muscle participation in this activity. However, it is not known how the body utilizes its own weight in performing work. This is a highly important factor in work efficiency. A schedule of study is now underway which is designed to investigate maximum tensile and compressive forces exerted by the body for various seated postures. We are attempting an analysis of exactly how the weights of the different parts of the body are put into play in these movements.

The apparatus consists of a framework of angle iron, 7 ft by 6 ft by 1 ft 8 in. A seat is mounted on two horizontal T-bars located midway between the upper and lower portions of the frame; it is made of three laminae: (1) a wooden base, (2) a metal frame resting on a tripod of pressure gages to record vertical forces, and (3) a wooden seat 19-1/2 in. by 15 in. resting on ball bearings on top of the metal frame and free to move only in the sagittal plane. Pressure gages are mounted in relation to the seat so that all the horizontal and all the vertical forces may be recorded at any moment. It is thus possible to determine gravity-line locations for any seated posture and the amount of this vertical force vector. Likewise, forward and

backward forces on the seat are recorded as the subject pulls or pushes on a dynamometer attached to the apparatus.

A nude model seated on the apparatus pulls or pushes until his maximum horizontal force is recorded on the hand dynamometer; then his posture, seen side-view, is photographed. Simultaneously the pressure dial on the front of the seat is observed and the two dynamometer dials on the back of the seat are photographed. Similar photographs and readings will be taken when the subject reaches a maximum sagittal push or pull in eight various postures. These test postures are based on the heights of the hand dynamometer above seat level. Dial readings are also made of the vertical components. With these photographic and recorded data, plus information on the weights and centers of gravity of parts of the body, analyses will be made to determine how the individual parts are used in the application of forces.

Approximately the 340 hours were devoted to the assembling and testing of the apparatus. The following activities have been carried on during April, May, and June:

- a. Various parts of the machine have been constructed and refined.
- b. Three models have been used in the testing of the apparatus, using the seat alone, and involving the application of maximum compressive and tensile forces with various seated postures.
- c. These tests brought out a number of mechanical malfunctions; additional work was therefore undertaken to revise the seat and recording mechanisms.

At present, maximum compression and tension runs are being made, using two models, with what appear to be successful seat and recording mechanisms. The work planned for succeeding months consists of:

- a. the incorporation of a footrest and a backrest into the apparatus already designed (the footrest has been constructed and assembled, but delay in the shipment of pressure gages has held up further work along this line)
- b. a concentrated data-gathering period through July, utilizing three test subjects and introducing various additional postures using

(1) the seat alone, (2) the seat plus footrest, and (3) the seat plus footrest plus backrest; and

- c. analysis of data in conjunction with information obtained from the dismemberment of cadavers and from detailed measurement of regional volumes on the test subjects themselves.

6. An earlier period devoted to the anatomical analysis of the major extremity joints (Quarterly Report No. 4) showed an unanticipated complexity in joint mechanisms. No joint acts as a pin-centered mechanism; instead, the axis of rotation shifts position with each degree of joint bending. Furthermore, since joints may bear simultaneously at several points - and these differ, as the joint is moved - analysis based on structure alone is inadequate.

Methods of functional analysis (Quarterly Report No. 5) have been devised. Since March, cadaver joints have been subjected to an analysis involving actual articular contact and movement. The method demands very meticulous work and many repetitions; consequently, data are slow in accumulating. At present several specimens of the ankle joint, of the elbow, and of the shoulder joints have been analysed completely. The hip, knee, and wrist, however, have not been studied as yet, and additional specimens of the joints studied should be worked on.

Budget limitations have forced a suspension of this basic work as of the first of June. Information of this sort, however, is absolutely necessary if a primary objective of this research project - a layout manikin - is to be reached satisfactorily. The functional study of the hinge points of the human body outlined here represents the culmination of an interest in joints that goes back to the first days of 1952.

Continued work for the remainder of the summer months should emphasize processing of data on living subjects and the processing of data obtained from the dismemberment of cadavers. Further work, involving additional help as indicated above, should also be undertaken.

The current research team is a smoothly working, efficient group. If this group can be held together at least through the summer months by an early supplemental appropriation (application dated June 5) processing the bulk of our data will be assured and the preparation of a final report inclusive of all essentials by the contract deadline should be a certainty. Additional help for work on joint centers and cadaver work, however, will be necessary.

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