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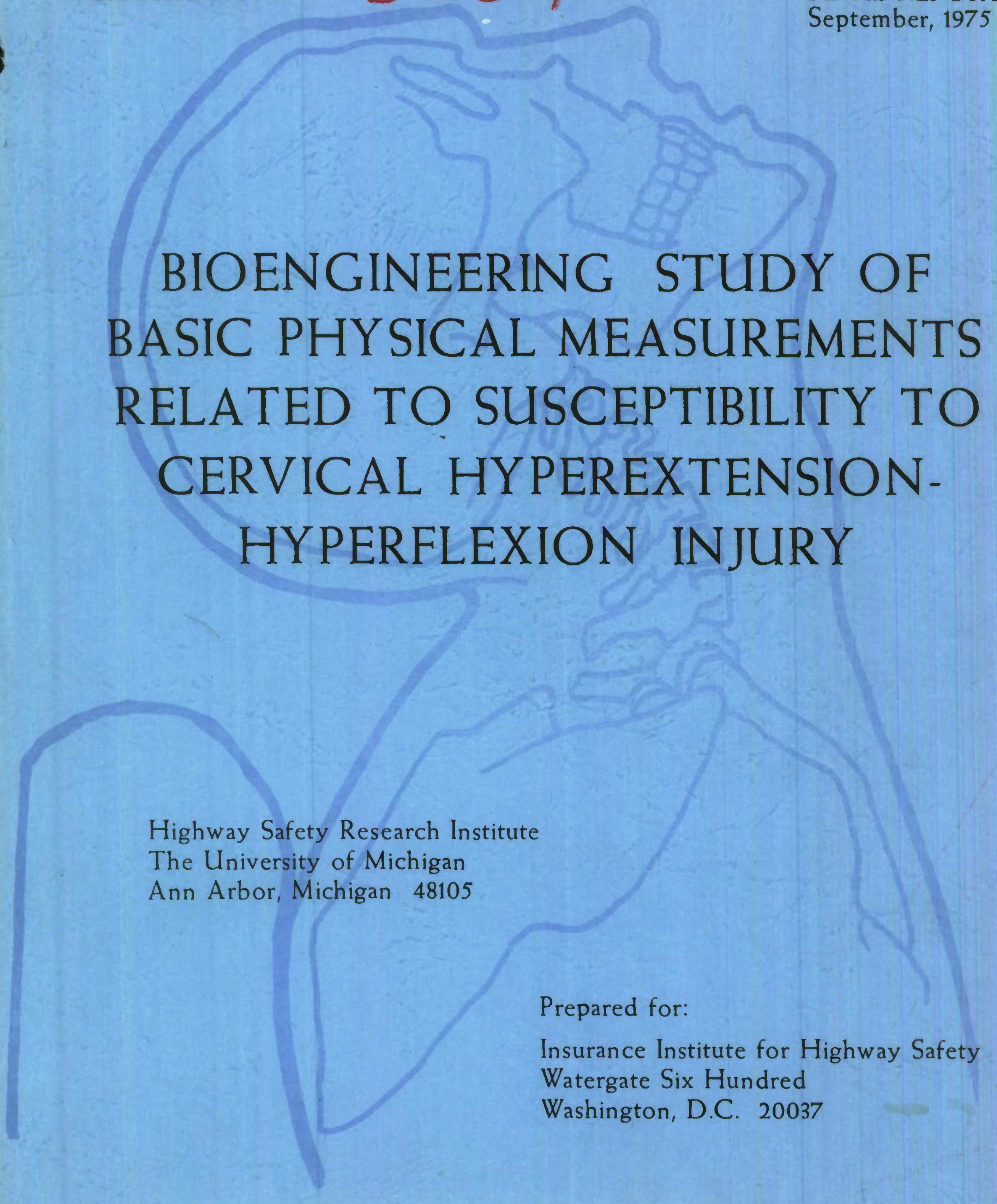

BIOENGINEERING STUDY OF BASIC PHYSICAL MEASUREMENTS RELATED TO SUSCEPTIBILITY TO CERVICAL HYPEREXTENSION-HYPERFLEXION INJURY

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48105

Prepared for:

Insurance Institute for Highway Safety
Watergate Six Hundred
Washington, D.C. 20037

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RICHARD G. SNYDER
DON B. CHAFFIN
DAVID R. FOUST

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48105

Prepared for:

Insurance Institute for Highway Safety
Watergate Six Hundred
Washington, D.C. 20037

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16. Abstract

Basic physical characteristics of the neck which may influence a person's susceptibility to "whiplash" injury during rear-end collisions have been defined using 180 human volunteer subjects chosen, on the basis of sex, age (18-74 years), and stature, to be representative of the U.S. adult population. Measurements from each subject included anthropometry, cervical range of motion from both x-rays and photographs, and the dynamic response and isometric strength of the neck flexor and extensor muscles. Summary data for key measurements are discussed in the text; complete summaries for each measure are in four appendices. The results were used to develop a method of predicting dynamic muscle force from isometric EMG data, and to examine injury susceptibility for various population groups using a biomechanical model. The data are presented in a format usable in the design of biomechanical models, anthropometric dummies, and occupant crash protection devices.

Experimental and modeling results suggest that the neck muscles can influence neck dynamic response to varying degrees for different population groups. Aging and sexual differences in cervical mobility, reflex time, and muscle strength were all found to be important factors in injury susceptibility.

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We are especially grateful for the support of the Insurance Institute for Highway Safety, and to Brian O'Neill, Vice President of Research, IIHS, who suggested the statistical design and monitored the study. Dr. Laurence Rosenstein monitored the early phases of the study.

Finally, our sincere appreciation is also due to the 500 volunteer subjects, of whom 180 were selected in accordance with the experimental design; their willingness to participate in the five diverse tests was critical to the success of the study.

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SUMMARY

Basic physical characteristics of the neck have been defined which have application to biomechanical models, anthropometric dummies, and occupant crash protection devices. The measurements necessary to define these characteristics were performed with a group of 180 human volunteer subjects, chosen by virtue of sex, age, and stature to be representative of the U.S. adult population. Subjects were grouped into 18 categories according to sex, age (18-24, 35-44, and 62-74), and stature (short, middle, and tall 20 percentiles of the population), with ten subjects per category.

The following measurements were obtained from each subject: 48 traditional measures of anthropometry, mostly of the head and neck; 16 anthropometric measures of the cervical spine (from x-rays); four replications of sagittal plane flexion and extension range of motion; range of motion of the cervical spine; neck muscle stretch reflex and reaction times; and voluntary neck muscle strength from both flexors and extensors. X-ray data were digitized for analysis, and certain of the active measurements were analyzed using a laboratory computer. Stretch reflex was induced by using a one-pound weight to impulsively load the head while measuring the response with electromyograms and two uniaxial accelerometers.

The complete results are presented in the numerous tables and figures in the text and in five appendices. Some of the more important accomplishments and results are summarized as follows:

1) Traditional anthropometry measures indicate that the subject pool for this study matches the U.S. population data very well and may be considered representative of the U.S. population.

2) Many height dimensions related to the seated position have been measured. Correlations and consistent proportions often permit the

prediction of one measure from another.

3) The combination of x-rays and photographs has been successfully used to determine that cervical range of motion is consistent over several replications. The average range of motion of the head and neck in the sagittal plane ranges from 85 degrees for average-stature elderly males to 146 degrees for tall young females. Range of motion is significantly restricted in older subjects. There is more range of motion in extension than in flexion, as measured from normal seated posture.

4) The size and mobility of the cervical spine vertebrae have been measured from x-rays. Total length of the cervical spine averages about 11 cm for females and 12 cm for males, with little difference due to stature and no difference due to age. Comparison of spinal column range of motion with that measured externally indicates that approximately 20 degrees of total range of motion is due to upper torso movement. Also, the range of motion between adjacent cervical vertebrae has been determined.

5) Female neck muscle strength is considerably less than that of males. Males and females exhibit different aging characteristics (males being stronger in middle age than when younger), but all elderly subject groups revealed considerably reduced strength capability. The average male was nearly twice as strong as the average female. The neck extensors average about one-third stronger than the flexors.

6) Average stretch reflex times of the neck flexor muscles, as measured to beginning of contraction (i.e., EMG onset), range from about 56 to 92 ms. The comparable range for extensor muscles is 54-87 ms. Females reflex faster than males of the same age. Reflex times increase gradually throughout life for males but only after middle age for females. On the average, the extensor muscles have slightly faster reflex times than do flexor

muscles (about 10%).

7) A technique has been developed to "calibrate" the EMG-force relationship for the neck flexor muscles which can be used to predict muscle force exerted during a reflex test. If proper precautions are taken during data collection, the technique is considered to be a reliable indicator of short-term muscle exertions in response to sudden disturbance.

8) The experimental data for range of motion and muscle strength have been used in the HSRI Two-Dimensional Crash Victim Simulator to investigate the effect of the measured parameters on dynamic response in a simulated 30 mph rear-end collison. It was found that the small elderly female group was most susceptible to injury since the neck muscles are not strong enough, even when fully tensed, to prevent the head from reaching its motion limit. Males were found to have enough strength to prevent limits of motion from being reached if the muscles are pre-tensed. Regardless of the population group, active neck muscle tension modified head/neck dynamic response.

Both the experimental and the modeling results suggest that certain segments of the population are more likely than others to sustain neck injuries in a given rear-end accident situation. Females regardless of age and elderly males would seem to be the most susceptible to injury, primarily because of reduced neck muscle strength. It is hoped that the data and results presented will be useful to researchers and designers who are working to prevent and reduce neck injuries in automobile accidents.

CHAPTER I

BACKGROUND

A. Introduction

The work reported in this study was conducted during the period January, 1972, through June, 1973, to determine characteristics of basic physical measurements related to susceptibility to cervical hyper-extension-hyperflexion injury in the sagittal (forward/rearward) plane. The study was initiated due to the need to better understand the basic mechanisms involved in such injuries, commonly (if incorrectly) termed "whiplash," which occur when the forward-facing occupant of a vehicle is struck from the rear, resulting in dynamic hyperextension-hyperflexion of the head and neck.

Although there is extensive literature related to the "whiplash" phenomenon, little information has been published concerning variation in head mass, center of gravity in the seated position, and neck muscle strength as related to age, sex, and physique variables. Furthermore, to our knowledge, there has been no directly related study of variation

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This study was supported by the Insurance Institute for Highway Safety, Washington, D.C., under contract ORA-72-613-B1, with initial technical monitorship by Dr. Laurence Rosenstein and continued under Brian O'Neill, Vice President of Research.

The rights, welfare, and informed consent of the volunteer subjects who participated in this study were observed under guidelines established by the U.S. Department of Health, Education and Welfare Policy on Protection of Human Subjects and accomplished under medical research design protocol standards approved by the Committee To Review Grants for Clinical Research and Investigation Involving Human Beings, Medical School, The University of Michigan.

in neck muscle response time to external acceleration stimulus (stretch reflex), although such measurements would appear to be of basic importance in consideration of sensitivity to hyperextension-hyperflexion injury. The purpose of this initial study was to evaluate a number of physical factors (not previously measured on a single population) on a sample representing the total U.S. adult population with respect to sex, an age span of 18 to 74 years, and a wide range of statures.

The results of this eighteen-month study have been only partially reported to date. A series of five quarterly progress reports to the sponsor were distributed on a limited basis (Snyder, Robbins, and Chaffin, 1972; Snyder and Chaffin, 1972a, 1972b; Snyder, Chaffin, Foust, and Baum, 1972, 1973), but a final comprehensive report was not initially intended. Publication of various aspects of the study in the open literature reported the following results.

The initial publication provided a comprehensive Bibliography of Whiplash and Cervical Kinematic Measurement (Van Eck, et al, 1973) consisting of over 2300 references related to whiplash injuries. A significant finding was that no basic study had been conducted which measured the variation in the adult driving population with respect to major parameters considered to influence susceptibility to cervical hyperextension-hyperflexion injury. While many individual factors, such as range of motion or muscle strength, have been previously studied, results were difficult to assess because investigators did not measure these factors on a single population.

Results of the study of cervical range of motion and cervical muscle response and strength were published in the Proceedings of the 17th Stapp

Car Crash Conference (Foust, et al, 1973). Mathematical modeling aspects providing illustration of the use of data obtained for prediction (and amelioration) of injury for protective design applications were presented in a Society of Automotive Engineers paper (Robbins, et al, 1974), while an analysis of C3 through C7 vertebral body dimensions has been accepted for publication in the American Journal of Physical Anthropology (Katz, et al, 1975). More recently other aspects of the study have been submitted or are in preparation for publication in the literature, including techniques for use of electromyography in biomechanical modeling (Chaffin and Foust, 1975); the relationship of cervical canal size to vertebral body size (Baum, et al, 1975); anthropometry, radiography, and photometric measurements related to whiplash susceptibility (Snyder, et al, 1975); cervical response to acceleration (Foust, et al, 1975); and a model of neck response to rearward accelerations (Foust, 1975).

A follow-on study, conducted from October, 1973, through December, 1974, was conceived to investigate the mechanisms which occur in injuries resulting from forces imposed in lateral flexion of the neck, such as would occur in side (lateral) impact to a vehicle or rear impact when the occupant's head is turned to one side. This report, entitled Basic Biomechanical Properties of the Human Neck Related to Lateral Hyperflexion Injury, was published in March, 1975 (Snyder, et al, 1975). Two additional papers, related to simulated occupant response to automotive side-impact collisions (Bowman, et al, 1975), and basic biomechanical properties of the neck related to cervical lateral hyperflexion injury (Schneider, et al, 1975), have resulted from the second phase of this continuing investigation.

During the course of the latter study it became apparent that more benefit to other researchers, modelers, engineers, and potential users of the data would occur if all of the original data were compiled and provided in a single source, rather than in scattered publications throughout the literature. The present publication was prepared during the period May-September 1975, allowing further analysis of the data and preparation in a format which, hopefully, will be of most use to those needing the information provided for the solution of applied problems.

It should be noted that information developed in this study has already been utilized in the design of the ATD-50 anthropometric dummy neck by General Motors Corporation, in seat designs by the Ford Motor Company, and in a study of jet fighter pilot seating position, and has been considered in the development of occupant protection and anthropomorphic dummy standards by the National Highway Traffic Safety Administration. Using data for strength, reflex time, and lateral range of motion from the study of biomechanical properties related to lateral hyperflexion injury, the MVMA-2D model was able to be adjusted for side-impact to simulate responses of the various subject groups to 10 and 30 m.p.h. side impacts. Studies of both sagittal and lateral plane biomechanical properties of the neck have also led to work, now in progress, involving an attempt to simulate responses of male U.S. military subjects to dynamic impact sled tests of varying g levels. By such model validation with empirical test data from one population group it may be possible to predict impact responses of other groups in the general population by using the data developed in the sagittal and lateral neck motion studies. It is anticipated that many additional uses for the data developed in these studies will be forthcoming.

B. Research Objectives

The primary purpose of this investigation was to obtain measurements related to the biomechanics of head/neck motion in the sagittal plane. More specifically, the tasks were:

1) To determine comprehensive anthropometry of the head and neck.

2) To determine variation in voluntary range of cervical motion, especially in regard to maximum extension and flexion.

3) To determine variation in muscle response time (myotatic or stretch reflex) with respect to external stimulus both in flexion and extension.

4) To measure variation in neck muscle strength in flexion and extension.

5) To measure the above-mentioned parameters for the range of physical, sexual, and age variation in a representative U.S. population.

6) To determine the sensitivity of the dynamic response of the human body to changes in the parameters developed in this study using mathematical models of a crash victim.

Basically the above tasks were designed to answer three questions: What are the physical dimensions of the neck; how fast and how strongly can the neck muscles react; and how far can the head and neck move before injury is likely to occur; and to answer those questions for a typical vehicle-using adult population. Since human volunteer subjects were to be used, it was necessary to test each of these parameters separately, at safe levels.

C. Background and Summary of Literature

The following background relative to cervical hyperextension-hyperflexion injury has been updated from the lateral hyperflexion injury report of March, 1975, and is included here to provide a brief review as well as to indicate additional sources of information related to the subject.

Rear-end collisions commonly result in neck injury to the occupants of automobiles. Jackson (1966) estimated that 85% of neck injuries from automobile collisions are caused by rear-end impacts. This incidence was confirmed in a 1969 study, by States, et al, of 13,800,000 vehicular collisions recorded in the U.S. during 1967. Of those, 78% were attributed to vehicle-to-vehicle impacts, and approximately 62% of these (6.5 million) were estimated to be due to rear-end collisions (Gurdjian and Thomas, 1970). Data prepared by the National Highway Traffic Safety Administration for 1968 indicated that rear-end collisions accounted for 23.5% of U.S. accidents and were responsible for 25.5% of the injuries and 4.5% of the fatalities (National Accident Summary Facts, n.d., Fig. 4). More recent data indicate that there were some 4,300,000 rear-end collisions during 1973 in the U.S. (National Safety Council, 1974, p. 47), which included 2,300 fatal impacts.

Resulting injuries to the neck are documented by an extensive clinical literature (Van Eck, et al., 1973). The cervical hyperextension-hyperflexion ("whiplash") injury is characterized by symptoms referable to the neck, including cervical pain, tenderness, ligamental damage, muscle spasm, occipital headaches, retropharyngeal hematoma, dysphagia, and cervical spine fracture. Other injuries reported include sub-arachnoid and subdural hemorrhage, vertigo, EEG abnormalities, unconsciousness, and ill-defined mental changes. Acute or chronic symptoms of these lesions may appear immediately and persist for years, while in other cases symptoms attributed to the accident may not appear for a considerable time.

According to Jackson, the term "whiplash" was initially used in 1944 by Davis to describe the mechanism of neck injuries which occur in head-on collisions (i.e., an abrupt flexion of the neck followed by a recoil in extension). While "whiplash" may occur in this manner, the term is most commonly associated with the rear-end collision which results in the target vehicle occupants' necks being abruptly hyper-extended, followed by rapid hyperflexion. It may also, however, refer to the lateral movement of the head resulting from side impact (called "sidelash" by Jackson) or rear impact with the occupant's head turned. The term "whiplash" has been widely misused in the literature to denote a medical diagnosis, rather than as a descriptive term indicating a mechanism of injury (Braunstein, et al, 1959; Knepper, 1963). The injury it is intended to describe results from hyperextension, hyperflexion or lateral flexion of the neck as the head rotates during collision impact.

To date the best treatment of the etiology of cervical injuries is by Jackson (1971). Injuries in head-on collisions causing forward hyperflexion of the neck followed by rearward hyperextension have been described as primarily placing traction on the anterior longitudinal ligament, the attachments of which may be stretched, torn, or avulsed at the margins of the vertebral bodies or at the annulus fibrosis of the intervertebral discs. Other injuries may include avulsion of fragments of the vertebral body, tears or ruptures of the annulus fibrosis, disc avulsion, tears of the longus colli and intertransverse muscle attachments, fractures of the spinous processes, laminae, articular facets, or the odontoid process, or avulsion of the capsular ligaments.

Similarly, whiplash injuries caused by rearward hyperextension of the head and neck followed by abrupt forward hyperflexion may involve tearing or stretching of the nuchal, the posterior longitudinal, the interlaminar, or the capsular ligaments, posterior facet dislocations (with or without cord injuries), vertebral body fractures, or other injuries. Otological aspects of "whiplash" injuries have been discussed by Pang (1971).

While several studies have been concerned with the occurrence of cerebral injury induced by whiplash, controversy over the mechanisms responsible continues. There is now a divergence of opinion concerning the respective roles of translational and rotational acceleration in the concussive mechanism of whiplash, and there is growing evidence of correlations between injury and such factors as head-to-restraint distance, rotational acceleration effects (Portnoy, et al, 1971), mass of the head, location of the center of gravity of the head, and orientation of the head at initiation of impact.

Studies of concussion have often been an outgrowth of "whiplash" experiments. Martinez (1965), for example, reported brain injury associated with whiplash in rabbits, while Mahone, et al, (1969), and Ommaya, et al, (1966, 1970), have utilized sub-human primates. A detailed discussion of the relationships reported in the literature may be found in Snyder (1970). A joint Army-Navy-Wayne State University experimental program of 236 dynamic human exposures to $-G_x$ impact acceleration in 1967-1969 (continued by the Navy at Michoud/NASA) resulted in independent measurement of the displacement of the head relative to the neck in the plane of rotation through electronic and photographic techniques (Ewing, et al, 1968; Ewing, et al, 1969; Ewing and Thomas, 1971, 1972, 1973), as well as a number of other parameters critical to protection against cervical injury. Clarke, et al, (1971) determined head linear and angular accelerations during human exposure to abrupt linear deceleration while restrained by an air bag plus lap belt restraint. In 14 tests with adult male volunteers at peak sled velocities to 26.2 ft./sec. and 7.8 to 10G, results indicated that peak head angular accelerations and linear resultants may have less traumatic consequences than the degree of head-neck hyperextension. In simulated rear-end collisions in crashes with 53 human cadavers, Clemens and Burow (1972) noted that the most common and serious injury was to the spine at the level of the sixth cervical vertebra. Unembalmed cadavers were also tested by Gadd, Nahum, and Culver (1971), who found ligamentous injury at a similar degree of hyperextension, but approximately 15% greater moment of resistance was noted during the time in the loading cycle when angular velocity was greatest.

The incidence and severity of "whiplash" injury apparently is not always related to the magnitude of the change in velocity of the impacted vehicle, since many other factors, such as effect of any head restraint, head-torso position and orientation to the force at the instant of impact, etc., influence the results. For example, one motorist who had been rear-ended by another received a liability verdict for resulting injuries of $452,000 in a 1973 case, although total damage to the injured person's vehicle was reported to be only $28 (USAA, 1973). On the other hand, the principal author, driving on a freeway at 55 mph, was rear-ended in a 1965 collision by a vehicle being chased by the police and clocked at 90 mph at impact. Although both cars were demolished, the author was uninjured by this 45-mph change-in-velocity impact.

Directly related to a better understanding of the mechanisms involved in and factors causing various aspects of whiplash injury is a need to understand the role that the basic properties of the human neck (such as anthropometry, range of motion, strength, and reflex time) play in preventing whiplash injury on impact. Prior to this study, however, variations in these physical properties of the neck with age, sex, and stature and consequent changes in susceptibility to whiplash injury were virtually unknown, although recent statistics indicate that such factors may have an important effect on injury susceptibility.

For example, recent clinical examinations of victims of whiplash injury indicated a significant preponderance of whiplash symptoms among females. Kihlberg (1969) reported a substantially greater frequency among women, "up to twice as high as among men." Gurdjian has reported 207 cases of hyperextension-hyperflexion injuries seen in a three-year period, of which 129 were female and 75 were male (Gurdjian, Cheng, and Thomas, 1970). Field investigations appear to confirm this assessment (O'Neill, et al, 1972). Schutt and Dohan (1968) have found disabling neck injuries to women "common" in accidents in metropolitan areas, ranging from 6.7 to 14.5/1,000/year, half occurring from rear-end collisions.

Along with these statistics it is interesting to note that Sinelnikoff and Grisorwitsch (1931) found that females exceed males in range of motion of all joints except the knee, often to a significant extent. Age-related diseases such as arthritis have been found to result in a marked decrease in joint mobility after age 45 (Smith, 1959). A decrease of about 21% in "normal" flexion-extension motions of subjects aged 15 to 74 was reported by Ferlic (1962). He also found a decrease of lateral bending motions of 35% and a decrease in rotation with age of about 20%, although he took no x-rays of these subjects. However, Lysell (1969), using 28 cadaver specimens, has reported that degenerative changes "had no effect on the range of motion in any planes or in any interspaces."

Cervical joint motion has been studied by various techniques, including multi-exposure films (Dempster, 1955), cyclograms (Drillis, 1959), and photographic techniques devised by Taylor and Blaschke (1951) and Eberhart and Inman (1951). Bhalla and Simmons (1969) have devised a simple apparatus to determine range of motion radiographically, and from studies on 20 student nurses between ages 19-23, have postulated that in flexion the injury would most likely occur at C6-C7 or C7-T1;

while in extension, injury would occur most often at C2-C3, C3-C4, or C5-C6. Mertz and Patrick (1971) have reported that the best indicator of the degree of severity of neck flexion is the equivalent moment of the neck and chin contact forces taken with respect to the occipital condyles.

The "normal" range of neck flexion has been studied in male subjects by Glanville and Kreezer (1937), Defibaugh (1964), and more recently summarized by Lysell (1969). However, difficulties reported have involved reproducibility, intra-individual range or variation, and lack of adequate landmark standards. As a result of the first major attempt to obtain linkage data on the mobility of the human torso, including the neck, the authors devised techniques which have provided an improved basis for study of neck motion (Snyder, Chaffin, and Schutz, 1971). Hadden (1973) has considered head injury from an epidemiological point of view and has proposed useful basic principles and considerations which should be employed. The mechanics of lateral bending were studied in 1972 by Veleanu and Klepp, using macerated vertebrae. Lange (1971) has also used human cadavers subjected to severe test-sled decelerations to determine gross injuries to the cervical vertebrae caused by torque, axial, and shear forces. Mertz and Patrick (1967) simulated the kinematics of rear-end collisions using anthropometric dummies, and reported that neck torque rather than neck shear or axial forces is the major factor in producing cervical trauma.

In an attempt to protect the automobile occupant subjected to rear-end impacts, Federal Motor Vehicle Safety Standard No. 202 (1968) required all passenger cars manufactured after 31 December 1968, for sale in the U.S., to be equipped with head restraints at each outboard front seating position. Up to that time, experimental data were limited (Severy, et al, 1968; Mertz and Patrick, 1967).

States, et al, (1969) have reported 6 cases of injury incurred by occupants while utilizing head-restraints, and hypothesized that two mechanisms, rebound and too low a head-restraint adjustment for the seated height of the individual, were responsible. In one case it was found that a head restraint adjusted in the lowermost position (25%), protecting occupants who are 5 feet six inches tall or shorter, failed to prevent whiplash to the 6-foot driver as he ramped up the seat back and his head hyperextended over the top. A recent study by O'Neill, Hadden, Kelley, and Sorenson (1972) found that 80% of all adjustable restraints surveyed were not properly positioned, and concluded that "head restraints are the first damage-reduction measure to be applied to the whiplash injury problem" (p. 405). Garrett and Morris (1972) also evaluated head restraint performance and reported approximately 73% of the adjustable head restraints examined were in the lowest position, indicating that proper usage for protection may present the same problem as getting motorists to use active seat restraints. They also found that cervical injury was lower when the amount of seat back rotation was large. Henderson (1972) evaluated head restraint in Australian vehicles and noted that, to be effective, seat belts also should be worn to prevent the body from sliding upwards and snapping the head over the back of the "restraint."

The effect of seat design on cervical injury has been examined by Berton (1968), who analyzed the effect of seat back height, seat back horizontal distance, rotation, and collision speed. Severy, Brink, and Baird (1968) also studied the effect of backrest and head restraint design. These tests, sponsored by Ford Motor Company and the Public Health Service, used a series of collision experiments to study various seat designs under crash conditions. An unpublished study by Hammond (1968) at Ford Motor Company estimated cervicale location, referenced to H-point for drivers sitting in an automotive type seat, as 19.31 inches above H-point for males and 19.27 inches for a combined male-female population. This estimate was located at the intersection of the SAE torso line with a 25° back angle.

Studies of rear-end collisions with two moving vehicles were undertaken in Ford Motor Company tests in 1967 utilizing movable barrier-to-car tests simulating car-to-car rear-end impacts at speeds "somewhat greater" than 10, 20, 30 m.p.h. Results indicated a dummy neck hyperextension of 70° without headrest, and 30° with headrest. In addition, "neck pull" of 14 g's without headrest versus 8 g's with headrest, a longitudinal acceleration of 20 g's without headrest and 11 g's with headrest, a longitudinal acceleration of 20 g's without headrest and 11 g's with headrest, and angular velocity of 1300 deg/sec without headrest versus 500 deg/sec with headrest, were reported (Berton, 1967).

Protection of the occupant from rear-impact collision loads to 80 km/hr through improved design has been reported in experimental tests by Ford Motor Company Limited, England (Burlard, 1974), by improving structure, stiffening the seat, and adding a foam padded roll of sheet metal for head restraint.

Metz and Ruhl (1972) found that under certain conditions crash helmets worn by racing drivers can actually contribute to whiplash injury rather than reduce it.

A recent patent application (Ommaya, et al, 1973) would employ an inflatable cervical collar, worn about the neck of the vehicle occupant and inflated with compressed gas during a rear-end collision to prevent a "whiplash-like head or neck injury." Thurston and Fay (1974) tested an inflatable air bag collar to limit head motion, using a single-degree-of-freedom mechanical system.

Mathematical models representing the neck and head motion of an occupant during rear impacts have been developed by Martinez and Garcia (1968), Higuchi, Morisawa, and Sato (1970), Furusho, Yokoya, Nishino, and Fujiki (1971), and Li, Advani, and Lee (1971). McKenzie and Williams (1971) developed a two-dimensional discrete parameter model of the head, neck and torso and explored the effects of seat back stiffness on head response. More recently, the same authors reported their study of impact severity on response using the same model (Williams and McKenzie, 1975). Melvin and McElhaney (1972) have considered improving occupant protection in severe rear-end collisions from the standpoint of high performance seat structures and both fixed and deployable head restraints, based upon two dimensional computer simulations. This resulted in development of prototype systems which were dynamically tested. Bowman and Robbins (1972) reported a parameter study involving several analytical vehicle occupant models for side, oblique, and rear-impact situations. They concluded that, besides being extensible and having at least two joints, 3-D neck representations should account for coupling between the forces resisting rotational motions which can occur between the head and torso.

A recent study has been undertaken by Hess (1975) to develop a new biomechanical model of the human neck in the dynamic flexion which results from an occupant who is wearing seat and torso belts being involved in a frontal collision. Hess' model recognizes the importance of active neck musculature and incorporates new detail as to musculature and neck geometry and kinematics. He suggests the need for a new test dummy neck mechanism incorporating both passive properties and an active set of non-linear elastic and visco-elastic properties. Results are expected to be published in 1976.

D. Order of Reporting

The foregoing review illustrates that many of the clinical, physiological, biomechanical, and equipment aspects of the cervical hyperextension-hyperflexion problem have been addressed. However, until the present study, there has been no experimental work performed to cohesively measure the same set of response-related parameters from a population representative of the major characteristics of adults exposed to cervical injury.

Subsequent chapters of this report will describe the methodology by which subjects were selected and their neck characteristics tested (Chapter 2); the results of the tests, some observations about those results, and a description of a new muscle-force prediction technique (Chapter 3); the use of the results in a two-dimensional biomechanical model of a crash victim (Chapter 4); and a discussion of the inferences and conclusions which are derived from the results (Chapter 5). Following Chapter 5 are several Appendices with detailed data of interest to other researchers and to product designers.

CHAPTER 2

DATA ACQUISITION AND DATA REDUCTION

Each subject who completed the study participated in six different evaluations or tests. This chapter presents the experimental protocol used in the study. Methods used to recruit and medically screen potential subjects are discussed, as are test objectives, equipment and methods for the anthropometric, range of motion, muscle reflex time, and muscle strength tests. Techniques used in data reduction are described in this chapter; results are presented in Chapter 3.

A. Subject Selection

1. Experimental Design. A basic objective of this study was to examine certain neck characteristics using a study group which was representative of the adult U.S. population. The first task, then, was to define a "representative" population. The study population was chosen to be representative of the three primary variables of sex, age and body stature. Sex was chosen as a primary variable because of indications that females more often incur whiplash injury than males. (O'Neill, Haddon, Kelley and Sorenson, 1972) Since it is generally believed that the aging process adversely affects both joint range of motion and muscle reflexes, age was considered an important variable. Stature was included as the third primary variable on a biomechanical supposition that neck responses could be affected by a person's overall height, sitting height, and neck length.

The final statistical design chosen was 2 by 3 by 3 factorial with 10 subjects per cell, for a total of 180 subjects. Subjects were picked from both sexes. The three age groups selected initially were young adults (ages 18-24), early middle-age adults (ages 35-44), and elderly (ages 65-74). The elderly age group was later extended to include ages 62-74 because recruiting of people in this group was very difficult. Short, average-sized, and tall stature groups were selected, as represented by the 1-20th, 40-60th, and 80-99th percentiles of the population within each sex and age group. The selection of specific age and stature groups was based upon the latest available comprehensive study of the United States adult population (U.S. Public Health Services, 1962). The final criteria used to select and assign subjects are illustrated in Table 2-1.

2. Subject Recruitment Techniques. It was necessary to use various techniques to recruit the needed 180 subjects. The easiest group to recruit was the young age group, since university students were readily available. Advertisements in dormitories, word-of-mouth from other subjects, and announcements in engineering classes were sufficient to obtain young subjects. The chief difficulty in working with the student groups was that they were transient; many subjects were lost due to moving or graduation between initial screening approval and final testing. Middle-age subjects were obtained primarily through local newspaper advertisements. The elderly group was recruited through newspaper advertisements, word-of-mouth, and personal contact with organized senior citizens' groups. The most productive recruitment technique for all age groups was by word-of-mouth and by referrals from other subjects.

3. Health Screening and Approval. Each potential subject was asked to fill out a general health questionnaire. The questionnaire, illus-

Table 2-1

Final Subject Selection Criteria

Subject Groups		Number of Subjects Desired	Stature Range	
			Inches	cm
Females				
18-24	1-20%ile	10	58.4-61.6	148.2-156.5
	40-60%ile	10	63.0-64.5	160.0-164.0
	80-99%ile	10	65.9-69.3	167.5-176.0
35-44	1-20%ile	10	57.6-61.4	146.2-156.0
	40-60%ile	10	62.8-64.1	159.6-162.6
	80-99%ile	10	65.5-69.0	166.4-175.3
62-74	1-20%ile	10	55.8-59.5	142.0-151.0
	40-60%ile	10	61.1-62.1	155.0-157.7
	80-99%ile	10	63.7-67.0	161.8-170.0
Males				
18-24	1-20%ile	10	62.6-66.5	159.0-169.0
	40-60%ile	10	67.9-69.3	172.5-176.0
	80-99%ile	10	70.9-74.8	180.0-190.0
35-44	1-20%ile	10	62.3-66.4	158.2-168.5
	40-60%ile	10	68.1-69.2	173.0-175.5
	80-99%ile	10	70.7-74.1	179.5-188.0
62-74	1-20%ile	10	60.8-64.8	154.5-164.6
	40-60%ile	10	66.2-67.5	168.0-171.5
	80-99%ile	10	68.9-72.0	175.0-183.0
	Total	180		

trated in Figure 2-1, was adapted from the Cornell Medical Index and was modified to include questions related to auto accidents and bone and joint disorders which might influence neck characteristics. These questionnaires were reviewed by Dr. Janet Baum, the radiologist consultant to the study. If the subject's medical history was acceptable, approval was given for x-ray screening.

The next step was to obtain from each subject a series of five x-rays, of which two were used by Dr. Baum only for further clinical screening. These clinical x-rays were an anterior-posterior view of the cervical spine and a lateral view of the head and neck to the region of the T-1 vertebra, with the shoulders pulled down to expose the lower cervical spine. The remaining three lateral x-rays (neutral sitting position, maximum voluntary flexion, and maximum voluntary extension) were screened by Dr. Baum and were also analyzed to provide range of motion data as will be discussed later. From these x-rays, Dr. Baum could determine whether there were any abnormalities of the neck or arthritic conditions present that would disqualify a subject.

Each subject was thoroughly briefed on the nature of the tests being conducted and the amount of physical activity required. If the subject agreed to participate, he or she was asked to sign a subject consent form (shown in Figure 2-2). At this point, the subject was considered to be part of the final subject pool. Each subject was then scheduled for active response testing, to be conducted in a separate session.

4. Subject Scheduling. It was necessary to make contact with each subject at least three times. The first contact was to obtain the medical questionnaire. This was usually accomplished by telephone and

Date________________ HEALTH QUESTIONNAIRE (Please Print) Subject No.____________

NAME_________________________________ PHONE(S):______________
Last First Middle ______________

ADDRESS____
Street City State Zip

Soc. Sec. No.________________ Birthdate____________ Age______

Height__________ Weight__________

DIRECTIONS: Answer all questions. If you are uncertain as to how to best answer a question please circle Yes or No and explain further either at space provided after question or at the end of the questionnaire with the letter and number marked.

SECTION I:

1. Do you have a driver's license?.......................Yes No
   a. Approximately how many miles do you drive a year?__________
2. Has your eyesight changed recently?...................Yes No
3. Do you hear ringing or buzzing in your ears?..........Yes No
4. Do you have pains in your chest?......................Yes No
   a. If yes, explain ______________________________
5. Do you get short of breath long before anyone else?....Yes No
   a. If yes, explain ______________________________
6. Have you lost more than 10 pounds in the past 3 months.Yes No
7. Do you have severe pains in your abdomen (stomach)?....Yes No
8. Did a doctor ever say you had diabetes (sugar in the blood and urine)?..................................Yes No
9. Does severe rheumatism (or arthritis) interfere with your work?...Yes No
10. Are you now under a doctor's care?....................Yes No
   a. If yes, doctor's name and address ____________________

SECTION II:

1. Do you need glasses for reading or other close work?...Yes No
2. Do you need glasses for seeing things at a distance?...Yes No
3. Has your eyesight ever blacked out completely?.........Yes No
4. Do you ever see things double or blurred?.............Yes No
5. Do your eyes continually blink or water?..............Yes No
6. Do you ever have severe pains in or behind your eyes?..Yes No
7. Do you often see spots before your eyes?..............Yes No
8. Are your eyes often red or inflamed?..................Yes No
9. Are you hard of hearing?..............................Yes No
10. Have you had frequent severe ear aches?...............Yes No
11. Have you ever had a running ear?......................Yes No

Fig. 2-1. Health Questionnaire

SECTION III:

1. Have you ever been hoarse for more than a month?.......Yes No
2. Have you ever had frequent or severe nose bleeds?......Yes No
3. Have you had any x-rays, especially a chest x-ray?.....Yes No
4. Did your chest x-ray show anything in your chest?......Yes No
5. Were you ever in an automobile accident where you might have suffered "whiplash" or neck injury?...............Yes No

SECTION IV:

1. Has a doctor ever said your blood pressure was too high or too low?...Yes No
2. Does your heart often beat very rapidly?...............Yes No
   a. If yes, explain ______________________________
3. Do you ever have difficulty in getting your breath?....Yes No

SECTION V:

1. Do you have any difficulty in swallowing?..............Yes No
2. Are you often sick to your stomach with vomiting?......Yes No
3. Do you often have indigestion?.........................Yes No
   a. If yes, explain ______________________________

SECTION VI:

1. Have your joints ever been painfully swollen?..........Yes No
   a. If yes, explain ______________________________
2. Do your muscles and joints always feel stiff?..........Yes No
   a. If yes, explain ______________________________
3. Do you usually have severe pains in the arms or legs?..Yes No
   a. If yes, explain ______________________________
4. Are you crippled with severe rheumatism (or arthritis)?Yes No
   a. If yes, explain ______________________________
5. Does rheumatism run in your family?...................Yes No
   a. If yes, explain ______________________________
6. Do you suffer from weak or painful feet?...............Yes No
7. Do you have pains in the back or neck that make it hard for you to keep up with your daily activities?.........Yes No
8. Are you troubled by a serious bodily disability or deformity?...Yes No
   a. If yes, explain ______________________________

SECTION VII:

1. Do you have frequent severe headaches?.................Yes No
2. Do you often have spells of severe dizziness?..........Yes No
3. Have you fainted more than twice in your life?.........Yes No
   a. If yes, explain ______________________________
4. Are you ever aware of numbness or tingling in any part of your body?...Yes No
5. Was any part of your body ever paralyzed?..............Yes No
   a. If yes, explain ______________________________

Fig. 2-1. Cont.

6. Were you ever knocked unconscious?..................Yes No

a. If yes, explain ______________________________

7. Have you ever noticed a twitching of any part of your body? (other than eyes)................................Yes No

a. If yes, explain ______________________________

8. Did you ever have a convulsion (epilepsy)?...........Yes No

9. Has anyone in your family ever had convulsions (epilepsy)?...Yes No

SECTION VIII:

1. Are you definitely overweight?........................Yes No

2. Are you definitely underweight?.......................Yes No

3. Has there been any recent change in your weight?......Yes No

4. Have you ever had a serious operation?................Yes No

a. If yes, explain ______________________________

5. Have you ever had a serious injury?...................Yes No

a. If yes, explain ______________________________

6. Do you often have small accidents or injuries?........Yes No

a. If yes, explain ______________________________

SECTION IX:

1. Are you considered a nervous person?..................Yes No

Additional comments: (Please include dates, symptoms, frequency of occurrence, and any other relevant data.)

____

____

____

____

____

____

____

Note: This questionnaire modified from the Cornell Medical Index for the R.I.W.U. multiphasic testing, June 1951.

Fig. 2-1. Cont.

HIGHWAY SAFETY RESEARCH INSTITUTE
Institute of Science and Technology
Huron Parkway and Baxter Road
Ann Arbor, Michigan 48105

THE UNIVERSITY OF MICHIGAN

SUBJECT CONSENT FORM

I, The undersigned, understand that the purpose of this study is to determine basic information on the human neck necessary for improved protection of the occupant in automotive accidents. Specific tests in which I will be asked to be a subject include anthropometric measurements, neck muscle strength, voluntary range of motion, and variation in muscle response time. I acknowledge that I have received a complete briefing of these tests, am satisfied that I understand what is involved, and consent to any hazards involved. I have completed the health questionnaire, and am aware that my participation will be subject to medical screening both as to any history or subsequent x-ray findings which might make it inadvisable for me to continue. I realize that some discomfort or muscle strains could result from my participation, although the experimental procedures and apparatus have been designed to minimize these hazards. I also understand that I will be allowed, at any time, to stop for rest or to discontinue my participation in this study without prejudice or change in my pay. I further acknowledge that all the data are confidential and I agree to allow publication of any or all of the data collected on this data if presented in a coded form not identifying me.

Signature of Subject Date

Signature of Witness Date

Figure 2-2. Subject Consent Form.

through the mail. The second contact, for x-rays, and third, for active tests, required the subject to visit the laboratories at the Highway Safety Research Institute. The volume of scheduling and subject tracking activities was considerable, and a two-card system was initiated to prevent errors. Records were kept for each potential subject on a file card during the approval and screening process. When an approved subject became part of the subject pool, a second card (which identified the subject code number) was filled out. On the second card, the Subject Data Record, all pertinent information about the subject's progress through the study was kept. Items such as approval date, the date of each testing period, test numbers associated with the subject, and certain test results were all noted.

Each subject followed the same testing sequence. This sequence is itemized below in the order in which tests were conducted. Each of the tests is described in detail later in this chapter.

1st Session (after approval of questionnaire)

- Briefing and consent form signing
- Clinical and range-of-motion x-rays
- Range-of-motion photographic series
- Anthropometry (usually taken at this session)

2nd Session (after approval of x-rays)

- Anthropometry (if not taken at first session)
- Reflex time testing; flexors and extensors
- Muscle strength testing; flexors and extensors

Subjects were paid for their participation in the study.

B. Anthropometry

1. Objectives. The selection of anthropometric measurements for this study was designed to accomplish the following three objectives.

a. Obtain population comparison data. It was necessary to determine that the subjects chosen were as representative of the U.S. population as intended. Stature, erect sitting height, and weight were taken to satisfy this objective, since they were directly comparable measurements to those reported by the U.S. Public Health Survey.

b. Dimensionally describe the head and neck. Initial biomechanical modeling work indicated that head weight and head center-of-gravity location would affect dynamic response and thus influence the potential for neck injury. A primary objective, then, was to obtain as complete a physical description as possible of dimensional variables which might influence susceptibility to cervical hyperextension-hyperflexion injury. This objective was accomplished using both traditional means (measurements of head arc lengths and head and neck diameters and circumference) and by obtaining anthropometry from cervical x-rays (sizes and link lengths of the cervical vertebrae).

c. Comparisons with results from other investigators. Several measurements were taken to allow comparisons of this study population to other populations reported by other investigators. Included in this group were several measures from the lower body (such as hip breadth and sitting knee height) and several measures to assess body physique (skinfolds and joint diameters).

2. Measurements Obtained. A total of 54 anthropometric measures

were obtained from each of the 180 subjects and an additional ten from a subset of 61 young subjects. Of these, 48 body measurements were taken using traditional instruments and techniques and 16 were measured from the x-rays. Subjects were lightly clothed, wearing shorts and a sleeveless top, but measurements were made directly on the body in all cases. Body weight was taken to the nearest 0.5 lb, utilizing a Continental Medical Scale. Stature was taken with a Siber and Hegner anthropometer fixed to the wall. [It should be noted that this is the identical anthropometer used by Dempster in his classic biomechanical studies of joint range of motion (1955).] Two additional anthropometers were used for lineal measures. Other measurements were taken with a steel tape, sliding caliper, or hinged caliper.

A listing of the 64 measurements, grouped into six general categories, is contained in Table 2-2. The first 48 were taken in the order listed. A definition, detailed description, and illustration of each of the 48 traditional measures are contained in Appendix A to this report. The detailed definitions are included so that interested investigators may use the data appropriately and compare it with the results of other studies.

The four measures in Group A, Table 2-2, were taken with the subject in erect standing posture and the head in Frankfort Plane.* These included two population comparison checks (weight and stature) and two measures relating to neck length in standing posture (cervicale height and chin-neck intersect height).

---

* See definitions of anthropometry technical terms in the glossary to Appendix A.

Table 2-2

List of Anthropometric Measurements

A. STANDING (ERECT)

1. Weight
2. Stature
3. Cervicale (C7) Height
4. Chin-Neck Intersect Height

B. SEATED (ERECT)

5. Sitting Height
6. Sitting Cervicale Height
7. Sitting Right Shoulder (Acromion) Height
8. Sitting Left Shoulder (Acromion) Height
9. Left Tragion Height
10. Right Tragion Height
11. Nasal Root Depression Height
12. Left Sitting Eye Height
13. Sitting Suprasternale Height
14. Biacromial Breadth
15. Shoulder Breadth (Bideltoid)
16. Lateral Neck Breadth (Mid)
17. Anterior-Posterior Neck Breadth (Mid)
18. Anterior Neck Length
19. Posterior Neck Length

C. SEATED (RELAXED)

20. Sitting Height (Slumped)
21. Left Sitting Eye Height (Slumped)
22. Superior Neck Circumference
23. Inferior Neck Circumference
24. Head Circumference
25. Head Ellipse Circumference (Bennett)
26. Head Breadth
27. Head Length
28. Head Height
29. Sagittal Arc Length
30. Coronal Arc Length
31. Bitragion Diameter
32. Minimum Frontal Diameter
33. Minimum Frontal Arc Length
34. Bitragion Minimum Frontal Arc Length
35. Bitragion Inion Arc Length
36. Posterior Arc Length

37. Sitting Knee Height
38. Sitting Knee Height (Maximal Clearance)
39. Right Anterior Iliac Spine Height
40. Hip Breadth
41. Biceps Flexed Circumference (Right)

D. STANDING (RELAXED)

42. Calf Circumference (Right)
43. Femoral Biepicondylar Diameter (Right)
44. Humerus Biepicondylar Diameter (Right)
45. Right Triceps Skinfold
46. Right Subscapular Skinfold
47. Right Suprailiac Skinfold
48. Right Posterior Mid-calf Skinfold

E. CERVICAL SPINE LINKS (from x-rays)

49. C2 Link Length
50. C3 Link Length
51. C4 Link Length
52. C5 Link Length
53. C6 Link Length
54. C7 Link Length

F. VERTEBRAL BODY DIMENSIONS (from x-rays of young subjects)

55. C3 Height
56. C3 Depth
57. C4 Height
58. C4 Depth
59. C5 Height
60. C5 Depth
61. C6 Height
62. C6 Depth
63. C7 Height
64. C7 Depth

The location of many body landmarks with respect to a seating surface was determined with nine of the 15 Group B (seated erect) measures. These included the population comparison measure of erect sitting height (illustrated in Figure 2-3) and several measures to locate head, neck, and torso points with respect to each other (for example, tragion, cervicale, and suprasternale heights). Both left and right measurements were obtained from tragion (ear) and acromion (shoulder) to assess the amount of head tilt or shoulder slope of subjects in otherwise erect posture. Two shoulder-breadth measures completed the upper torso data. The remaining four measures in this group were external measures of neck size — two breadths and two lengths. The lateral neck breadth measurement is shown in Figure 2-4.

The six neck length, breadth, and circumference measures were devised for this study and had not previously been obtained from a large population. They were intended to define the cylindrical nature of the neck for modeling purposes, and so were more detailed than the survey-type measurements usually taken of the neck. It was considered to be of interest to determine potential biomechanical differences in neck injury susceptibility between individuals having short thick necks and those with relatively long gracile necks.

For the next group of 22 measurements (Group C), the subject was instructed to maintain body position but to relax into a normal slumped posture. Two slumped seated measures were then obtained relative to the seating surface. Two neck circumferences were taken in this group (inferior neck circumference is shown in Figure 2-5) to complete the description of the neck. The next thirteen measures were taken to fully describe the size

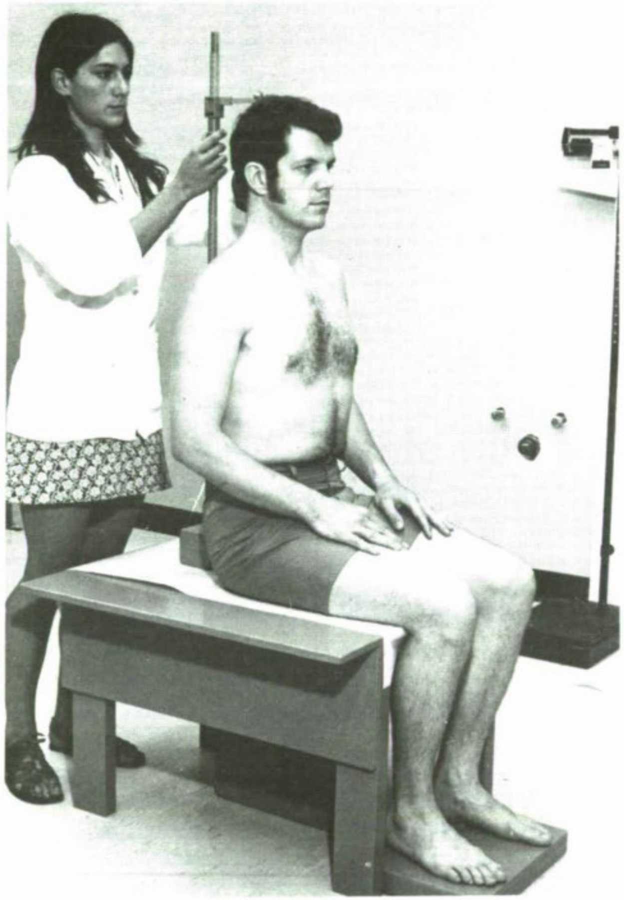

Figure 2-3. Erect seated height measurement being taken. Note that the hand-held anthropometer is fitted inside a small wooden block to assist the measurer in keeping the instrument aligned vertically.

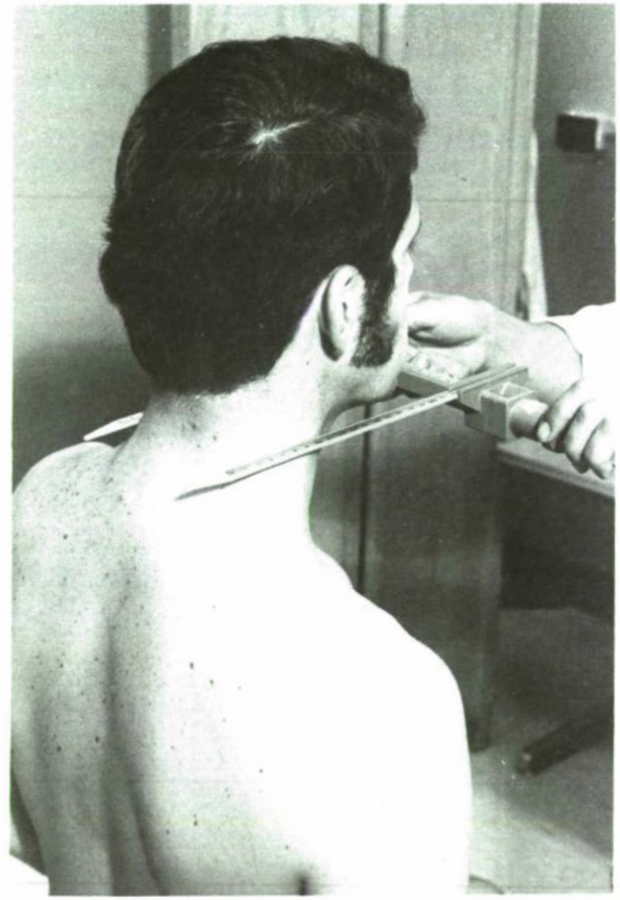

Figure 2-4. Lateral Neck Breadth measurement. This is taken at the midpoint of the neck.

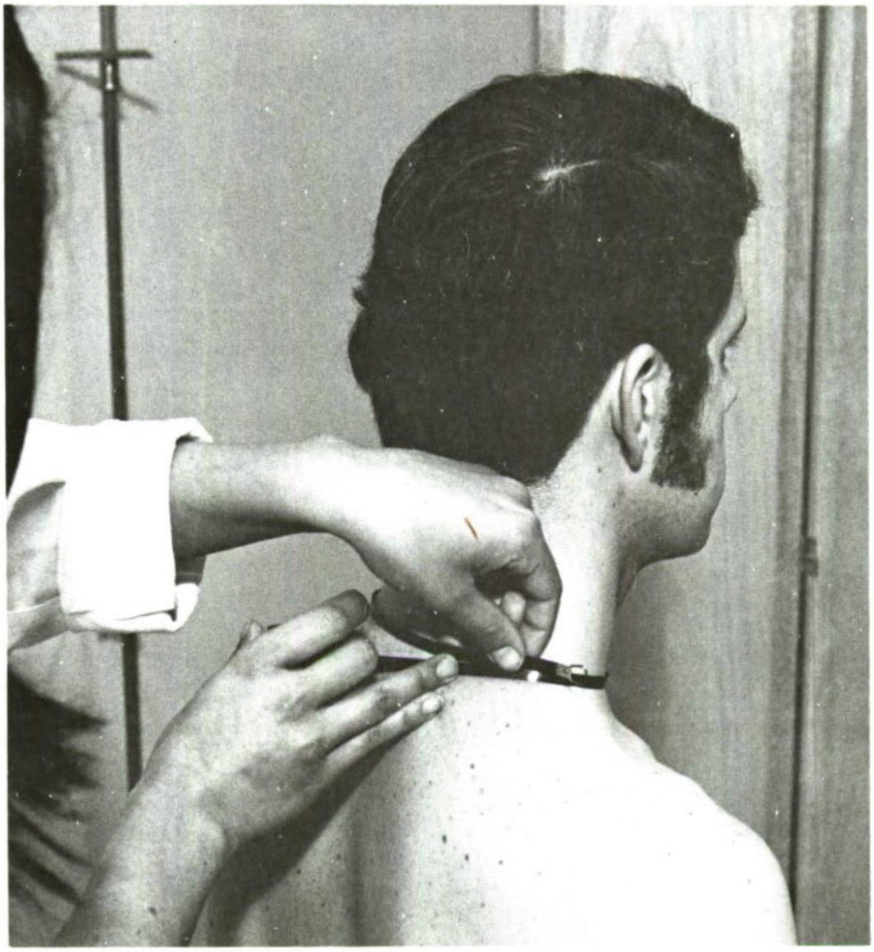

Figure 2-5. Inferior Neck Circumference measurement. This measurement was taken at the base of the neck, as near to the level of cervicale as possible.

and shape of the head for biomechanical modeling purposes. Spans (bitragion diameter, head length), circumferences, and arcs (bitragion-inion, coronal) were measured. Also, several lower body measures were taken of the lower leg and pelvic areas. The subject reassumed erect posture for iliac spine height and hip breadth measures, and hip breadth was usually taken over underclothing.

The last traditional measures (Group D) were all taken with the subject standing in relaxed posture and were all designed to assess body physique using the Heath-Carter technique (Heath and Carter, 1967). This group of skinfolds, limb circumferences, and bony diameters is analyzed to provide a universal somatotype rating scale which is applicable to both sexes at all adult ages. Ratings for each individual are expressed as a three-number sequence, each number representing evaluation of one of the three primary components of physique which describe individual variations in human body form and composition. This system differs from the classical technique of photographing the nude body in three views and subjectively assigning ratings, in that it is claimed to be entirely objective. The technique has been incorporated into a computer program designed by Dr. Clyde Snow at the FAA Civil Aeromedical Institute and modified by Schanne (Schanne, 1972). This program has previously been used by the authors to determine somatotypes in a study of USAF Daisy Track Test volunteers (McElhaney, et al, 1971), and in a USAF study of body linkages of the human torso (Snyder, Chaffin, and Schutz, 1971).

Six cervical spine link lengths were obtained from the neutral position x-ray of each subject, and these measures constitute Group E of the anthropometry list. Figure 2-6 illustrates an x-ray film,

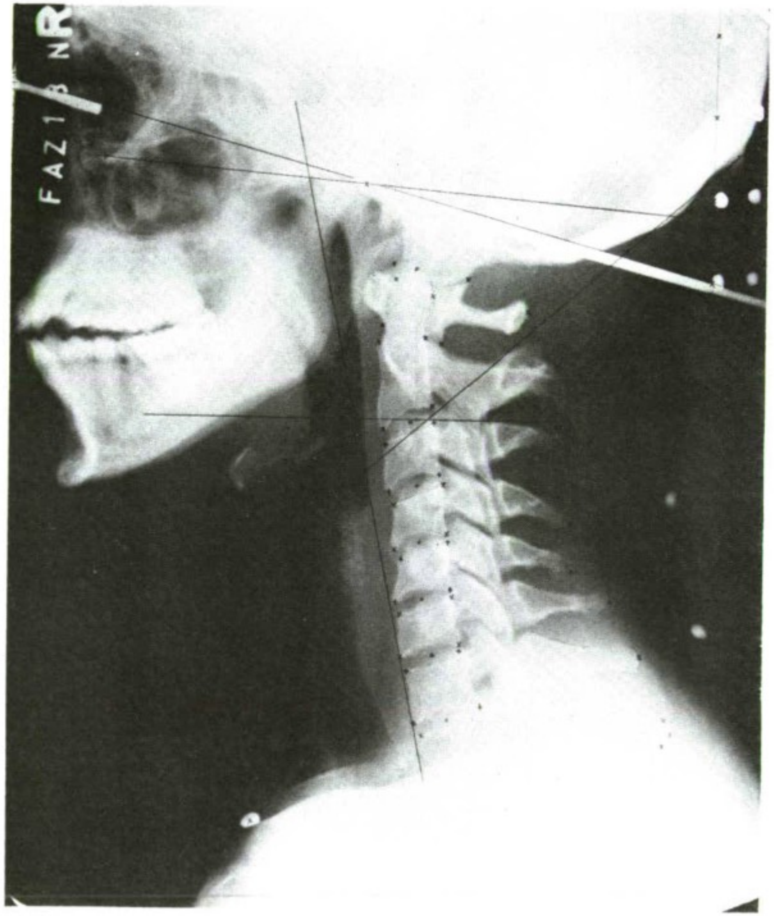

Figure 2-6a. Neutral Position x-ray, marked for coding.

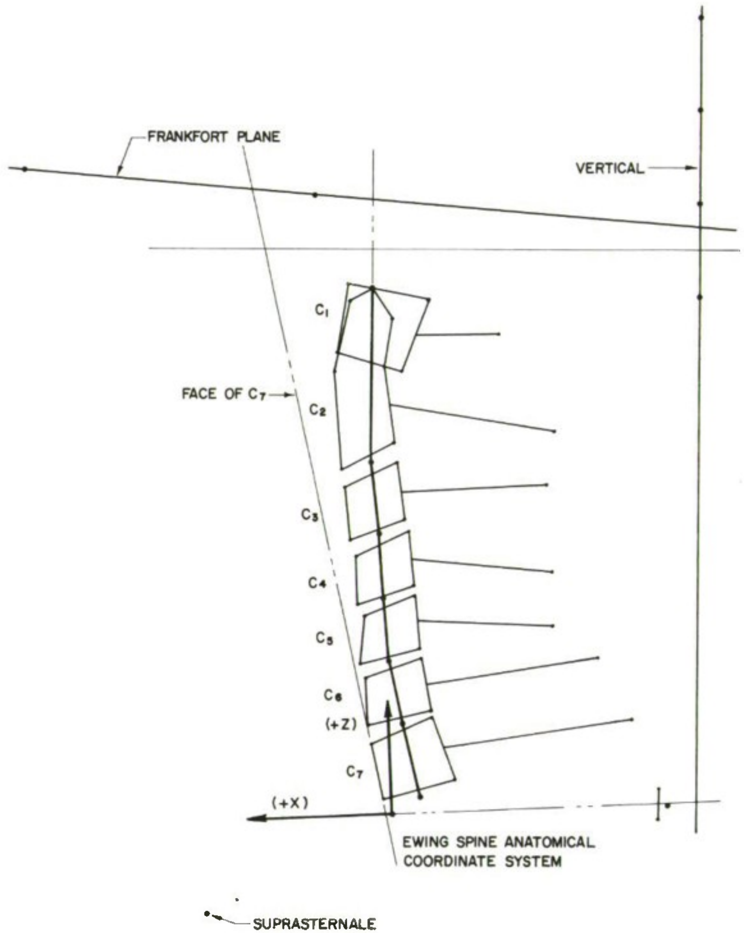

Figure 2-6b. Diagram of information coded from x-ray at left.

Figure 2-6. Anthropometry from Neutral Position x-ray. Cervical spine links are shown in heavy black line, mid-sagittal shape of vertebral bodies is described by connecting the four corners of the body.

appropriately marked, and a diagram of the spine as coded from the x-ray. Each link of interest is defined as the length between the estimated locations of the nucleus of each intervertebral disk. For example, the length of the C4 link, as shown in heavy line in Figure 2-6b, is the distance between the C3-C4 and C4-C5 disk centers. The exception is C2, the axis vertebra link, which is defined as the distance from the C2-C3 disk center to the tip of the odontoid process. This definition accounts for the height of C1 and C2 combined, since examination of x-rays reveals that the tip of the odontoid process is even with or superior to the top of C1.

The final group of ten anthropometric measures taken from the x-rays (Group F) were obtained only from 61 young subjects. These are the mid-sagittal height and depth of the cervical vertebral bodies from C3 through C7. These data were analyzed for the paper by Katz, et al (1975). The definitions of height and depth were based on the shape of the vertebral body as coded from the x-ray (Figure 2-6b). Height was defined as the average of the dorsal and ventral edge lengths, and depth was the average of the superior and inferior edge lengths. It is recognized that the vertebrae in cross-section are neither straight-edged nor rectangular. A limited comparison of areas between the rectangular approximation and planimeter data indicated only very slight differences.

An attempt was made to avoid inter-measurer error by having measurements taken by a single individual. Early in the study the initial measurer left unexpectedly to resume her postgraduate education. In order to assure continuity in measurement technique, all subjects measured to that time were remeasured by the new anthropometrist.

Repeat measurements were made periodically on the same subjects, and these data were analyzed to insure measurement accuracy during the data collection phase.

3. Data Reduction and Analysis. As the 48 traditional anthropometric measures were taken, a recorder repeated the dimension and wrote it onto an anthropometry form. The measurements, a subject code number, and a code number for the subject's race were keypunched onto computer cards and verified by a different keypuncher. A listing was obtained and the data were scanned and edited to remove or correct any obviously inaccurate number. Statistical analysis was accomplished using a series of computer programs available through the Statistical Research Laboratory of the University. Descriptive statistics such as mean, standard deviation, and percentiles were obtained, and trends or interactions were explored with analysis of variance, analysis of covariance, and correlation techniques. Additional editing of the original data was accomplished after the descriptive statistics were obtained, by examining the results for unusually wide ranges. Other data-handling errors were assumed to be random and insignificant.

The methods used for reducing and analyzing the radiographic data will be discussed in more detail in the next section. In brief, the points of interest were marked directly onto the x-ray film. For the link-length data, the points were converted to computer code by a digitizing device, and lengths were calculated using a computer algorithm. The estimated link pivots were coded from each of the three x-rays, so the link data reported in Appendix D are based on the average of three measurements per subject. For the vertebral body height and depth analysis, measurements were taken directly from the marked neutral position x-ray, using a vernier caliper. They were then averaged appropriately and descriptive statistics and analysis of variance were calculated using a statistical desk-top calculator.

C. Sagittal Plane Range of Motion

1. Objectives. One of the basic physical measurements of primary interest in this study was the voluntary range of motion of the head and neck - the limits of forward and backward movement. Three objectives evolved for this measurement: first, to determine range of motion in the automotive seated position relative to a reference external to the body; second, to measure range of motion of the head relative to the base of the cervical spine (which determines the role of the torso in neck range of motion); and third, to obtain the range of motion of the cervical vertebrae relative to each other. An additional constraint, and one in which this study differed from classical range of motion studies, was that the flexion and extension motions used were intended to simulate the kinetics of automotive crash conditions. Finally, a substudy was conducted to determine the repeatability of the measurements - whether a person, subjectively responding to the same instructions, would achieve the same position in repeated trials.

2. Measurement Techniques. Two methods were used to acquire the cervical range of motion data.

First, three lateral x-rays of the head, neck, and upper torso were taken, using a range-of motion sequence consisting of neutral, maximum voluntary flexion, and maximum voluntary extension positions.
Ten by twelve inch film size was used to provide adequate detail

and coverage for each position. The subject was seated in an unpadded, simulated automotive seat, designed to the specifications of Dempster (1955), with a seat pan angle of 6 degrees below horizontal and seat back angle of 103 degrees to seat pan. The chair was mounted on a wheeled platform so that subject positioning relative to the x-ray source could be accomplished without disturbing the seated subject. The subject was seated with the mid-sagittal plane of the body along the centerline of the seat, the buttocks firmly against the seat back, and the shoulders resting comfortably against the seat back. X-ray-opaque lead markers were taped to the skin at suprasternale, cervicale, the C5 spinous process, tragion, and sellion. A metal rod, attached to a head band which was fitted around the subject's head, was then adjusted to be in the sellion-tragion plane. This rod was used to determine the head position relative to vertical in the neutral position views. The headpiece and rod were removed for the flexion and extension positions. A wooden pendulum which had four lead shot markers placed at one-inch intervals was exposed in each x-ray view to provide external vertical and magnification factor references.

Immediately after the x-ray sequence was complete, the subject, with lead markers still taped to the skin, was taken to the cervical measurements laboratory. There, the subject was seated in a seat identical to the one in the x-ray laboratory (but fixed to the floor). High-contrast markers were taped over the lead markers at sellion, tragion and suprasternale and also on the shoulder. The subject was then photographed in the same sequence - neutral, flexion and extension - using two orthogonally-placed cameras. The sequence was photographed three times. The one x-ray and three photographic sequences gave four replications of each position and provided the data for the repeatability substudy noted above.

Two 35mm Praktina cameras were used to obtain the photographs of the subject. They were fixed to camera stands and arranged so that the lens axes intersected each other at a 90 degree angle. One camera photographed the front of the subject, the other photographed the right side. A 24-volt dc power supply was used to trigger solenoids which in turn tripped the camera shutter release. A single remote control could then be used by the experimenter to take both pictures simultaneously when the subject had achieved the desired position. Only the side view was analyzed for range of motion; the front view was used as a check to insure planar head motion.

The same position definitions were given to each subject as described below.

1) Neutral position: "Assume a normal, relaxed sitting position, looking straight ahead." This is illustrated in Figure 2-7a. The neutral head position, rather than Frankfort Plane neutral position, was chosen to more closely simulate the automotive seating condition. Flexion and extension motions were then reported relative to the neutral position. (In actuality neutral seated and Frankfort Plane neutral positions show head location differences of only a few degrees.) The subject was instructed to return to this position after each motion.

2) Maximum voluntary flexion: "Without moving shoulders or upper torso, thrust chin straight ahead and then tuck chin under as far as possible, trying to touch chest with chin." The subject shown in Figure 2-7b had good range of motion in flexion and was nearly able to touch her chin to her chest. The two-phase movement was chosen to simulate front-end impact deceleration in which the subject is wearing an upper torso

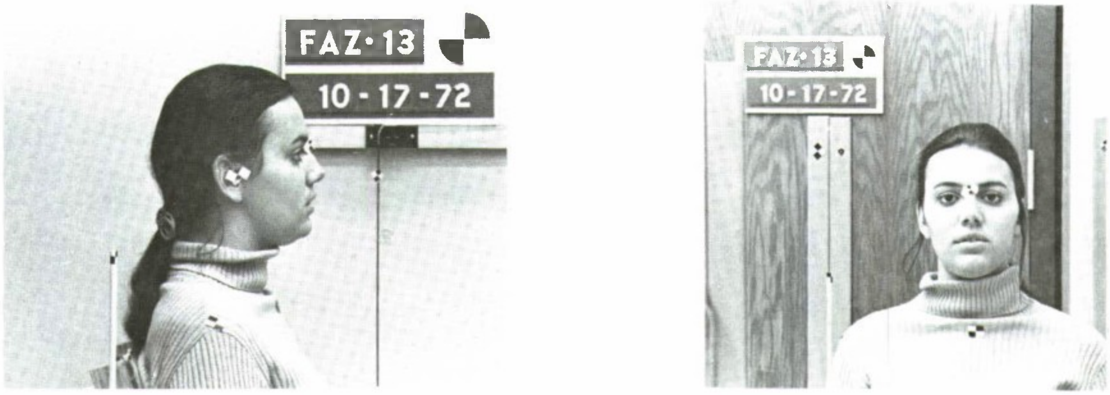

Figure 2-7a. Neutral, or normal, sitting position.

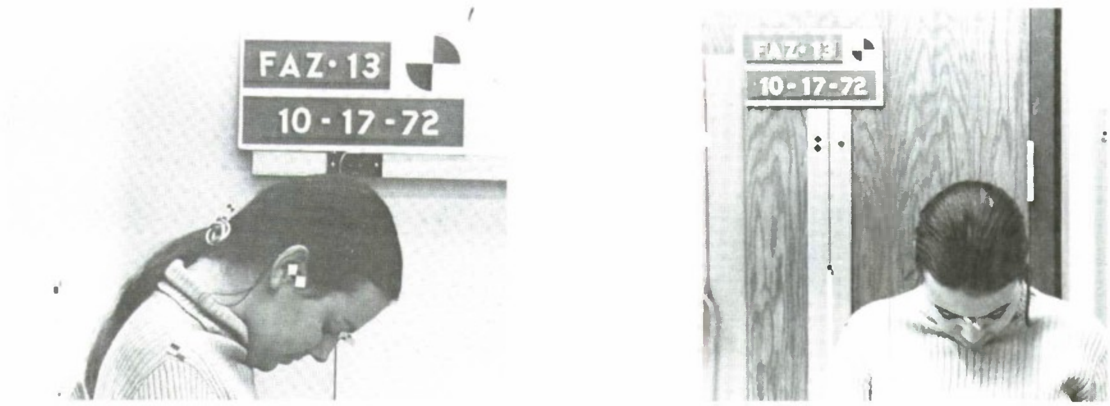

Figure 2-7b. Maximum voluntary flexion position.

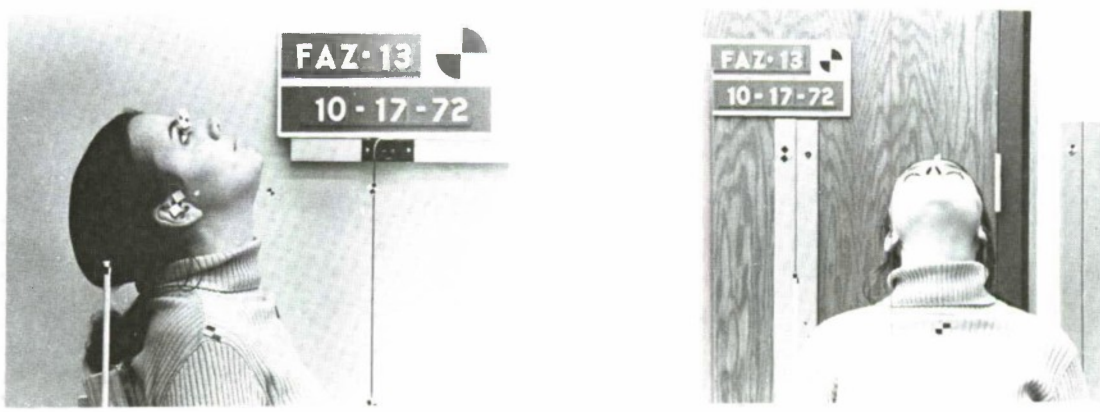

Figure 2-7c. Maximum voluntary extension position.

Figure 2-7. The three positions photographed for range of motion analysis. Three such sequences were obtained for each subject. Range of motion was measured between the sellion-tragion plane and the vertical marker.

restraint. Ewing and Thomas (1972, p.84) have shown that the momentum of the head carries it straight forward when the restrained torso stops, simultaneously causing extension in the upper cervical spine and flexion in the lower cervical spine. When the head is finally restrained by the neck, it pivots down and completes the hyperflexion of head and neck. This functional method of measuring flexion was chosen because of its practical relationship to the automotive situation.

3) Maximum voluntary extension: "Without moving shoulders or upper torso, and with the jaw completely relaxed so that it opens, allow head and neck to rotate backward as far as possible." This position, demonstrated in Figure 2-7c, was intended to simulate a rear-end collision with complete surprise and no head restraint. The relaxed and open jaw allowed a few more degrees of extension from each subject and provided a more practical simulation of the surprise rear collision.

Two changes in the x-ray methodology were made in the initial stages of the study. The rod and headpiece described above were originally left in place for all x-ray and photograph tests. Analysis of data from 26 subjects revealed that there was significant movement of the rod alignment due to scalp skin excursion. Subsequently, the headpiece was aligned only for the x-ray of the neutral position and other boney landmarks were used for range-of-motion analysis.

The second x-ray methodology change involved the seating surface. Initially, one neutral position lateral x-ray was taken with the subject sitting in a Ford Pinto bucket seat which had been modified slightly to have the same seat back angle as the hard seat. After 27 subjects had been so tested, a t-test was performed comparing the difference in head-neck orientation between the soft and hard seats. The mean difference was 1.2 degrees, which was not significantly different from zero at an α significance level of one percent. This meant that the head position was not statistically different in either seat and that the hard seat could be considered an adequate representation of the actual automobile seating position. At that point, the soft seat x-ray was eliminated in favor of the dropped-shoulders neutral position view. (This view had been requested by the radiologist because the position of the shoulders in normal seated position often blocked the view of the lower cervical spine and hampered the clinical evaluation.)

3. Data Reduction and Analysis. Range of motion of the head relative to an external marker was determined manually from both x-rays and photos. For the three photographic sequences the 35mm film negative was projected onto the back of translucent glass. In each photo, the angle between the sellion-tragion plane markers and the vertical line was measured to the nearest 1/2 degree. Flexion and extension angles were then calculated and reported, together with the sellion-tragion angle relative to vertical and the total range of motion (flexion plus extension). For the x-rays, a "skull plane" was defined tangent to the base of the skull, and the changes in angulation of this plane relative to the external vertical markers were used to calculate flexion and extension ranges. The metal rod, aligned in the sellion-tragion plane, provided neutral head position data. Finally, a line through the face of the seventh cervical vertebra was projected to intersect the skull plane. Angular changes between these two references provided the data for flexion and extension of the head relative to the base of the cervical spine.

The neutral head position and range of motion data from the x-rays and three sets of photographs were keypunched onto cards. Statistical analyses included descriptive statistics, analysis of variance, and correlation.

The x-rays were also subjected to an extensive analysis by computerized techniques. Each of the neutral, flexion, and extension position views was coded as shown in Figures 2-8, 2-9, and 2-10. The figures illustrate the x-ray as marked for coding and a diagram showing the coded points connected to highlight the vertebral bodies, cervical spine links, and planes of interest. The subject in these three x-rays is the same subject as shown in Figure 2-7.

After the x-rays were marked, they were digitized for computer analysis using a BB&N Model 303 Data Coder. This device punches a paper tape with x-y coordinates for each coded point on the x-ray. A total of 218 points was coded from each set of three x-rays.

The digitized paper tapes were then analyzed by Dr. S. A. Kelkar, using a Hewlett-Packard 2100 minicomputer. The computer algorithms calculated the lengths of the cervical spine links and a series of angles including Frankfort and Ewing plane angles* to vertical and cervical spine link angles relative to adjacent links. These data were used to calculate descriptive statistics for range of motion of the individual vertebrae.

D. <u>Sagittal Plane Response to Low Levels of Acceleration</u>

1. <u>Objective</u>. The objective of this portion of the study was to measure the dynamic response of the head and neck to a low-level acceleration pulse. The neck response was defined in terms of the

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*Ewing plane angle is the +X axis of a spine anatomical coordinate system with origin at T1 (see Figure 2-8).

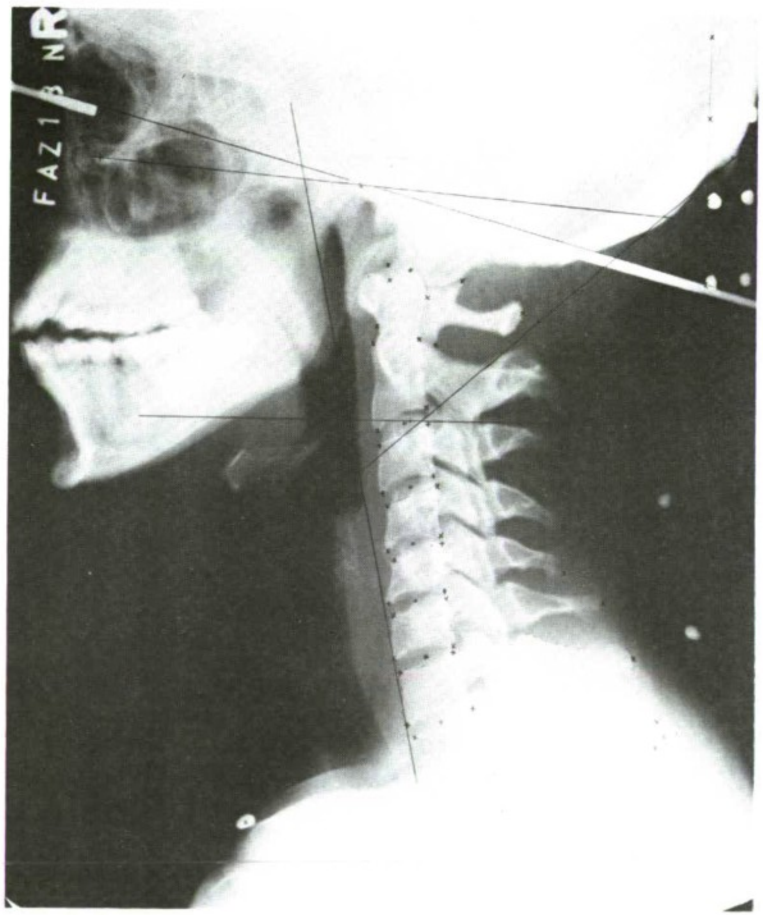

Figure 2-8a. Neutral Position x-ray, marked for coding.

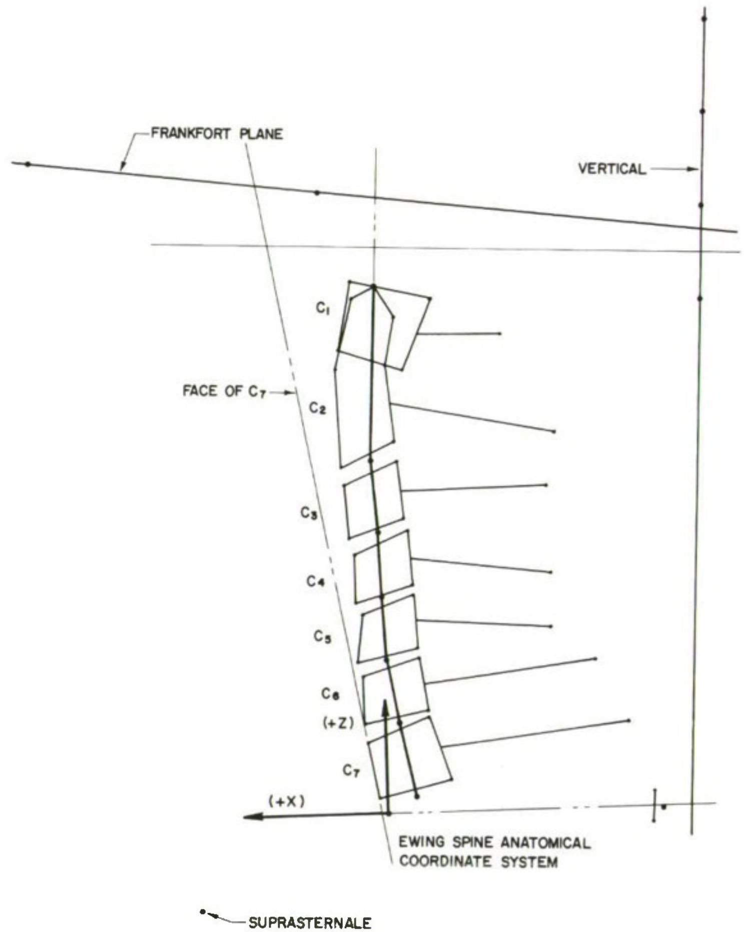

Figure 2-8b. Diagram of coded Neutral Position x-ray.

Figure 2-8. Range of motion analysis from Neutral Position x-ray. Note metal rod aligned in sellion-tragion plane, vertical marker pendulum, and definitions of Frankfort Plane and Ewing spine anatomical coordinate system. Same subject as in Figure 2-7.

Figure 2-9a. Flexion Position x-ray, marked for coding.

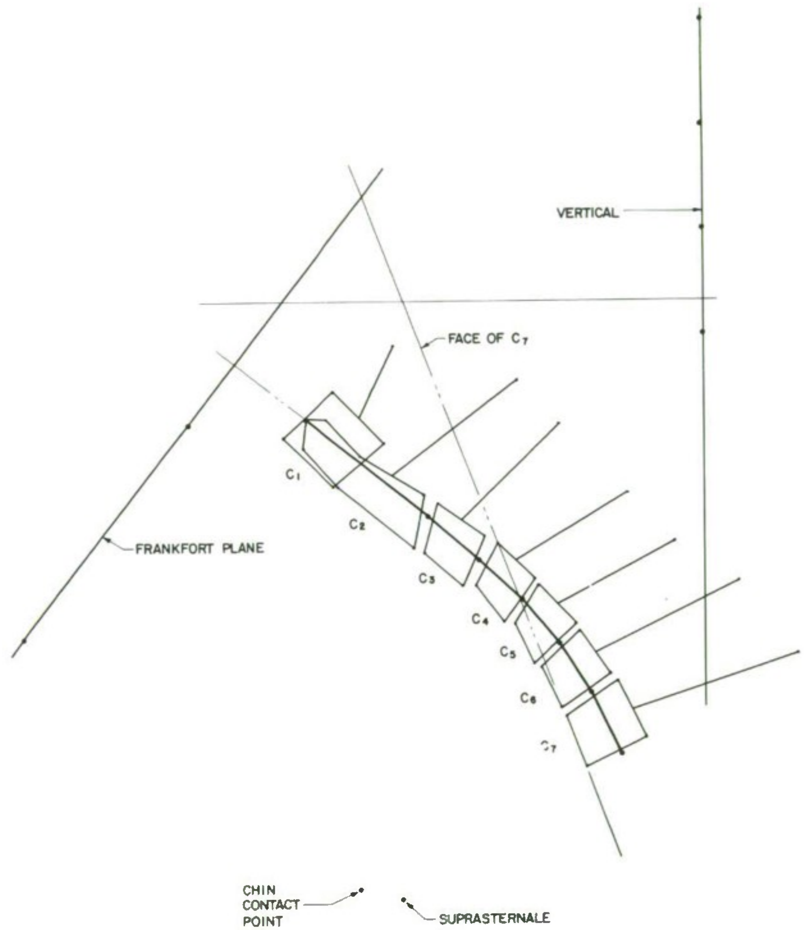

Figure 2-9b. Diagram of coded Flexion Position x-ray.

Figure 2-9. Range-of-motion analysis from Flexion Position x-ray. Note the relative positions of the vertebral bodies and that the skin surface of the chin nearly contacted the chest.

Figure 2-10a. Extension Position x-ray, marked for coding.

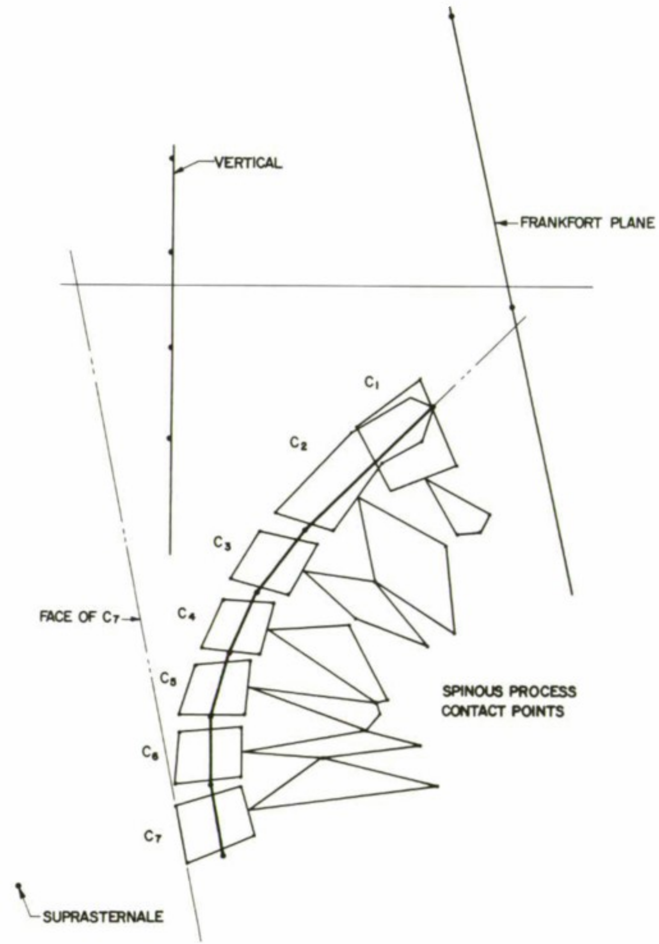

Figure 2-10b. Diagram of coded Extension Position x-ray.

Figure 2-10. Range-of-motion analysis from Extension Position x-ray. Note that in this position, the probable points of contact of the spinous processes are coded, to assess the degree of maximum possible extension achieved.

involuntary stretch reflex time of the neck muscles, while head response was described by acceleration time-history.

2. Methodology and Equipment Used for Stretch Reflex Test. The stretch reflex times of the cervical flexor and cervical extensor muscles were determined using a controlled "jerk" of the head to induce muscle response and electromyography (EMG) to indicate when the reaction had taken place. Prior to testing, pairs of Beckman 16mm surface electrodes were attached in a bipolar arrangement to the skin over the sternomastoid (flexor) and splenius and semispinalis capitis (extensor) muscles. The active muscle electrodes were positioned according to the recommendations of Davis (1959), with modifications as necessary for subject size. A fifth (ground) electrode was placed over the C7 spinous process. The subject was then seated in the same simulated car seat as used for the range-of-motion tests, and a headpiece, modified from a welder's helmet liner and weighing 225 g, was fitted tightly around the head. Attached to the headpiece were two uniaxial Bruel and Kjaer type 4333 piezoelectric accelerometers, mounted at the top and front of the headpiece with their sensitive axes parallel. A rear-quarter view of a subject with the electrodes and headpiece in place is shown in Figure 2-11. Also attached to the headpiece (visible in Figure 2-11) was a cord, made of 25-pound-test woven nylon fishing line, and anchored to the headpiece at both sides, near the level of the head center of gravity. This cord was passed over a pulley and through a one-pound weight which was held in place by an electromagnet. The cord was then tied to a two-ounce "pre-tensioning" weight which removed the slack from the cord and which was adjustable to catch the one-pound weight and limit its travel. For each subject, the pre-tensioning weight was initially positioned to stop the one-pound weight after a drop

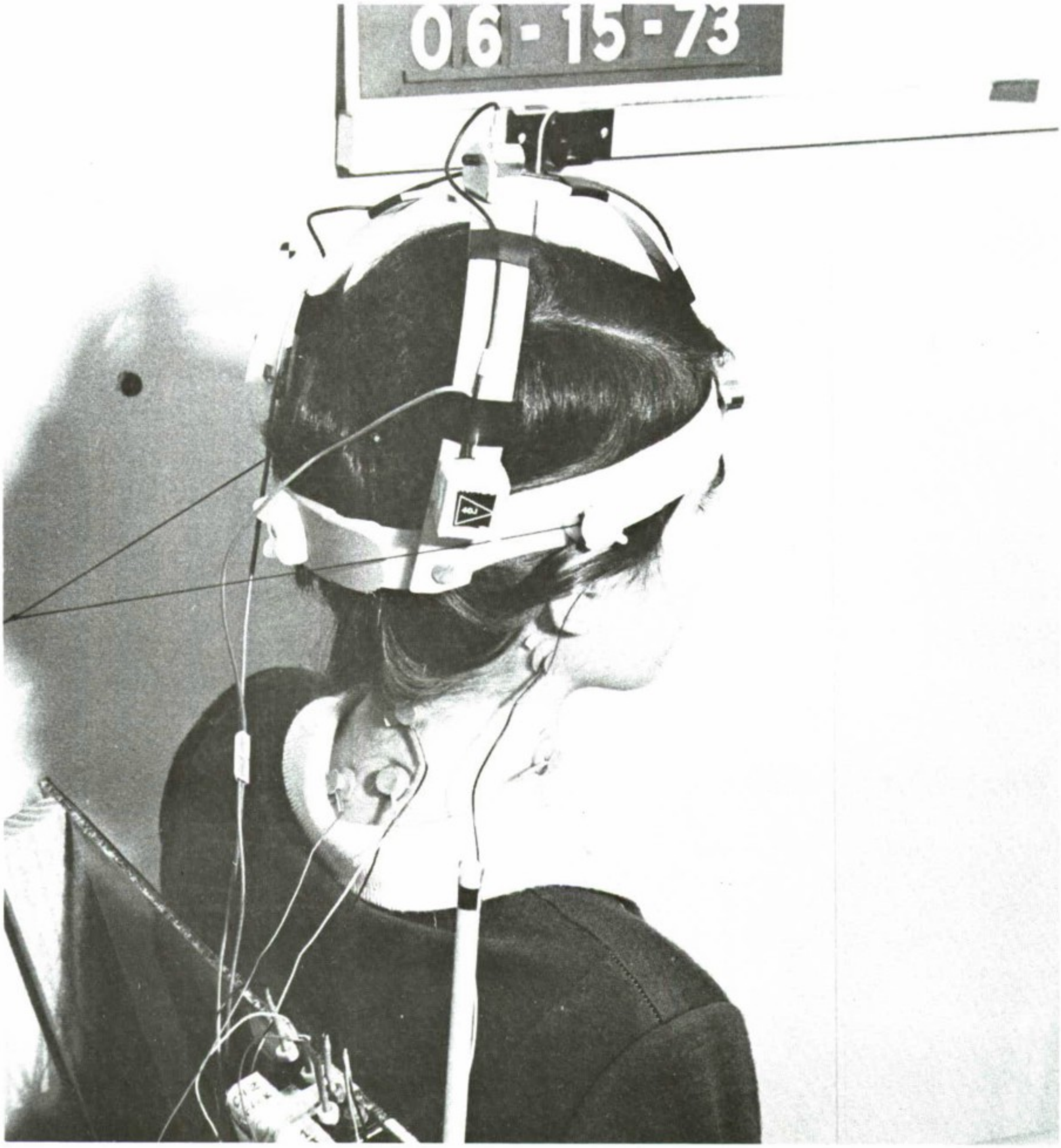

Figure 2-11. View of reflex test subject, showing electrodes and headpiece. Two electrodes each are placed over the cervical flexor and extensor muscles on the right side; the ground electrode is over the C7 spinous process. It was often necessary to trim hair to place the upper rear electrode properly. The headpiece was adjusted to fit tightly around the head. The two accelerometers may be seen at the top and front of the headpiece.

of four inches. If the subject did not exhibit a stretch reflex, the weight was readjusted for a drop of 6, 8, or (rarely) 10 inches. In all cases the minimum weight drop needed to produce a stretch reflex response was used. The test setup for a stretch reflex test of the neck flexor muscles is shown diagramatically in Figure 2-12. The same arrangement is illustrated in Figure 2-13 to show a test subject in place and the relationship of the test operator's console to the subject. In order to measure the stretch reflex time of the extensor muscles, the mounting board for the pulley and electromagnet was moved to the upright guides in front of the subject. For those tests, a mask attached to the mounting board was used to block the subject's view of the weight.

Reflex time testing was conducted in the following manner. The subject, in position as shown in Figure 2-13, was encouraged by the experimenter to relax the neck muscles. The EMG signal from the muscles of interest was monitored with an oscilloscope. At a random time after a relaxed muscle signal was observed, the experimenter would operate a silent switch on the console. This would momentarily interrupt the electrical power to the electromagnet, allowing the one-pound weight to drop onto the pre-tensioning weight - pulling the head backward (for flexor tests) or forward (for extensor tests). The accelerometers on the headpiece measured head motion and acceleration and the electrodes detected muscle activation. Enough repetitions of the test to produce three reflex time data points were conducted for each head-loading direction.

The signal amplifying, monitoring, and recording instrumentation is illustrated in Figure 2-14. All testing control and amplifying functions were performed at a seven-channel console. Six channels each had a separate amplifier, signal filtering switch, ac-dc mode selector, and VU meter. The

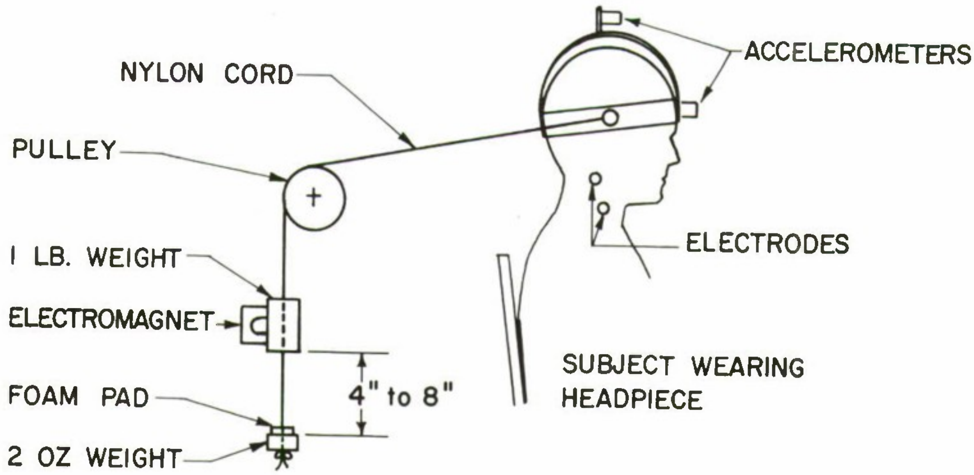

Figure 2-12. Diagram of reflex test setup. Test operator momentarily interrupts current to the electromagnet, allowing the one-lb weight to drop onto the 2 oz weight, thus imparting a controlled "jerk" to the head.

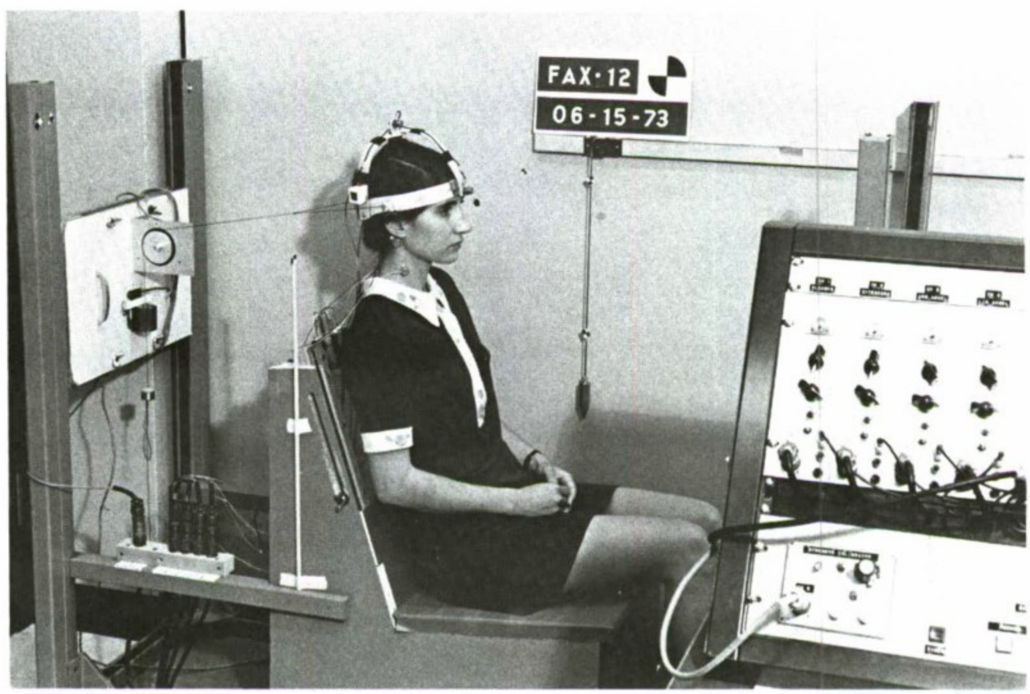

Figure 2-13. Photograph of subject ready for test of flexor muscle reflexes. Subject sits in relaxed normal sitting position in simulated automobile seat.

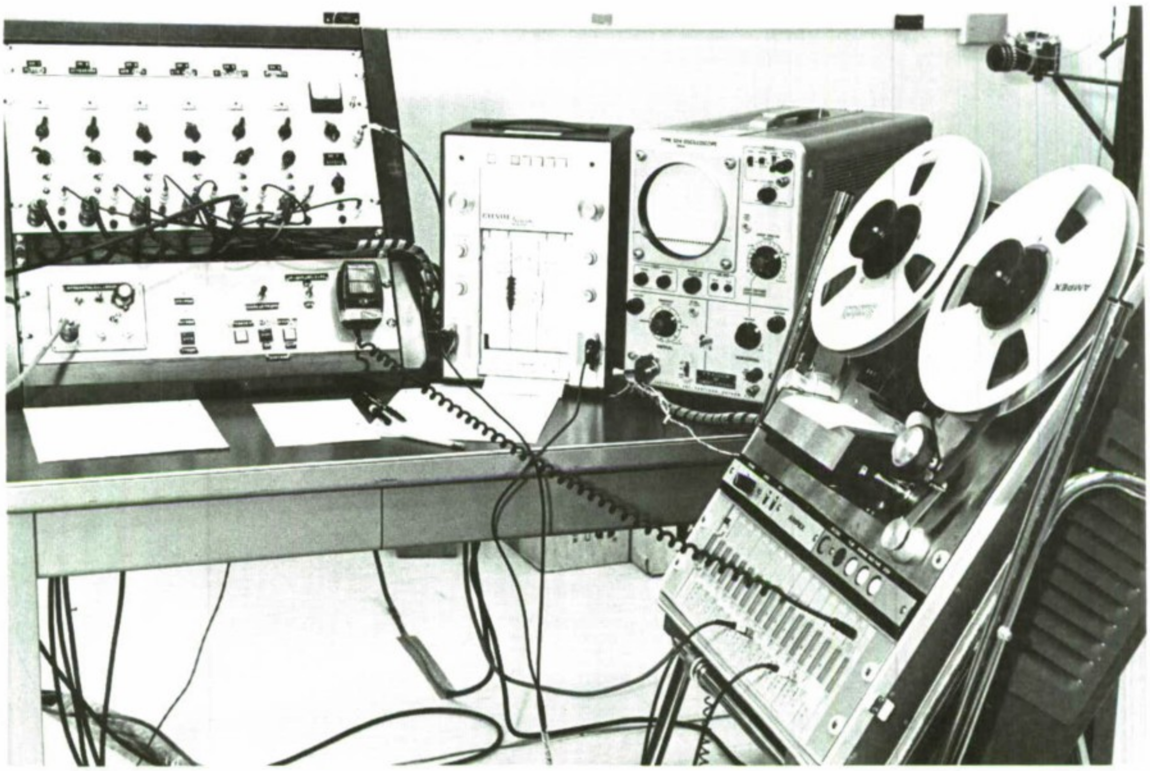

Figure 2-14. Test instrumentation, monitoring and recording equipment. The test conductor's console, with seven-channel amplification, strength test calibrator and tape recorder controls, is shown on the left. Monitoring equipment included the Brush recorder (post-test monitoring) and an oscilloscope (pre-test monitoring). The instrumentation recorder had capability to record and reproduce seven channels of data plus a voice track.

seventh channel was the "control" channel which put a constant level dc signal (chosen by a switch on the console) onto the recording tape and also noted when the switch was activated to initiate a test. Also on the console was a calibrator for the strength test (to be described in the next section), an override switch to prevent the weight from being dropped, the microphone, and remote on-off controls for the tape recorder. The entire test could be conducted and recorded from the console. Pre-test monitoring was accomplished by observing EMG signals in the oscilloscope. Post-test monitoring was achieved with the two-channel Clevite Brush strip-chart recorder. Two channels of interest (the primary muscle group and the accelerometer at the top of the headpiece) were taken off the appropriate playback channels of the tape recorder and displayed on the Brush recorder. The experimenter then knew immediately: (a) that the test had been recorded properly, and (b) whether the reflex was clear enough to provide data. The unprocessed results of each test were recorded using an Ampex PR500 seven-channel instrumentation recorder-reproducer with a voice track. Since many test signals had large low-frequency components, FM recording was used for each channel. As each test was performed, the test number and special conditions were noted on the Subject Data Record card.

For each reflex time test, the following data were recorded: two channels of EMG (flexors and extensors); two channels of acceleration (top and front of headpiece); head linear displacement (measured when the cord rotated the pulley attached to a potentiometer mounted on the pulley axis); and the control channel. A six-channel strip chart record of a single test is reproduced in Figure 2-15, to illustrate the data as they were tape-recorded.

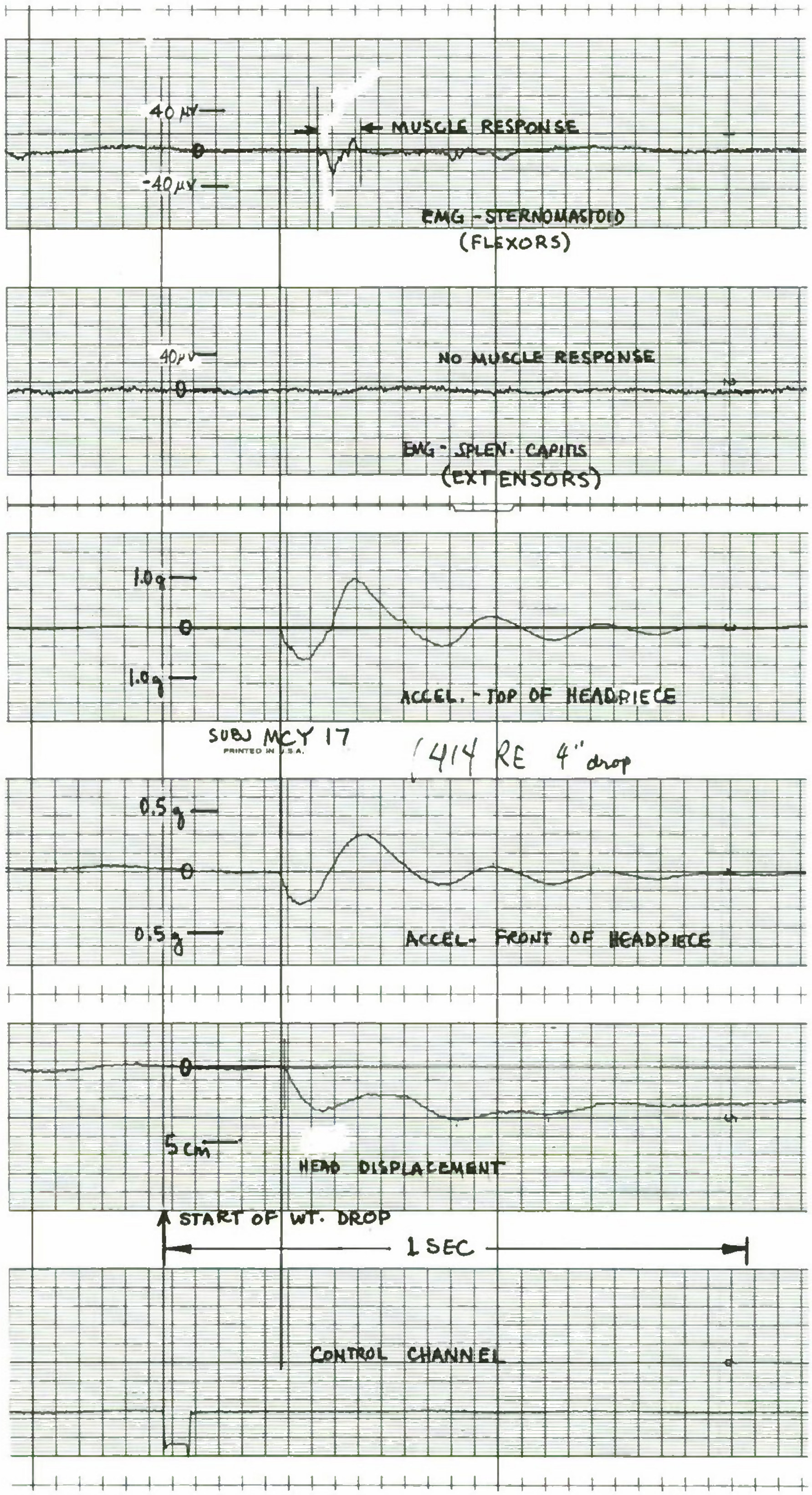

Figure 2-15. Strip-chart record of a stretch reflex test. Shown are two channels each of EMG and acceleration, linear head movement and the control channel. Since this was a flexor test (weight dropped behind head), no response was expected from extensor muscles, and none is seen.

3. Data Reduction and Analysis. The response data of primary interest were obtained by analyzing the strip chart records obtained immediately post-test. Five items of data were measured from each test record: muscle reflex time (from EMG trace), and peak magnitude and time to peak magnitude of both head acceleration and head deceleration. Stretch reflex time was defined as the time difference between onset of head acceleration and onset of significant change in muscle activity. Time to peak deceleration was of interest because it represents the point of maximum rearward movement of the head and therefore is indicative of reaction time (stretch reflex plus sufficient muscle contraction to stop head motion). The stretch reflex and head deceleration measurements from a typical strip-chart record are illustrated in Figure 2-16. Since three identical trials were conducted for each subject, the data from the three trials were averaged and reported as the results for that subject. The data from flexor and extensor tests were then keypunched for computerized statistical analysis, as described previously.

Initially, it was intended that the test data be reduced and analyzed by a computer algorithm. (This is why the control channel was included in the console.) Such a program was written, and it had the capability to sample up to six channels of data from the tape recorder, store the digitized raw data onto magnetic tape, compute the desired reflex times and acceleration data, and route the results to a line printer. The design logic of the program is described in some detail in the Third Quarterly Technical Report (Snyder and Chaffin, 1972a). Unfortunately, the program depended on virtually noise-free signals to produce accurate results, and, while the test apparatus produced such signals, the tape recorder-reproducer did not. Consequently, the change in EMG signal that occurred at the onset

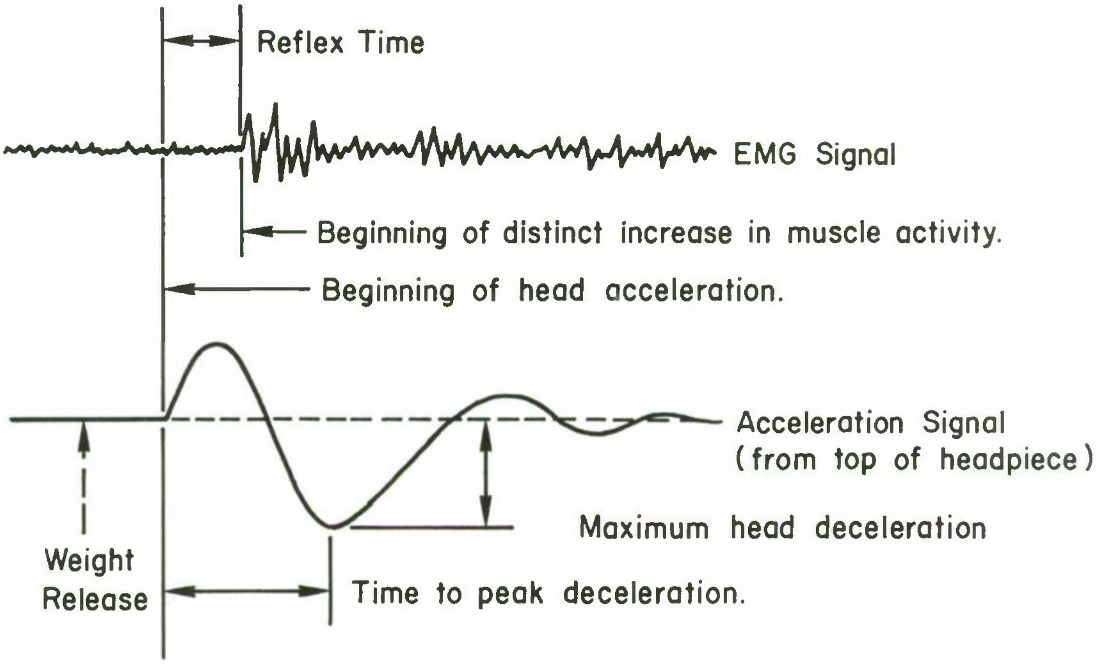

Figure 2-16. Diagram of typical stretch reflex test result. Stretch reflex, head acceleration, and head deceleration data were obtained for each test.

of stretch reflex action was insufficient to be detected by the computer program, even when obvious to the trained human eye. All of the test runs were ultimately computer-processed, but the results were too often unsatisfactory. Therefore, the reflex test results reported in Chapter 3 of this document are those obtained from the manual analysis of strip charts. (It should be noted that the program did produce acceptable strength test results. These will be discussed in the next section.)

To provide data for a proposed method of estimating muscle strength applied during a reflex test (to be described later), it was necessary to produce an integrated EMG result for the precise period over which the muscles were active. This integrated EMG was obtained by measuring the area of the raw EMG signal using a planimeter in the manner described by Lippold (1952). These data were collected for all of the reflex tests from a 24-member subset of the subject population.

E. Voluntary Isometric Strength of Neck Muscles.

1. Objectives. Two objectives were identified for the study of neck muscle isometric strength. The first was to measure the maximum voluntary strength of the flexor and extensor muscles as an assessment of the resistance a person might offer to crash forces. The second was to explore the relationship between the EMG of a muscle and its developed tension.

2. Test Methodology and Equipment. Cervical muscle strength was measured by having the subject exert a force with the neck muscles against a stainless steel force ring. The force ring was instrumented with strain gages arranged in a four-gage bridge circuit so that a slight deformation of the ring provided a large change in a dc signal. Repeated calibrations demonstrated the linearity of force ring response throughout

the range of interest. The force recorded by the force ring is the reported muscle strength. No attempt was made to adjust for anthropometry or mechanical advantage to estimate actual muscle fiber tension, since that would have introduced inaccuracies and made the data more difficult to compare among subject groups.

The following technique was used for measuring flexor muscle strength. The subject was seated in the simulated auto seat, in normal sitting position. A two-inch-wide inelastic headband was placed around the forehead, above the eyebrows, so that the line of force would be approximately through the center of gravity of the head. The inelastic dacron cord connecting the headband and the force ring were adjusted so that there was no slack when the subject was in neutral sitting position. This test arrangement is shown in Figure 2-17. After the subject was briefed about what was desired, a series of "muscle force calibrations" was conducted. The subject was asked to pull with exactly zero, five, ten, fifteen and twenty pounds of force. The subject observed a meter to know when the proper force was being exerted. This sequence was always carried out in five-pound increments, and the subject was asked after each increment if he desired to go on to the next. For each of these calibrations, the muscle force and corresponding EMG signals were recorded for later comparison.

After the calibration series, the subject was allowed to relax, then four maximum effort trials were conducted. The subject was again briefed about the desired action, and it was emphasized that the subject should pull forward against the headband, bracing the back against the seat, as hard as he or she was "voluntarily able." The first maximum effort trial was performed to allow the subject to get the feel of the procedure and

Figure 2-17. Measurement of flexor muscle isometric strength. Subject is seated in normal position. Electrodes recorded the EMG, and the force ring behind the subject measured muscle force.

Figure 2-18. Measurement of extensor muscle isometric strength. Subject now pulls backward with the neck muscles. Note that the body is not braced and that no lap belt is used.

was unrecorded. Then three trials were recorded. Each trial lasted five seconds (the experimenter began counting when the force reached the expected maximum level). The subject was allowed to rest for at least one minute between trials to preclude fatiguing the muscles. An observer watched the subject during testing to be sure the subject remained in a normal seated posture.

After completion of the flexor muscle tests, the testing apparatus was moved to the front of the subject, and the entire test sequence was repeated to calibrate and measure the strength of the neck extensor muscles. This arrangement is illustrated in Figure 2-18. Note that the subject was not restrained by a lap belt, nor were the arms or feet braced. This technique was adopted to isolate neck muscle strength from back muscle strength as much as possible. The test observer again watched to assure that the subject remained in normal posture and did not raise up off the seat.

For each strength test, four channels of information were recorded on magnetic tape: neck flexor EMG, neck extensor EMG, the strength signal from the force ring, and the control channel. Figure 2-19 is a 4-channel strip-chart record illustrating a complete flexor muscle test sequence. A two-channel strip chart record was made for each maximum strength trial.

3. Data Reduction and Analysis. The strip chart records for each maximum strength trial were analyzed manually to provide the strength results reported herein. The three individual trials and the average of those trials, for each force direction, were keypunched and subjected to statistical analysis.

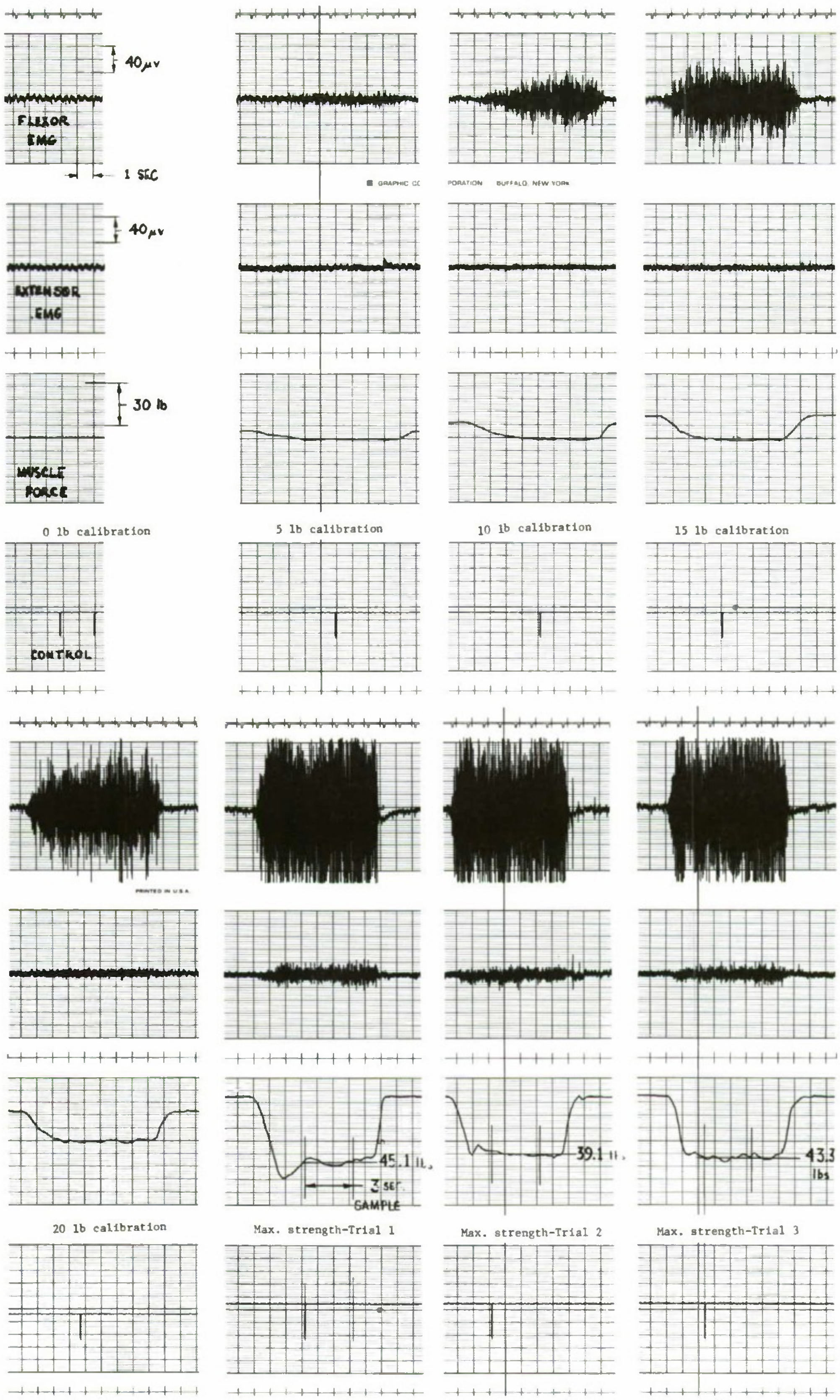

Figure 2-19. Strip-chart of complete flexor muscle strength test. The flexor muscles exert the most force, as expected, but the extensor muscles also exhibit some activity at higher force ranges.

Manual analysis of EMG data would have been extremely difficult and cumbersome, so the computer algorithm described previously incorporated a method of calculating the RMS-average integrated EMG and corresponding force for each of the calibration and maximum strength trials. These results were then analyzed for each subject, using least-squares regression techniques, to develop the relationship between EMG and muscle tension on a subject-by-subject basis.

CHAPTER 3

RESULTS AND DATA ANALYSIS

Reported in this chapter are the most significant results from the study. Except for some of the anthropometry, all of these results pertain to motion and forces in the sagittal plane. The results are presented in both tabular and graphical form so they may be useful both for biomechanical modeling and for readily comparing results among different subject groupings. Selected results are included in Chapter 3, reported for combinations of the primary variables. Complete statistical summaries of the anthropometry, range of motion, reflex, and strength results, by subject category, are included in Appendices B, C, D, and E.

In reading this chapter, the reader should keep in mind that most of the comments and observations are made relative to the average (arithmetic mean) results and that individual differences could cause an exception to virtually any observation. For this reason, standard deviations are given in the tables so the amount and significance of variation may be considered.

A. Analysis of Subject Pool

1. Final Configuration. As previously described, the experimental design called for 180 subjects, with ten subjects in each of 18 combinations of sex, age and stature. The final subject pool did consist of 180 persons. However, because of high rejection rates of x-rays in the short elderly male group, there was a slight imbalance in favor of females: 93 to 87. Substantial data losses due to procedureal problems resulted in the elimination of data from two females. Therefore, the results presented in this chapter are based on complete data from 178 subjects, subdivided

as follows: 91 females and 87 males; with ten subjects in 13 of the 18 stratifications by sex, age, and stature; 11 each in three strata; 9 in one; and 6 in one.

In order to obtain the 180 subjects desired, it was necessary to screen nearly twice as many questionnaires. About 500 medical questionnaires were distributed to individuals and groups; 351 were returned, with approximately equal numbers of males and females. The disposition of the questionnaires is shown in Table 3-1. Seventeen percent of all questionnaires were rejected for medical reasons (history of neck injury, known arthritis, etc.). Another 17 percent of all responses were not usable because categories were filled or the potential subject became unavailable. Total loss rates for various sex and age groups ranged from about one-quarter to nearly one-half, with an overall average of 34%.

After medical questionnaire screening, 233 potential subjects remained. Of these, 230 participated in the second, or x-ray, screening. Table 3-2 summarizes the results and indicates that 36 sets of x-rays were rejected for medical reasons. The large majority of rejections (28) were in the 62-74 age group and most of those were because of degenerative arthritis in the cervical spine. Existence of arthritis per se did not cause rejection, since that condition is normal with age. However, potential subjects with more than "moderate" arthritis (as defined by the radiologist) were rejected to minimize any potential hazards. As a result, nearly one-third of all elderly people were rejected when the x-rays were reviewed. By contrast, only 8 of 144 (5.5%), of the subjects in the other two age categories were rejected. Other than arthritis, unusual neck shape (such as kyphosis or kyphoscoliosis) was the most common cause of rejection. Also discovered were a healed vertebral

Table 3-1

Subject Pool - Summary of Questionnaires

	TOTAL QUEST. REC'D.	MEDICAL REJECT.	OTHER REJECT/ LOSSES	TOTAL REJECT/ LOSSES	% MEDICAL REJECT.	% TOTAL REJECT.
Females						
18-24	60	7	11	18	12	30
35-44	43	8	2	10	19	23
62-74	67	17	7	24	25	36
Males						
18-24	72	9	25	34	13	47
35-44	49	11	5	16	22	33
62-74	60	9	7	16	15	27
All Females	170	32	20	52	19	31
All Males	181	29	37	66	16	36
All Subjects	351	61	57	118	17	34

Table 3-2

Subject Pool - Summary of X-rays

Subject Groups		Number Taken	Number Usable	Number Rejected By Radiologist
Females				
18-24	1-20%ile	11	11	0
	40-60%ile	15	14	0
	80-99%ile	15	11	2
35-44	1-20%ile	11	10	1
	40-60%ile	11	10	1
	80-99%ile	11	11	0
62-74	1-20%ile	15	10	5
	40-60%ile	15	10	5
	80-99%ile	13	11	2
Males				
18-24	1-20%ile	11	10	1
	40-60%ile	14	11	1
	80-99%ile	14	12	0
35-44	1-20%ile	11	10	1
	40-60%ile	11	10	1
	80-99%ile	10	10	0
62-74	1-20%ile	13	6	7
	40-60%ile	17	11	6
	80-99%ile	14	10	3
Females				
18-24		41	36	2
35-44		33	31	2
62-74		43	31	12
Males				
18-24		39	33	2
35-44		32	30	2
62-74		42	26	16
All Females		117	98	16
All Males		113	89	20
All Subjects		230	187	36

Note: Rejection Rates
Elderly: 28/86=32.6%
Younger: 8/144=5.5%

fracture in one subject and a young male who did not know he had a congenital fusion at C2-C3. After screening, 187 subjects were approved for reflex and strength testing, and 180 were actually tested.

2. Comparison of Key Anthropometric Measures. In order to judge whether the study population was representative of the U.S. population, a comparison was made for the anthropometric variables of stature, erect sitting height, and weight. The measurement technique was comparable in the two studies. The results are contained in Table 3-3. Since the age and stature categories for the study were chosen based on the USPHS results, a close match of statures was expected. Table 3-3 shows that a very close match of stature was achieved in the two younger age groups. Because of the high rejection rate, elderly subjects had to be taken less selectively. Consequently, their average stature was somewhat greater than that reported for the U.S. population. An even closer match was achieved for average erect sitting height, which differed only a few millimeters from the U.S. population average. Although weight was not a primary variable, the two populations compared closely in weight also. On the basis of the three population-comparison measures, the study population sample appears to be representative of the U.S. population with respect to: (a) sex and age distribution and (b) general body dimensions.

B. Anthropometry

A total of 48 traditional and 6 x-ray anthropometric measurements were obtained from each subject. These have been grouped into 27 different combinations of sex, age, and stature. It would be impractical to present all of these data in the body of this report, but they are of potential value to investigators who are interested in population differences. Therefore,

Table 3-3

Comparison of Population Measures

	N	Wt(Kg) STUDY POP	Wt(Kg) US POP	Ht(cm) STUDY POP	Ht(cm) US POP	Erect Sit Ht(cm) STUDY POP	Erect Sit Ht(cm) US POP
Females							
18-24	30	58.4	57.7	162.7	162.1	85.7	85.3
35-44	30	59.4	64.6	161.4	161.3	85.4	85.6
62-74	31	65.2	65.5	158.5	156.2	82.7	81.5
Males							
18-24	30	71.4	71.8	174.9	174.5	91.1	90.9
35-44	30	83.4	77.3	173.9	174.0	90.5	91.2
62-74	27	72.9	71.8	171.3	169.9	88.7	88.1
All Females	91	61.1	63.6	160.9	160.0	84.6	84.6
All Males	87	76.0	75.5	173.4	173.2	90.1	90.4
All Subjects	178	68.4		167.0		87.3	

only selected measures are summarized in this chapter to illustrate their variability in the population. Complete statistical summaries of each measurement are contained in Appendix B, categorized as follows:

Table B.1	Anthropometry for all subjects combined
Tables B.2 - B.3	Anthropometry grouped by sex for females and males
Tables B.4 - B.9	Anthropometry grouped by sex and age for females, 18-24 years, through males, 62-74 years
Tables B.10 - B.27	Anthropometry grouped by sex, age, and stature for females, 18-24, short, through males, 62-74, tall.

The statistics reported for each measurement variable include sample size, mean, standard deviation, range, coefficient of variation, and percentiles.

1. Traditional Anthropometry. As described in Section 2.B, the measurements taken using standard anthropometric techniques were intended to give a general body description, locate the heights of various parts of the body with respect to a common seating surface, and describe the head and neck. Several measurements from each of these categories are shown in Tables 3-4, 3-5, and 3-6, for each of the 27 combination groups of subjects.

The general body measures of weight, stature, and erect sitting height are contained in Table 3-4. These are the same measures as presented in Table 3-3, but are stratified into more groupings to illustrate stature-related differences. Stature and erect sitting height show a secular trend throughout the sample (comparable stature groups are shorter with increasing age). Erect sitting height generally has less variance than stature. Comparison of the final results with the selection criteria

Table 3-4

Selected General Body Measures

Subject Groups		WEIGHT (kg) N	$\bar{x}$	S.D.	STATURE (cm) N	$\bar{x}$	S.D.	ERECT SITTING HT(cm) N	$\bar{x}$	S.D.
Females										
18-24	1-20%ile	10	52.9	5.6	10	153.5	4.0	10	87.1	3.0
	40-60%ile	10	60.0	7.1	10	161.5	1.7	10	85.2	1.6
	80-99%ile	10	62.5	7.5	10	173.0	4.7	10	89.6	1.5
35-44	1-20%ile	10	52.9	5.6	10	154.2	3.1	10	82.8	1.8
	40-60%ile	9	57.4	7.1	9	161.2	2.1	9	84.9	1.8
	80-99%ile	11	67.1	17.7	11	168.2	2.5	11	88.1	1.8
62-74	1-20%ile	10	61.0	10.0	10	151.0	2.3	10	79.7	1.7
	40-60%ile	10	66.7	3.9	10	157.4	1.7	10	82.0	1.8
	80-99%ile	11	67.6	14.4	11	166.4	4.5	11	86.1	3.8
Males										
18-24	1-20%ile	10	59.4	6.4	10	165.4	1.7	10	87.0	1.6
	40-60%ile	10	69.6	9.0	10	174.2	1.7	10	91.5	1.7
	80-99%ile	10	85.2	11.9	10	185.0	3.8	10	94.8	2.6
35-44	1-20%ile	10	84.8	15.5	10	165.5	6.2	10	86.8	2.7
	40-60%ile	10	76.6	6.9	10	173.9	1.6	10	90.0	2.7
	80-99%ile	10	88.9	15.9	10	182.4	5.0	10	94.7	1.6
62-74	1-20%ile	6	64.3	9.0	6	162.2	5.2	6	83.7	2.8
	40-60%ile	11	76.2	8.6	11	169.8	1.8	11	88.3	1.9
	80-99%ile	10	74.4	8.0	10	178.6	3.0	10	92.2	3.2
Females										
18-24		30	58.4	7.8	30	162.7	8.9	30	85.7	3.7
35-44		30	59.4	13.0	30	161.4	6.4	30	85.4	2.9
62-74		31	65.2	10.6	31	158.5	7.1	31	82.7	3.8
Males										
18-24		30	71.4	14.1	30	174.9	8.6	30	91.1	3.8
35-44		30	83.4	14.0	30	173.9	8.4	30	90.5	4.0
62-74		27	72.9	9.4	27	171.3	7.1	27	88.7	4.1
All Females		91	61.1	11.0	91	160.9	7.7	91	84.6	3.7
All Males		87	76.0	13.8	87	173.4	8.1	87	90.1	4.1
All Subjects		178	68.4	14.5	178	167.0	10.1	178	87.3	4.8

(Table 2-1) shows that the average stature of each subject group falls within the desired stature range, but usually in the upper half of the range. This point will be addressed further in the discussion section. Body weight was directly related to stature in females and young males. A large proportion of short males in the 35-44 age group were overweight and this is reflected in the results. Generally, taller individuals showed wider variations in body weight.

Table 3-5 is included to illustrate three height measurements, all taken from the same horizontal seat surface, with the subject in erect posture. Each is located on a different major body segment; tragion is on the head, suprasternale on the upper torso, and anterior-superior iliac spine on the pelvis. For purposes of mathematical modeling, these three major segments are often treated separately. Therefore it is important to know where the three segments are located relative to each other, and the three landmarks of Table 3-5 help determine those relationships. Tragion height, suprasternale height, and iliac spine height all reflect the same pattern as the stature groups--the average value of each increases as percentile of stature increases. However, the closer the landmark is to the seat surface, the less distinct are the differences in size. An average difference between stature groups of 3-4 cm is noted for tragion height, but iliac spine height usually differs by a cm or less. This is probably related to the number of articulations between the seat surface and the landmark; as the distance from the measurement baseline increases, the number of bones and joints, all of which have variable growth patterns,

Table 3-5

Selected Seated Measures

Subject Groups		RIGHT TRAGION HT.* N	x̄	S.D.	SUPRASTERNAL HT. N	x̄	S.D.	ANTERIOR SUPERIOR N	x̄	S.D.
Females										
18-24	1-20%ile	10	68.9	3.0	10	52.0	2.7	10	21.4	1.2
	40-60%ile	10	72.1	1.6	10	54.1	1.1	10	21.1	0.9
	80-99%ile	10	76.4	1.7	10	56.9	1.4	10	22.5	1.2
35-44	1-20%ile	10	70.0	2.0	10	52.7	1.9	10	20.9	1.0
	40-60%ile	9	72.3	2.0	9	54.0	1.8	9	21.4	0.9
	80-99%ile	11	74.4	1.4	11	55.6	1.2	11	22.4	0.9
62-74	1-20%ile	10	66.5	1.7	10	50.7	1.9	10	21.1	1.3
	40-60%ile	10	68.7	1.5	10	52.5	1.2	10	22.2	1.0
	80-99%ile	11	72.9	3.8	11	54.8	2.9	11	22.7	1.0
Males										
18-24	1-20%ile	10	73.8	1.7	10	55.1	1.9	10	21.6	0.9
	40-60%ile	10	77.4	1.6	10	57.3	1.7	10	22.4	1.2
	80-99%ile	10	80.5	2.7	10	59.5	1.9	10	23.4	1.5
35-44	1-20%ile	10	73.1	2.4	10	55.9	2.5	10	22.3	1.3
	40-60%ile	10	76.5	2.8	10	57.3	2.5	10	23.0	1.4
	80-99%ile	10	80.8	1.9	10	60.6	2.0	10	24.1	1.8
62-74	1-20%ile	6	69.9	2.4	6	52.3	2.3	6	21.8	1.1
	40-60%ile	11	75.0	1.5	11	57.3	1.8	11	22.9	0.9
	80-99%ile	10	78.7	3.4	10	59.4	2.8	10	24.0	1.4
Females										
18-24		30	72.5	3.8	30	54.3	2.8	30	21.7	1.2
35-44		30	72.3	2.6	30	54.2	2.0	30	21.6	1.1
62-74		31	69.5	3.7	31	52.7	2.7	31	22.0	1.2
Males										
18-24		30	77.3	3.4	30	57.3	2.6	30	22.5	1.4
35-44		30	76.8	4.0	30	57.9	3.0	30	23.1	1.6
62-74		27	75.2	4.1	27	57.0	3.5	27	23.0	1.4
All Females		91	71.4	3.6	91	53.7	2.6	91	21.8	1.2
All Males		87	76.4	3.9	87	57.4	3.0	87	22.9	1.5
All Subjects		178	73.9	4.5	178	55.5	3.4	178	22.3	1.5

* Note: All dimensions in cm.

increase. It is also interesting to note that the tragion and erect sitting heights, which are measured from the same segment, have nearly identical standard deviations.

Head circumference, neck breadth in the anterior-posterior direction, and superior neck circumference results are summarized in Table 3-6. It is apparent that these measures are not stature-related to any significant degree. Head circumference tends to increase slightly with increasing stature, but the difference between categories exceeds one cm only twice. Head circumference remains constant with age, and males are slightly larger, on the average, than females. Neck breadth and circumference tend to follow a pattern related to weight rather than stature. This relationship is shown most clearly in the 35-44 male group, where the effect of the short overweight males on those two measurements is quite obvious. Males are somewhat larger than females, and there is an aging effect, with elderly women and both middle-age and elderly men having larger neck dimensions than their younger counterparts.

With the subject in erect sitting posture the heights of both left and right acromial processes were measured. The results (contained in Tables B.1 through B.9 of Appendix B) reveal that the left acromion landmark is consistently higher, on the average, than the right. In males, the left acromion averaged 3.9 mm higher than the right; in females, 2.2 mm higher. When the subjects were categorized by sex and age, the average difference ranged from 1.4 to 7.4 mm, the left always being the higher. Similar results, but with smaller average differences, were found for the left and right tragions. These differences may be due to articulation, bone formation, or actual tipping of the shoulders and head, but they are

Table 3-6

Selected Head and Neck Measures

Subject Groups		HEAD CIRCUM N	$\bar{x}$	S.D.	A-P NECK BREADTH N	$\bar{x}$	S.D.	SUPERIOR NECK CIRCUM N	$\bar{x}$	S.D.
Females										
18-24	1-20%ile	10	55.2	1.4	10	9.2	.7	10	31.7	1.9
	40-60%ile	10	55.5	1.9	10	9.3	.5	10	32.6	1.3
	80-99%ile	10	55.7	2.0	10	9.4	.4	10	32.0	1.0
35-44	1-20%ile	10	55.2	1.6	10	9.6	.5	10	32.0	1.4
	40-60%ile	9	55.8	1.4	9	9.6	.6	9	32.2	1.8
	80-99%ile	11	56.4	1.6	11	9.9	.9	11	33.6	2.6
62-74	1-20%ile	10	54.3	1.8	10	10.6	.8	10	35.4	3.8
	40-60%ile	10	56.7	2.0	10	10.7	.8	10	35.4	1.4
	80-99%ile	11	56.8	2.7	11	10.5	.7	11	35.8	2.7
Males										
18-24	1-20%ile	10	56.6	1.3	10	10.3	.5	10	34.7	1.5
	40-60%ile	10	57.6	.7	10	11.0	.7	10	37.2	1.6
	80-99%ile	10	58.8	2.1	10	11.4	.8	10	38.8	2.3
35-44	1-20%ile	10	57.9	1.7	10	12.4	1.0	10	42.7	3.4
	40-60%ile	10	58.8	2.1	10	11.4	.8	10	38.8	2.3
	80-99%ile	10	58.8	2.8	10	12.4	.9	10	40.7	3.2
62-74	1-20%ile	6	57.0	1.4	6	12.1	1.2	6	40.1	2.3
	40-60%ile	11	57.8	1.2	11	12.9	.8	11	42.9	2.8
	80-99%ile	10	58.4	2.0	10	12.6	.7	10	40.6	1.9
Females										
18-24		30	55.5	1.7	30	9.3	.5	30	32.1	1.4
35-44		30	55.8	1.6	30	9.7	.7	30	32.6	2.1
62-74		31	56.0	2.5	31	10.6	.7	31	35.6	2.7
Males										
18-24		30	57.7	1.7	30	10.9	.8	30	36.9	2.5
35-44		30	58.2	2.0	30	12.2	.9	30	41.2	3.1
62-74		27	57.8	1.6	27	12.6	.9	27	41.4	2.6
All Females		91	55.8	2.0	91	9.9	.9	91	33.5	2.6
All Males		87	57.9	1.8	87	11.9	1.1	87	39.8	3.5
All Subjects		178	56.8	2.1	178	10.8	1.4	178	36.5	4.4

Note: All dimensions in cm.

consistent. It is interesting to note this consistency, but from the practical standpoint it is important to realize that the difference is extremely small (almost within measurement error), especially considering the number of joints and articulations that are involved in the construction of the shoulder girdle and the skull.

An analysis was made with repeated measurements on the same subject at different times. This analysis was performed to assess the degree of intra-measurer error. When a slim subject was re-measured, the error was acceptable, at about one percent for most measures. When a heavier subject was retested the error remained less than one percent for bony-landmark measurements but was somewhat more pronounced (about 4%) for weight-related measures. In both cases, it was concluded that intra-measurer error was generally random and within acceptable limits.

2. Anthropometry from Radiographs. The length of cervical spine "links," defined as the distance between successive disk centers, was measured from x-ray films of each subject. Average length for individual links from C1/C2 through C7 are contained in Appendix B. The total length of the cervical spine, from the tip of the C2 odontoid process to the C7-T1 disk center, was calculated by adding together the individual link lengths; this represents the total length of the cervical spine (the effective length without any spinal curvature). These results are presented in Table 3-7.

Cervical spine length is directly related to stature. In each category in Table 3-7, cervical spine length increases with increased stature. Males average slightly more than one centimeter greater spine length than females, and there is virtually no aging effect. These data indicate that, internally, there is very little difference in average

Table 3-7

Total Length of Cervical Spine

Subject Groups		N	$\bar{x}$	S.D.
		Cervical Spine Length, cm		
Females				
18-24	1-20%ile	10	10.8	.6
	40-60%ile	10	11.6	1.1
	80-99%ile	9	12.0	.8
35-44	1-20%ile	10	11.0	.6
	40-60%ile	9	11.5	.4
	80-99%ile	11	11.8	.8
62-74	1-20%ile	9	10.9	.7
	40-60%ile	9	11.1	.9
	80-99%ile	10	11.7	1.6
Males				
18-24	1-20%ile	9	12.1	.5
	40-60%ile	8	12.3	.5
	80-99%ile	7	13.3	.6
35-44	1-20%ile	6	11.7	.3
	40-60%ile	7	12.8	.5
	80-99%ile	8	13.2	.7
62-74	1-20%ile	6	11.9	.8
	40-60%ile	5	11.9	.8
	80-99%ile	8	13.2	.5
Females				
18-24		29	11.4	.9
35-44		30	11.4	.7
62-74		28	11.2	1.2
Males				
18-24		24	12.5	.7
35-44		21	12.6	.8
62-74		19	12.4	.9
All Females		87	11.4	.9
All Males		64	12.5	.8
All Subjects		151	11.9	1.1

Note: Measurements taken from radiographs.

neck length throughout the population. There also tends to be less variation between individuals than with other data; coefficients of variation are usually well under 10%.

For their paper, Katz, et al (1975) measured vertebral body dimensions in the mid-sagittal plane for all of the 18-24 year subjects. The average dimensions of height, depth, and cross-sectional area for C3 through C7 are presented in tabular form in the publication and are summarized graphically in Figure 3-1. Males tend to be larger, on the average, than females, in each dimension for each vertebrae. Since they have been developed for a subset of the population, the complete results are not contained in Appendix B. However, the results for the smallest and largest vertebrae (C3 and C7 respectively) are tabulated in Table 3-8. The sizes, even at these extremes, are very similar. Statistical analysis indicated no significant difference for stature, but a significant difference (at $\alpha = .05$) for sex.

3. Comparisons Among Anthropometric Measures - Correlations and Predictions. A complete intercorrelation matrix was prepared (using all subject data combined) to investigate correlations among various measurements. High correlations between measures provide some degree of confidence that the value of one measurement can be predicted based upon another and perhaps easier-to-obtain measure. Selected measurements which had the most significant correlations were compiled to form the partial intercorrelation matrix shown in Table 3-9. For clarity, only correlation coefficients greater than 0.707 are reported ($r = 0.707$ indicates that 50% of the variance between the two measures is explained by their relationship). The measures included in Table 3-9 are

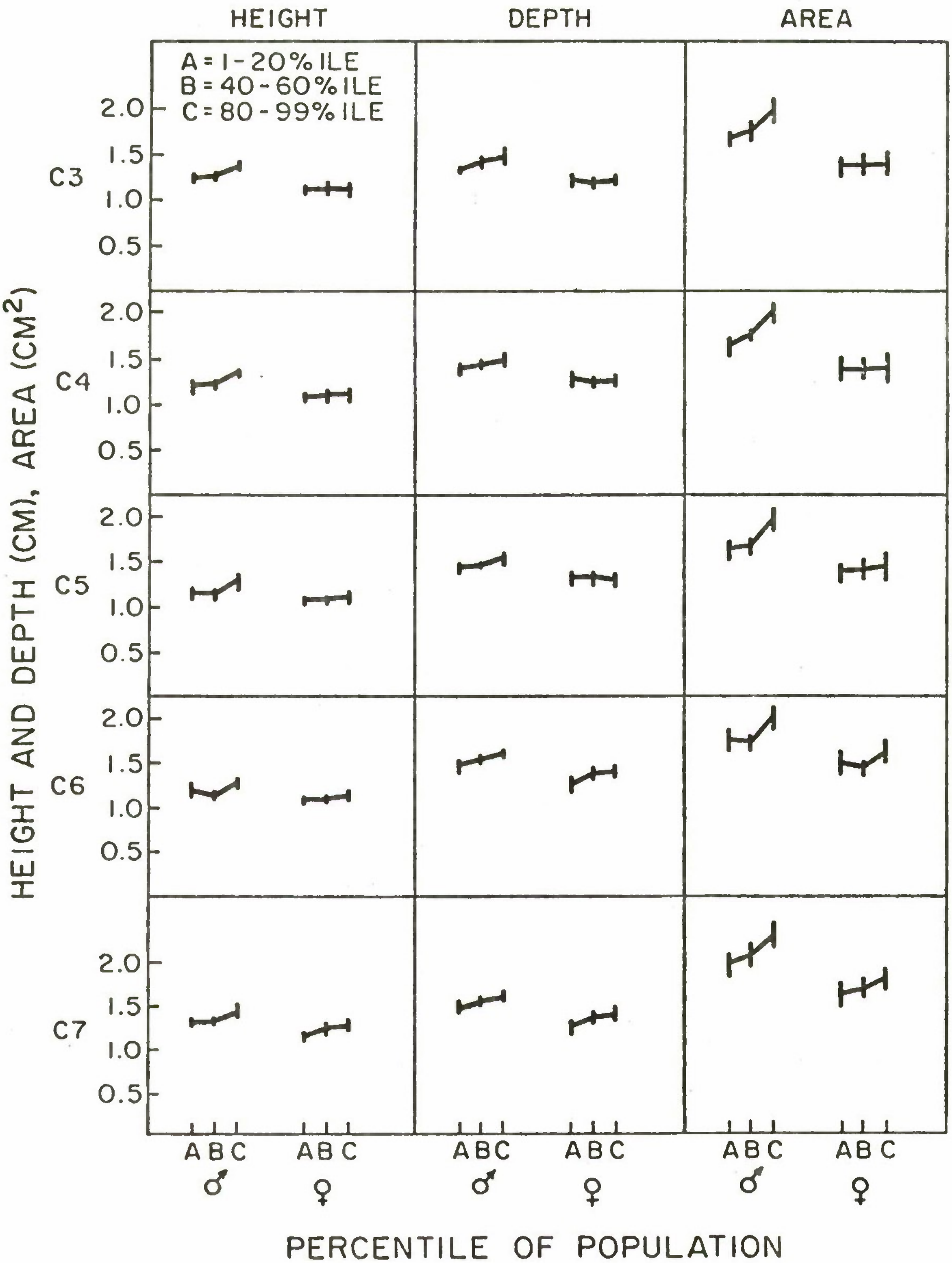

Fig. 3-1. Comparison of Cervical Vertebral Body Dimensions. From Katz, et al, 1975. Horizontal lines connect means; vertical lines are ± one std. dev.

Table 3-8

Height and Depth of C3 and C7 Vertebral Bodies

	C3				C7			
	HEIGHT		DEPTH		HEIGHT		DEPTH	
	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$
FEMALES								
1-20%ile	11	1.2	11	1.3	11	1.2	11	1.4
40-60%ile	10	1.1	10	1.2	10	1.3	10	1.4
80-99%ile	10	1.1	10	1.2	10	1.3	10	1.4
MALES								
1-20%ile	10	1.2	10	1.3	10	1.3	10	1.5
40-60%ile	10	1.3	10	1.4	9	1.3	9	1.6
80-99%ile	10	1.4	10	1.5	9	1.4	9	1.6

Table 3-9

Partial Intercorrelation Matrix for Anthropometry

	Weight	Stature	Erect Sit Ht	Rt Acromion	Rt Tragion	Suprasternale	Biacromial Br	Bideltoid	Superior Neck Cir	Inferior Neck Cir
Erect Sit Ht		.92	--	.92	.99	.94				
Rt Acromion		.83	.92	--	.91	.89				
Rt Tragion		.91	.99	.91	--	.95				
Nasal Rt Dep		.89	.97	.88	.97	.98				
Lt Eye		.89	.96	.89	.98	.94				
Suprasternale		.84	.94	.89	.95	--				
Bideltoid Br	.86						.79	--		
Lateral Neck Br	.75						.76	.84		
Slumped Sit Ht	.75							.73		
Superior Nk Circum		.88	.95	.87	.94	.91				
Inferior Nk Circum	.79							.77	--	
Bitragion Dia	.79						.72	.83	.87	
Sitting Knee Ht									.73	.71
Max Sit Knee Ht	.85	.95	.80	.71	.78	.73				
Biceps Circum	.83	.95	.82	.72	.79	.74		.75	.74	.74
Calf Circum								.74		
C3 Link		.73	.75		.74					
Tot Neck Length		.73	.78	.73	.77	.71				

Note: Selected correlations for which r ≥ 0.707

Matrix based on data for all subjects combined representative. Several others (such as sitting cervicale height, left tragion height, and chin-neck intersect height) also had high correlation with other measures, they are not contained in the table because they tended to duplicate the correlation pattern of measures which are included.

Examination of Table 3-9 reveals that the largest number of highly significant correlations occurs with the most commonly obtained measures: weight, stature, and erect sitting height. Erect sitting height is an excellent predictor of any of the other height measurements on the head and upper torso ($r > 0.92$ for all 7 reported). In general, stature tends to be highly correlated with height measures and weight with circumferences and breadths. The table also shows some unusual and probably irrelevant correlations; for example, biceps circumference with stature at $r = .95$, sitting knee height with neck circumferences at $r = .73$ and .71. It is interesting to note that sitting knee height and maximum sitting knee height, which are very similar measures and highly correlated to each other ($r = .99$), are not both correlated to the same measure anywhere in the table. A finding consistent with other reported research is that stature and weight are not highly correlated ($r = .61$).

The anthropometric data available to the designer of biomechanical models is often very limited. Sometimes stature or erect sitting height are the only known dimensions from which an occupant must be described. In these cases, a knowledge of body proportions is valuable. Several examples of body segment proportions are reported in Table 3-10 for the results of this study. Relationships of sitting-to-standing, sitting-to-sitting, and breadth-to-height measures are given. The results indicate complete consistency in proportions across all population variables;

Table 3-10

Anthropometry Proportions

	ESH/S $\bar{x}$	ESH/S COEF VAR	C7HT/S $\bar{x}$	C7HT/S COEF VAR	RTR/ESH $\bar{x}$	RTR/ESH COEF VAR	RIS/ESH $\bar{x}$	RIS/ESH COEF VAR
Females								
18-24	.53	2.3%	.85	.9%	.85	1.1%	.25	5.1%
35-44	.53	2.2	.85	.7	.85	.9	.25	4.6
62-74	.52	2.4	.86	.9	.84	1.1	.27	4.3
Males								
18-24	.52	2.2	.85	1.0	.85	1.0	.25	4.9
35-44	.52	2.3	.85	1.0	.85	1.2	.26	5.4
62-74	.52	2.1	.86	.8	.85	1.9	.26	4.2
All Females	.53	2.3	.85	.9	.84	1.1	.26	5.2
All Males	.52	2.2	.85	1.0	.85	1.4	.25	5.2
All Subjects	.52	2.3	.85	.9	.85	1.3	.26	5.2

	SSH/ESH $\bar{x}$	SSH/ESH COEF VAR	BIBR/S $\bar{x}$	BIBR/S COEF VAR	BIBR/ESH $\bar{x}$	BIBR/ESH COEF VAR
Females						
18-24	.97	1.7%	.22	5.0%	.41	5.2%
35-44	.97	1.5	.22	6.2	.42	5.9
62-74	.98	1.7	.23	7.3	.43	6.5
Males						
18-24	.96	1.9	.23	3.9	.44	4.9
35-44	.97	1.9	.23	5.4	.44	5.5
62-74	.96	1.6	.23	4.3	.44	4.5
All Females	.97	1.5	.22	6.4	.42	5.2
All Males	.97	1.9	.23	4.5	.44	4.9
All Subjects	.97	1.7	.23	5.7	.43	5.8

Key to Table Abbreviations

ESH = Erect Sitting Ht
C7HT = Cervicale Ht
S = Stature
RTR = Rt Tragion Ht
RIS = Rt Iliac Spine Ht
SSH = Slumped Sitting Ht
BIBR = Biacromial Breadth

neither age nor sex affect the proportion. For example, erect sitting height for this population is 52-53% of stature whether the occupant is male or female, young or old. The coefficients of variation are also very small, in most cases less than three percent, indicating very little variation among individuals. Using the results from Table 3-10, it would be possible, given only stature and erect sitting height, to predict standing cervicale height, sitting right tragion and iliac spine heights, slumped sitting height, and biacromial breadth, all with a high degree of accuracy. Table 3-11 is an example of the use of the reported proportions. Here predicted values for the young female groups are compared with the average value measured for the same group. The accuracy achieved is quite adequate for establishing areas of major body mass for a biomechanical model.

Table 3-11

Comparison of Predicted and Measured Values

Predicted Measurement	Prediction	Actual	% Error
Given average stature for group of 162.7 cm:			
Erect Sitting Ht.	86.2 cm	85.7 cm	0.6%
Standing C7 Ht.	138.3	138.8	0.3
Biacromial Br.	35.8	35.5	0.8
Given average erect sitting height of 85.7 cm:			
Slumped Sitting Ht.	83.1	82.8	0.4%
Right Tragion Ht.	72.8	72.5	0.5
Right Iliac Spine Ht.	21.4	21.7	1.3
Biacromial Br.	35.1	35.5	1.0

Modeling at the detailed level can require the knowledge of cervical spine link lengths. Without the benefit of x-rays from which measurements may be taken directly, it would be valuable to be able to predict link lengths based on measurements taken externally. To this end, a detailed analysis was performed by S.A. Kelkar (1973) using the x-ray and traditional anthropometry data to develop prediction equations for link lengths and range of motion. Eight traditional anthropometry measures were selected because of their anticipated relationship to either stature or range of motion. These were correlated with the computer derived link lengths and stepwise regression techniques were used to select the three measures which best predicted cervical spine link lengths (according to the link definition used in this study). For these data erect sitting height, posterior neck length and head length were the best predictors. Covariance analysis was then applied to develop a group of prediction equations for segments of the population based on sex and stature (age not being highly correlated to link lengths). The prediction equations are multiple linear regression equations of the form

$$Y_g = b_g + \sum_{i=1}^{3} m_i x_i$$

where

$\bar{Y}_g$ = predicted link length for a population group
b_g = y-intercept for the population group
m_i = regression slope coefficients for the specified independent variable
x_i = independent variable

The intercepts and coefficients necessary to predict links C2 through C7 are presented in Table 3-12. Also given is the percent of the variance explained by the regression equation.

A spot-check of the prediction equations was performed using two categories of subjects. For females, 40-60%ile, C2, C3, C4 and C7 links were calculated and compared with the measured value for the group. The

Table 3-12

Regression Equations for Predicting Cervical Spine Links

Link, Y	Intercept, b						Slope Coefficient, m (Indep. Variable)			% Variance Explained
	Female 1-20%ile	Female 40-60%ile	Female 80-99%ile	Male 1-20%ile	Male 40-60%ile	Male 80-99%ile	1 (ERSITHT)	2 (POSTNKLG)	3 (HEADLG)	
C2	+.2115	+.2607	+.2937	+.2465	+.3124	+.3483	+.0066	+.0037	+.0301	51
C3	-.2437	-.2341	-.2546	-.2198	-.2299	-.2013	+.0090	+.0018	+.0046	62
C4	-.1137	-.1053	-.1041	-.0869	-.0907	-.0713	+.0072	+.0059	+.0030	54
C5	-.2631	-.2800	-.2882	-.2528	-.2800	-.2638	+.0100	+.0061	-.0016	54
C6	-.3168	-.3265	-.3431	-.3105	-.3301	-.3292	+.0110	+.0038	-.0019	53
C7	-.2001	-.2027	-.2230	-.1756	-.2220	-.1973	+.0101	+.0012	+.0000	49

These coefficeents are for the equation

$$Y = b + m_1 \text{ (ERSITHT)} + m_2 \text{ (POSTNKLG)} + m_3 \text{ (HEADLG)}$$

To predict a length, select the proper intercept for the link and subject group of interest. Multiply the appropriate slope coefficients times the value of the corresponding independent variables (from Appendix B) and add them to the intercept.

Code: ERSITHT - Erect sitting height

POSTNKLG - posterior neck length

HEADLG - head length

average prediction error was 0.4%. For the males, 80-99%ile, predictions of C2, C5, C6, and C7 were also in error by only 0.4%.

C. Sagittal Plane Range of Motion

The detailed results of the range of motion study are of interest to potential users, but are too voluminous to include in the main text. Therefore, they are presented in Appendix C for head position and range of motion relative to external vertical references and in Appendix D for position and range relative to internal references as measured from x-rays. The subject groupings in Appendix C are identical to those of Appendix B: each of 27 combinations of sex, age and stature is included as a separate table. Because of the nature of the results, nine groupings are used in Appendix D.

1. Range of Motion - External Reference. As described in Section 2.C, a total of four range-of-motion replications was obtained from each subject - one x-ray and three photographic sequences of neutral, flexion, and extension positions. The data from each of these replications were compiled for neutral head position, degrees of flexion and extension from neutral position, and total range of motion. The summary statistics for each replication are contained in Appendix C. It was of interest to know if the results of the four replications were statistically equivalent: that is, if a subject assumed the same extremes of position each time the sequence was performed. An analysis of variance of range of motion for the four replications was performed to test the hypothesis that all four means were equal. The means compared were 117.36 degrees for the x-ray results and 115.21, 116.76, and 118.41 degrees for the three photos, respectively. The F-statistic thus calculated was 0.570, which had an

α-significance level of .63 (not significant). It was concluded that there were no significant differences among the results, and that the results could be combined for purposes of further analysis. Two groupings of data - one combining only the three photos (designated as PAVG) and the other combining the x-rays and the photos (designated as XPAVG) - are shown in Appendix C.

The combined x-ray and photo results are shown in tabular form in Table 3-13 for flexion, extension, and total range of motion. For flexion, there was little or no stature effect and, on the average, males and females had similar flexion capabilities. However, a definite aging effect was noted when comparing the 62-74 age group to the two younger groups. Analysis of variance of these flexion data revealed no significant difference among means for sex and stature, but a highly significant difference ($\alpha < .0005$) for age.

The extension results in Table 3-13 show a different pattern. In all but one category (short elderly males, which had a smaller sample size) extension mobility increases with stature. In addition, a steady decrease of extension is noted with increasing age for both males and females. These observations are borne out in the analysis of variance for these data. The sample means are significantly different for all major variables - for sex at $\alpha = .01$, for age at $\alpha = .0005$, and for stature at $\alpha = .001$. These results suggest that different segments of the population have different susceptibilities to hyperextension.

Total sagittal plane range of motion for an individual is the sum of flexion and extension. The results for the 18 categories of sex, age, and stature are shown graphically in Figure 3-2, with average range of motion for the group plotted against the mid-point of the group's age range.

Table 3-13

Range of Motion Results*

Subject Groups		FLEXION N	FLEXION $\bar{x}$	FLEXION S.D.	EXTENSION N	EXTENSION $\bar{x}$	EXTENSION S.D.	TOTAL RANGE OF MOTION N	TOTAL RANGE OF MOTION $\bar{x}$	TOTAL RANGE OF MOTION S.D.
Females										
18-24	1-20%ile	10	51.8	8.2	10	66.6	9.4	10	128.3	13.2
	40-60%ile	10	60.2	12.5	10	74.5	12.7	10	134.6	13.9
	80-99%ile	10	60.4	8.1	10	86.0	13.1	10	146.1	13.3
35-44	1-20%ile	10	60.3	8.0	10	57.8	10.0	10	118.0	14.3
	40-60%ile	9	58.1	10.2	9	63.7	11.8	9	121.8	17.0
	80-99%ile	11	59.5	8.0	11	66.3	8.2	11	125.8	15.6
62-74	1-20%ile	10	51.3	9.0	10	48.8	8.0	10	100.1	12.4
	40-60%ile	10	50.7	6.3	10	49.7	14.8	10	100.4	16.6
	80-99%ile	11	44.3	10.5	11	55.0	7.6	11	99.0	15.6
Males										
18-24	1-20%ile	10	62.3	9.8	10	70.1	7.7	10	132.4	14.3
	40-60%ile	10	63.6	5.9	10	74.6	9.2	10	138.1	7.3
	80-99%ile	10	64.7	7.4	10	76.8	13.1	10	141.5	12.0
35-44	1-20%ile	10	52.7	9.7	10	50.7	10.0	10	103.4	12.8
	40-60%ile	10	52.4	10.6	10	55.2	11.2	10	107.5	17.7
	80-99%ile	10	56.4	12.7	10	60.2	12.8	10	116.5	22.9
62-74	1-20%ile	6	49.9	7.2	6	46.0	6.0	6	95.6	7.8
	40-60%ile	11	44.9	11.0	11	40.1	9.6	11	85.0	17.6
	80-99%ile	10	50.2	9.0	10	55.6	10.[illegible]	10	105.8	12.5
Females										
18-24		30	60.8	9.5	30	75.7	14.0	30	136.4	15.0
35-44		30	59.3	8.4	30	62.7	10.3	30	122.0	15.1
62-74		31	48.5	9.2	31	51.3	10.6	31	99.8	14.5
Males										
18-24		30	63.5	7.7	30	73.8	10.3	30	137.4	11.8
35-44		30	53.8	10.9	30	55.3	11.7	30	109.2	18.5
62-74		27	47.9	9.5	27	47.1	11.4	27	95.1	16.5
All Females		91	56.1	10.5	91	63.1	15.4	91	119.2	21.1
All Males		87	55.4	11.3	87	59.2	15.7	87	114.5	23.6
All Subjects		178	55.8	10.9	178	61.2	15.6	178	116.9	22.4

* Note: Flexion and extension are expressed relative to neutral head position. All dimensions in degrees.

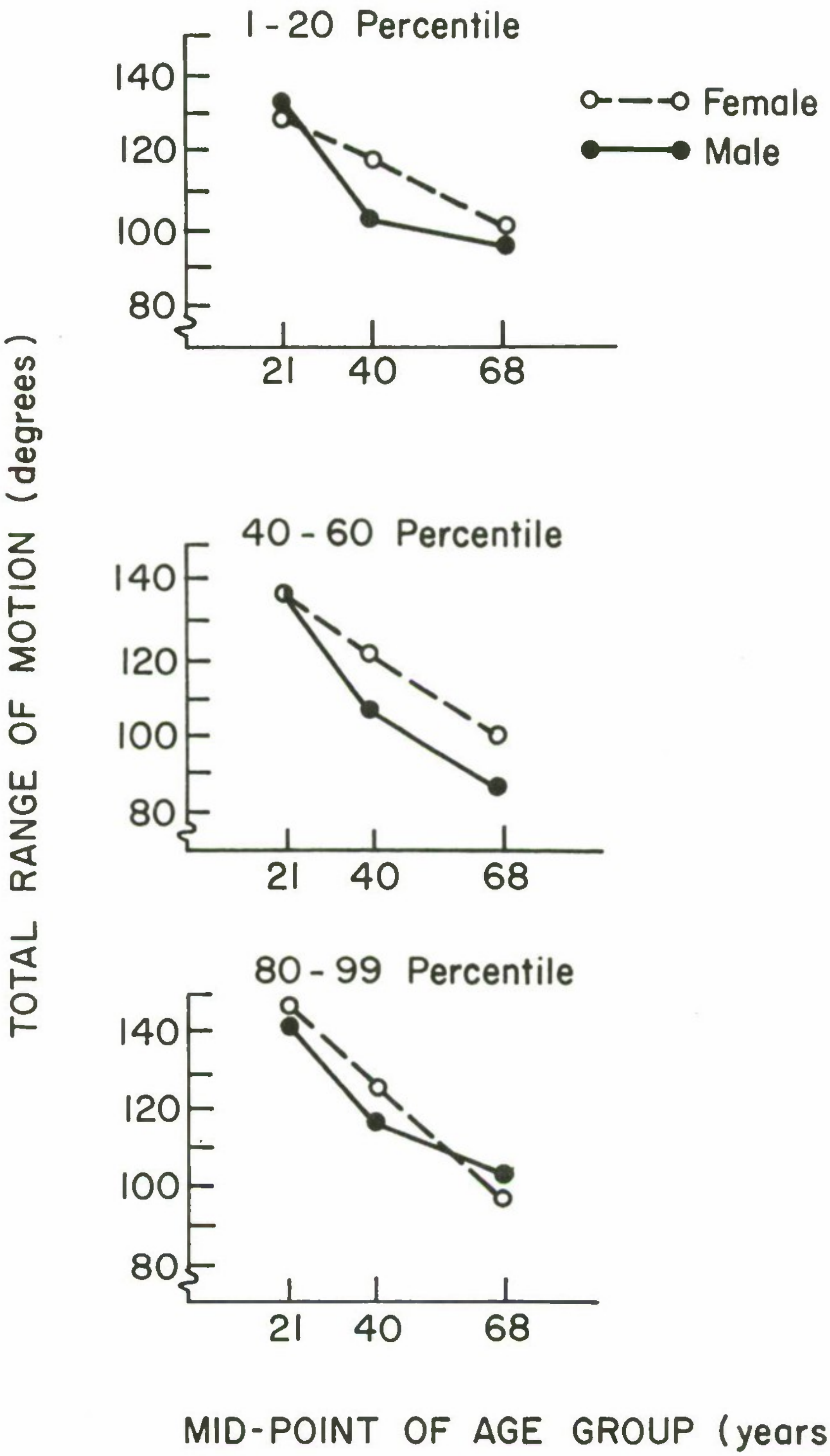

Fig. 3-2. Total Range of Motion for Population Segments. The results shown are mean values from Table 3-13.

There is a fairly strong stature trend in young subjects, which is less pronounced at middle age and non-existent in elderly subjects. Females tend to have somewhat greater range of motion than males, especially the middle age group. The most dramatic effect is that of age. The decrements in both flexion and extension add to produce a highly significant difference. Range of motion of elderly females is 27% less than that of young females; elderly males have 31% less range of motion than young males. As with extension, significant differences among means are found for all major variables. Overall, sex and stature are significant at $\alpha = .025$ and age at $\alpha = .0005$.

Since so many x-rays of elderly subjects were rejected because of arthritic conditions in the cervical spine, a brief analysis of range of motion from those x-rays was performed to determine if increased arthritis degraded range of motion. The results were inconclusive, since sample sizes were small in all cases. In some instances, arthritis definitely reduced range of motion, especially in flexion. In others, arthritis seemed to have no effect and ranges of motion were equal to or greater than the average for the accepted group. Since virtually every elderly subject had some degree of degenerative arthritis, it is felt that the exclusion of more severe cases did not adversely affect the results or make them less representative for this segment of the population.

2. Range of Motion from X-rays - Internal Reference. The three-position lateral x-rays taken during this study presented many unique opportunities for range of motion analysis. Several relationships between internal and external landmarks were examined and are presented in this section.

The effects of upper thoracic spine and torso movement on range of motion are shown in Table 3-14. Only x-ray data were used for this comparison. The comparisons are between range of motion as measured between the "skull plane" reference on the head and (1) the vertical marker external to the subject and (2) the face of the C7 vertebral body internal to the subject (see Section 2.C.3 for more detailed description). The internal measurement accounts for all motion from the head through the C6-C7 disk. The difference between the internal and external angles is accounted for at the base of the cervical spine (the C7-T1 disk) and in the torso. Technically, the movement at C7-T1 should be included with cervical spine movement, but T1 was not visible often enough during flexion and extension to permit this analysis. Examination of Table 3-14 shows that, in every case, there is some torso movement involved, even when care was taken to keep the shoulders against the seat back. The results show that the upper torso flexes more than it extends. This is expected, since the thoracic spine has a natural kyphosis in this area. The average torso movement seen is 14 degrees, or about one-quarter of the total flexion movement. Torso movement in flexion tended to decrease with age (internal became a greater percentage of external), and is similar between sexes for all ages. Little torso movement occurs in extension, since the internal angle averages 90% of the external angle (six degrees). The subject pushed back into the chair during the extension motion without moving the lower torso away from the seat. Thus, most of the difference is probably accounted for in motion between C7 and T1, and the reported external angle is closer to the true voluntary extension of the cervical spine. In extension the trend was reversed, with torso movement increasing with age. Females had less torso movement than males.

Table 3-14

Range of Motion from Internal and External References

Subject Groups	N	Angle Relative to External Vertical Reference: Flexion $\bar{x}$ (SD)	Extension $\bar{x}$ (SD)	ROM $\bar{x}$ (SD)	N	Angle Relative to Internal C7 Reference: Flexion $\bar{x}$ (SD)	Extension $\bar{x}$ (SD)	ROM $\bar{x}$ (SD)	Proportion (Internal/External): Flexion	Extension	ROM
Females: 18-24	30	60.9 (8.5)	77.1 (18.5)	137.6 (19.0)	30	41.4 (10.7)	76.4 (11.2)	118.8 (12.4)	.68	.99	.86
35-44	30	59.1 (10.7)	61.5 (12.6)	120.6 (13.5)	30	44.6 (8.6)	56.0 (14.2)	100.6 (12.6)	.75	.91	.83
62-74	31	45.3 (10.7)	51.6 (12.3)	96.9 (15.4)	31	36.0 (10.1)	44.8 (10.7)	80.8 (11.5)	.79	.87	.83
Males: 18-24	30	62.5 (7.8)	79.6 (15.2)	142.1 (15.9)	30	43.5 (9.1)	71.1 (10.0)	114.5 (13.4)	.70	.89	.81
35-44	30	51.2 (13.2)	56.8 (11.8)	108.0 (18.5)	29	38.3 (13.3)	47.5 (14.5)	85.3 (16.9)	.75	.84	.79
62-74	26	47.6 (9.5)	49.5 (11.2)	97.1 (17.0)	25	36.9 (10.3)	40.9 (11.7)	77.7 (14.5)	.78	.83	.80
All Females	91	55.0 (12.2)	63.3 (18.0)	118.2 (23.2)	91	40.6 (10.4)	58.7 (17.8)	99.7 (19.7)	.74	.93	.84
All Males	86	54.0 (12.1)	62.5 (18.2)	116.6 (25.7)	84	39.7 (11.3)	53.8 (17.8)	93.3 (21.9)	.74	.86	.80
All Subjects	177	54.5 (12.1)	62.9 (18.0)	117.4 (24.4)	175	40.2 (10.8)	56.4 (17.9)	96.6 (21.0)	.74	.90	.82

A computer algorithm was used to analyze the digitized x-rays and calculate angular relationships between various segments of the cervical spine. The angle formed between the links of adjacent vertebrae was determined for flexion and extension positions and for total range of motion. The results of this analysis are presented in Appendix D. The reader will note that Appendix D has nine categories instead of the usual 27 and that an abbreviated format is used which reports only the mean and standard deviation for the link ranges of motion. The addition of the range and coefficient of variation for these data would be misleading for several reasons. First, no effort was made to standardize the configuration of the neck in neutral position. The subject asssumed a normal sitting position, and large differences in initial neck position were observed. Second, the precision of the digitizer is limited by the discrete coordinate system used in the machine. The finest resolution is approximately .08 inch and the assignment of the x-y coordinate depends upon the position of the cursor. Third, the link lengths were specified subjectively on the x-rays. Since two x-rays must be used to calculate any given angle of movement, slight differences between the two x-rays in the position of a point could either minimize or compound error. Fourth, each link is less than three cm long, and slight digitizing errors can introduce large computational errors when angles are calculated between the two links in two views. The combinations of these four factors tend to cause great variability in results. However, the digitizing errors are random - just as likely to reduce as increase errors - and it is felt that the mean value is very close to what it would have been had the angles all been measured manually.

The mean values for range of motion between adjacent links with the least and greatest mobility are shown in Table 3-15. The smallest range of motion occurred between the C2 and C3 vertebrae with only 4.5 degrees total range on the average. In the case of elderly males, a negative flexion of 1.2 degrees is shown. This is equivalent to extension of 1.2 degrees and occurs because of the nature of the flexion movement. When the subject thrusts the chin straight forward in the initial part of the motion, it causes extension in the upper cervical spine. This extension may or may not be overcome as the head is tilted down to complete the movement. The greatest range of motion in the cervical spine occurs at the C5-C6 disk and averages 21.3 degrees. The pattern observed at the gross level is repeated at these levels; flexion mobility is not particularly affected by age, but extension capability and total range of motion decrease. Little difference, on the average, is observed between males and females.

Of particular concern in biomechanical modeling is the relationship between landmarks located on different major body masses. Several researchers have addressed this problem. For the study of neck dynamic response, for example, Ewing and Thomas (1972) have defined three coordinate systems: two anatomical and a laboratory reference. The head anatomical system has the origin at tragion and principal x-axis in the Frankfort Plane; the spine anatomical system is on the torso, originating at the anterior superior corner of T1 with principal x-axis along a line through the tip of the T1 spinous process (see Figure 2-8); the laboratory reference is external to the subject with principal x-axis horizontal. The same principal axes were defined on the x-rays in this study (for the

Table 3-15

Range of Motion of Cervical Spine Segments

	Angle between C2 & C3 link, deg				Angle between C5 & C6 link, deg		
	Flexion		Exten-sion	ROM	Flexion	Exten-sion	ROM
	N	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$
Females							
18-24	30	3.8	3.1	6.8	1.9	20.7	22.7
35-44	30	2.8	1.8	4.7	9.9	10.8	20.7
62-74	30	2.4	2.2	4.7	9.7	9.6	19.3
Males							
18-24	30	3.5	.9	4.4	11.4	15.4	26.8
35-44	30	3.0	1.5	4.6	11.1	11.0	22.2
62-74	25	-1.2	2.6	1.3	9.7	5.3	15.1
All Females	90	3.0	2.3	5.4	7.2	13.7	20.9
All Males	85	1.9	1.6	3.5	10.8	10.8	21.7
All Subjects	175	2.5	2.0	4.5	9.0	12.3	21.3

neutral position only) and their angular relationships were computed. The results are contained in Appendix D for the head and spine x-axes relative to vertical and to each other. Appendix D shows that the variability among subjects was very great, with a mean angle for all subjects of 12 degrees and a standard deviation of 10 degrees. (In Appendix D, a negative angle for the Frankfort Plane - Ewing measurement means the x-axes intersect in front of the head; a positive angle indicates intersection behind the head.)

3. <u>Correlations Between Range of Motion and Anthropometry</u>. Since anthropometric measures are usually easier to obtain than range of motion, the potential use of anthropometry to predict mobility was explored. Using the set of data for the 178 subjects, an intercorrelation matrix was prepared for the range of motion and all anthropometric measures. No correlations greater than r = .6 were obtained, so it seemed unlikely that anthropometry could be a reliable predictor of range of motion. Several measures that were of interest because of their potential relation to range of motion are shown in Table 3-16, together with their correlation coefficients for flexion, extension, and total range of motion. Although the degree of correlation is not high, several relationships exist. Weight and weight-related measures are negatively correlated; as weight or neck breadths and circumference increase, range of motion decreases. It is somewhat surprising to note that stature and sitting height have virtually no correlation with range of motion.

The analysis performed by Kelkar (see Section 3.B.3) was applied to predicting the range of motion of individual links, as well as predicting their lengths. Both flexion and extension prediction equations were

Table 3-16

Correlation Matrix of Range of Motion vs. Anthropometry

	FLEXION	EXTENSION	RANGE OF MOTION
Weight	-.20	-.23	-.25
Stature	.04	.19	.15
Ponderal Index	.27	.49	.47
Erect Sitting Ht.	.12	.22	.21
Lateral Neck Br.	-.08	-.17	-.16
A-P Neck Br.	-.32	-.49	-.50
Superior Neck Circ.	-.30	-.42	-.43
Inferior Neck Circ.	-.21	-.28	-.29
C6 Link	.17	.24	.26
Total Neck Length	.02	.21	.17

Note: Correlations are based on all subject data combined developed from the x-ray data, and it was found that only one of the anthropometric measures, anterior neck length had any bearing on cervical spine mobility. In order to predict cervical spine range of motion, it is necessary to know range of motion with respect to an external reference. While this is not extremely difficult to obtain, it means that the model designer must know both physical and mobility data about a subject group in order to predict at a very detailed level.

Kelkar's prediction equations were, unfortunately, developed based on the x-ray data. The independent variables he selected were the neutral, flexion, and extension angles between the arbitrary skull plane and external vertical. The equations predict the flexion and extension positions for subject groups very well, but their applicability is limited because it would first be necessary to know skull plane angles from x-rays. It would be possible to re-develop the equations so they would predict true ranges of motion of individual links, but that would require a major manipulation of the data beyond the scope of this report.

D. Voluntary Isometric Strength of Neck Muscles

The force exerted by the subject's neck muscles was detected by a force ring. Three maximum effort trials were conducted for each subject with both flexors and extensors. The data were analyzed in two ways - by manual data reduction from strip chart records and by a computer algorithm. The results from the strip-chart analysis are presented in this section and in Appendix E. The computerized analysis was used to assess muscle force in relation to EMG signal, and that analysis is in the next section.

1. Pull Force of Flexors and Extensors. Both flexor and extensor

muscle groups were tested for maximum isometric strength. The force produced by each is reported in Table 3-17, with more detailed summary statistics in Appendix E. In computing the means for Table 3-17, the value which was used for each subject was the average of that subject's three strength trials. With rare exceptions, the results of the three trials were within two or three lbf of each other. This indicated that learning or fatigue trends were not present, which allowed averaging the data for each subject. The mean values for the sex-age-stature groupings from Table 3-17 have been plotted in Figure 3-3. The figure shows similar patterns of strength for both flexors and extensors. For males there is a mild stature trend in the young group, and average strength actually increases between the young and middle age groups. Females show neither of these tendencies, tending instead to exhibit a slight but continuous decrease in strength throughout adulthood. It is also noted that the short subject groups always have the lowest average strength, that females are always weaker on the average than males, and that extensor strength is always greater than flexor strength. When statures are combined, it is seen that females gradually lose 29% of flexor strength and 16% of extensor strength between youth and old age, while males first increase by 7% and 20% then decrease by 25% and 25% for flexors and extensors, respectively. Females, on the average, are 53% as strong as males for flexors and 65% as strong for extensors.

Analysis of variance indicates that all of these differences are significant. The mean values for flexors are significantly different from each other for sex (α = .0005), age (α = .0005), stature (α = .01), and a combination of sex and age (α = .025). For extensors, significant

Table 3-17

Voluntary Force Exerted by Neck Muscles

Subject Groups		FLEXORS* N	FLEXORS* $\bar{x}$	FLEXORS* S.D.	EXTENSORS* N	EXTENSORS* $\bar{x}$	EXTENSORS* S.D.
Females							
18-24	1-20%ile	10	17.5	2.9	10	24.1	7.5
	40-60%ile	10	20.5	4.9	10	28.7	6.2
	80-99%ile	10	20.3	6.9	10	28.3	8.5
35-44	1-20%ile	10	15.6	4.0	10	23.5	6.6
	40-60%ile	9	18.3	5.6	9	28.5	5.7
	80-99%ile	11	16.1	3.5	11	28.2	6.3
62-74	1-20%ile	10	11.7	2.9	10	17.9	5.2
	40-60%ile	10	13.8	3.6	10	23.5	6.3
	80-99%ile	11	15.6	7.1	11	26.7	10.3
Males							
18-24	1-20%ile	10	27.5	9.2	10	33.6	4.4
	40-60%ile	10	33.4	7.5	10	36.6	11.6
	80-99%ile	10	36.3	11.7	10	43.0	8.5
35-44	1-20%ile	10	33.1	10.6	10	43.5	8.8
	40-60%ile	10	35.9	6.9	10	46.3	10.5
	80-99%ile	10	35.5	8.6	10	45.6	10.0
62-74	1-20%ile	6	23.3	5.9	6	32.2	9.1
	40-60%ile	11	28.8	9.5	11	35.1	10.0
	80-99%ile	10	25.3	4.3	10	33.5	4.8
Females							
18-24		30	19.4	5.2	30	27.0	7.5
35-44		30	16.6	4.4	30	26.7	6.5
62-74		31	13.8	5.1	31	22.8	8.3
Males							
18-24		30	32.4	10.0	30	37.7	9.3
35-44		30	34.8	8.6	30	45.1	9.5
62-74		27	26.3	7.3	27	33.9	8.0
All Females		91	16.6	5.4	91	25.5	7.6
All Males		87	31.3	9.3	87	39.1	10.0
All Subjects		178	23.8	10.6	178	32.1	11.2

*Note: Dimensions are in lbf.

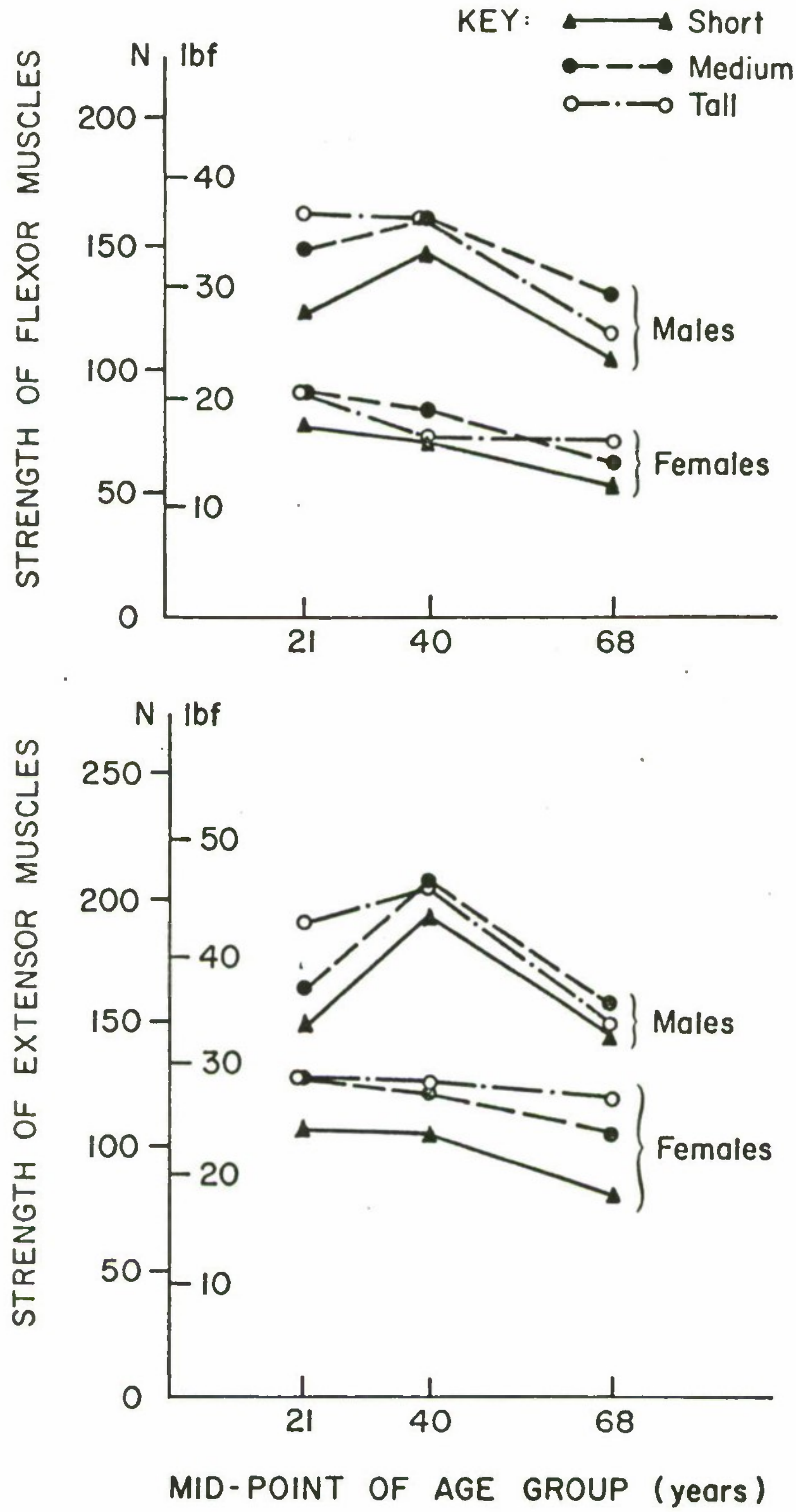

Fig. 3-3. Isometric Strength Test Results. Note that shorter people average less strength, that males and females exhibit different aging characteristics, and that extensors average stronger than flexors.

differences are also noted for sex ($\alpha = .0005$), age ($\alpha = .0005$), stature ($\alpha = .001$) and sex-age combined ($\alpha = .025$). The results indicate that the population stratification which a person fits into can have a significant effect on how strong the neck muscles are. Extensor muscle strength is significantly greater than that of flexors ($\alpha = .0005$), so the direction of impact is also important.

The headband used in the strength test was oriented approximately in the plane of the head center of gravity, and thus the results are indicative of the muscle force that could be brought to bear to resist head motion. It would be of interest to translate this pull force into actual muscle tension. This cannot be done with the present data, however, since (expecially in flexion) no single muscle is responsible for all of the force generated. For example, it is known that the sternomastoid muscles stabilize the lower spine and are the primary flexors of the neck, but they originate posterior to the head-neck junction, so the force they exert cannot stabilize the upper spine. Other muscles such as the longitudinal spinal muscles must do the stabilizing. Since the force ring measures only the lumped effort of all of the muscles, there is no possibility of separating components of force and calculating tension in a specific muscle.

2. Strength Correlations with Anthropometry. On the assumption that strength of the neck muscles could be directly related to some of the anthropometric variables measured in this study, the correlation between strength and anthropometry was studied. The results, shown in Table 3-18, indicate that moderate correlations were found between certain measures. Flexor muscle strength was moderately correlated ($r \geq .66$) with erect sitting height, lateral neck breadth, and bideltoid breadth. Bideltoid

Table 3-18

Correlation Matrix of Strength vs. Anthropometry

	FLEXORS	EXTENSORS
Weight	.59	.56
Stature	.62	.60
Erect Sitting Ht.	.66	.61
Biacromial Br.	.62	.59
Bideltoid Br.	.72	.68
Lateral Neck Br.	.68	.63
A-P Neck Br.	.55	.53
Superior Neck Circ.	.57	.54
Inferior Neck Circ.	.62	.60
C3 Link	.52	.50
Total Neck Length	.50	.48

Note: Comparisons are for all subjects combined.

breadth was the best predictor of extensor muscle strength. Strength is better correlated to stature than to weight.

3. Comparison With Other Research. Late in 1972, while data for this study were being collected, a paper was published by Marotzky which described neck strength testing using an apparently similar protocol. The paper was translated and found to be similar enough in methodology to allow a detailed comparison of the results.

Marotzky tested 307 subjects, of which 207 (164 male, 43 female) were "young" (average age 23, age range 19-37) and 100 were "older" (45 males, 55 females, average age 73, age range 50-90). His groupings are relatively consistent with the age ranges tested in this study. The subjects were tested for isometric strength of flexor and extensor muscles, though the same young subjects seldom pulled in both directions. According to the paper 70 young males pulled forward and 71 backward for the "maximum" trials and 43 elderly males pulled in each direction. For the test trials similar to those of this study, the subjects were seated (torso-leg angle 90°) and were lap-belted. Precautions were taken to prevent leg bracing and the hands were in the lap. The subjects pulled against a force-measurement transducer attached to a headband; the headband was positioned in the plane of the head center of gravity. Subjects held the exertion for 5-10 seconds and were given a rest period of 1-2 minutes between trials. Only one trial was conducted for each condition, and the paper does not specify if the strength reported is maximum seen in the trial or an average over a specific time period. In addition to tests similar to those conducted in this study, Marotzky conducted "maximum effort" tests with the arms braced and adding to the strength.

Table 3-19 contains a comparison of test results for similar subject groupings. Agreement is excellent between the two studies for the results with young subjects under similar testing conditions. Extensor strength results for Marotzky are 23% higher than for this study, suggesting that the lap belt his subjects wore allowed more back muscles to exert force than in this study with no lap belt in use. There is wide disagreement, however, between the two studies with respect to results for elderly subjects. IIHS subjects were four times stronger for flexors and three times stronger for extensors. Table 3-20 tabulates the percentage loss with age between the two studies.

Marotzky also cites a study in which percentage loss from the arms is expected to be approximately 40%. The extreme degradations of strength suggests either that there are great ethnic differences between elderly Americans and Germans or that severe motivation effects were encountered among Marotzky's elderly subjects. A certain amount of caution was noted among many elderly IIHS subjects also (particularly females), but the data were not as substantially affected.

Martozky also examined the correlation of weight and stature vs strength, using the maximum effort (arms braced) results. He found "no relationship" between stature and strength, but significant correlation (α = .05) between weight and strength. The correlation coefficients are compared in Table 3-21 for the two studies. It is interesting to note that both the pattern of significance and the value of the correlation coefficients are similar, even where the absolute values of the somewhat dissimilar tests are quite different.

Table 3-19

Comparison of Strength Test Results

Average Strength,[1] lbf.

	Flexors			Extensors		
	IIHS[3]	Marotzky	Marotzky, with bracing	IIHS	Marotzky	Marotzky, with bracing
	$\bar{x}$ (SD)	$\bar{x}$	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$	$\bar{x}$ (SD)
Females						
young[2]	19.4 (5.2)	18.0	21.6 (8.6)	27.0 (7.5)	32.8	46.9 (9.2)
older	13.8 (5.1)	4.4	6.1 (3.5)	22.8 (8.3)	7.0	11.2 (5.5)
Males						
young	32.4 (10.0)	32.1	39.6 (12.1)	37.7 (9.3)	46.6	80.1 (22.0)
older	26.3 (7.3)	6.4	11.4 (8.1)	33.9 (8.0)	11.6	18.9 (10.3)

Notes:

[1]Standard Deviation reported by Marotzky only for maximum effort trials.

[2]Age definitions:

	Marotzky subjects			IIHS subjects		
	N(equiv)	average	range	N	average	range
Female, young	33	21	19-31	30	21.9	18-25
older	55	75	49-90	31	66.3	61-74
Male, young	70	23	19-37	30	21.4	18-26
older	45	74	50-89	27	68.6	62-74

[3]IIHS and Marotzky are comparable test conditions. Marotzky also reported maximum effort results with hands braced and arms exerting effort.

Table 3-20

Percentage Loss of Strength with Age

	Flexors			Extensors		
	IIHS	Marot.	Marot., w. bracing	IIHS	Marot.	Marot.,w. bracing
Females	28.9	75.8	70.0	15.6	78.5	76.5
Males	18.9	80.2	73.0	10.1	75.0	75.5

Note: Data for young subjects = 100%.

Table 3-21

Comparison of Correlation Coefficients
between Weight and Strength

	Flexors		Extensors	
	IIHS	Marotzky, with bracing	IIHS	Marotzky, with bracing
Females, young	.28(N.S.)	N.S.	.33(N.S.)	.37*
older	.43*	N.S.	.17(N.S.)	N.S.
Males, young	.52*	.64*	.50*	.27*
older	.42*	.37*	.32(N.S.)	.32*

N.S. = not significant at $\alpha = .05$

* = significant at 5% level

In summary, these two studies were conducted independently in different countries but using similar techniques. They achieved very comparable results for young subject groups and widely differing results for older subjects. The degree of comparability indicates that neck muscle strength for younger individuals has been well-defined. The disparity of results for elderly subjects remains unresolved.

E. Neck Muscle Response to Low Levels of Acceleration

In analyzing and presenting the results of the neck response portion of the study, several areas of interest were explored. First, the two time components of response were defined-reflex time and muscle force buildup time--which when combined equal reaction time. Second, since care had been taken to "calibrate" the relationship between EMG signals and developed muscle tension, a substudy was undertaken to use that relationship to estimate the tension developed by the sternomastoid muscles during the impulsive reflex time test. Finally, a brief examination of the acceleration data was conducted. These three topics are discussed in order in this Section.

1. Reflex Time and Reaction Time of Neck Muscles. The methods used to impart a controlled jerk to the head and to reduce the data were described in Section 2.D. Reflex times and time to maximum deceleration of the head (which is equivalent to zero rearward velocity, maximum rearward movement of the head and total muscle reaction time) were obtained from the strip-chart records. Summaries of results for reflex time, muscle force buildup time, and total reaction time are presented for the appropriate subject categories in Appendix E.

Reflex test results for both flexor and extensor muscles are presented in Table 3-22. In computing these values, the reflex time specified for a given individual is the average of at least three trials, each having similar results.

For the flexor (sternomastoid) muscles, Table 3-22 shows that males and females tend to have different reflex times, that reflexes degrade somewhat with age, and that there is little apparent stature effect. Statistical analysis verifies these observations: significant differences between means (α = .0005) are found for subjects grouped by sex and by age. There are no significant differences found for other subject groupings. Figure 3-4 (left bar chart) was then prepared to illustrate the relationships for subjects grouped by sex and age. In each age group, females had faster reflexes than males. Reflexes became slower with increasing age, although males slow gradually in all age groups and females slow after middle age. Female flexors slow by 16% between young and elderly groups; males, by 23%. Overall, females average 15% faster reflexes than males. Slightly different patterns emerge for the extensor muscles. Table 3-22 reveals little difference due to sex and stature, while the age variation remains large. Analysis of variance results indicate no significant difference in means due to sex, highly significant difference for age (α = .0005) and a stature difference (α = .01). Also, the analysis indicated that the eighteen means for subjects grouped by sex, age, and stature were statistically different at the α = .05 level. This result has little practical significance since most of the variation is attributable to age. The data for groupings by sex and age are plotted in Figure 3-4 (right bar chart) and show that females still have faster reflexes throughout life than males, but the difference is less than for

Table 3-22

Neck Muscle Reflex Time

Subject Groups		FLEXORS* (weight dropped behind head) N	$\bar{x}$	S.D.	EXTENSORS* (weight dropped in front of head) N	$\bar{x}$	S.D.
Females							
18-24	1-20%ile	10	58.9	8.2	10	54.3	7.4
	40-60%ile	10	60.1	8.4	10	57.1	6.7
	80-99%ile	10	67.3	10.6	10	59.5	9.7
35-44	1-20%ile	10	55.6	12.4	10	55.1	10.4
	40-60%ile	9	66.3	16.1	9	60.7	12.7
	80-99%ile	11	64.0	11.3	11	60.6	7.2
62-74	1-20%ile	10	74.2	19.5	10	72.3	9.5
	40-60%ile	10	78.5	17.7	10	73.2	11.3
	80-99%ile	11	71.8	14.8	11	74.8	11.1
Males							
18-24	1-20%ile	10	65.4	11.5	9	53.9	5.7
	40-60%ile	10	64.9	9.7	9	64.9	14.1
	80-99%ile	10	74.3	12.9	9	58.1	5.3
35-44	1-20%ile	9	82.4	11.6	9	61.3	6.3
	40-60%ile	10	75.5	14.8	10	60.8	6.3
	80-99%ile	10	74.0	14.1	10	64.5	9.5
62-74	1-20%ile	6	79.4	15.2	6	66.7	4.2
	40-60%ile	11	91.6	10.5	11	75.7	8.6
	80-99%ile	10	89.4	22.0	10	86.7	15.7
Females							
18-24		30	63.3	9.6	30	57.0	8.1
35-44		30	61.9	13.6	30	58.8	10.2
62-74		31	74.7	17.0	31	73.5	10.4
Males							
18-24		30	68.2	11.9	27	59.0	10.1
35-44		29	77.1	13.6	29	62.2	7.5
62-74		27	88.1	16.7	27	77.8	13.3
All Females		91	66.4	14.9	91	63.2	12.1
All Males		86	77.4	16.1	83	66.2	13.2
All Subjects		177	71.8	16.4	174	64.6	12.7

*Note: Dimensions in milliseconds

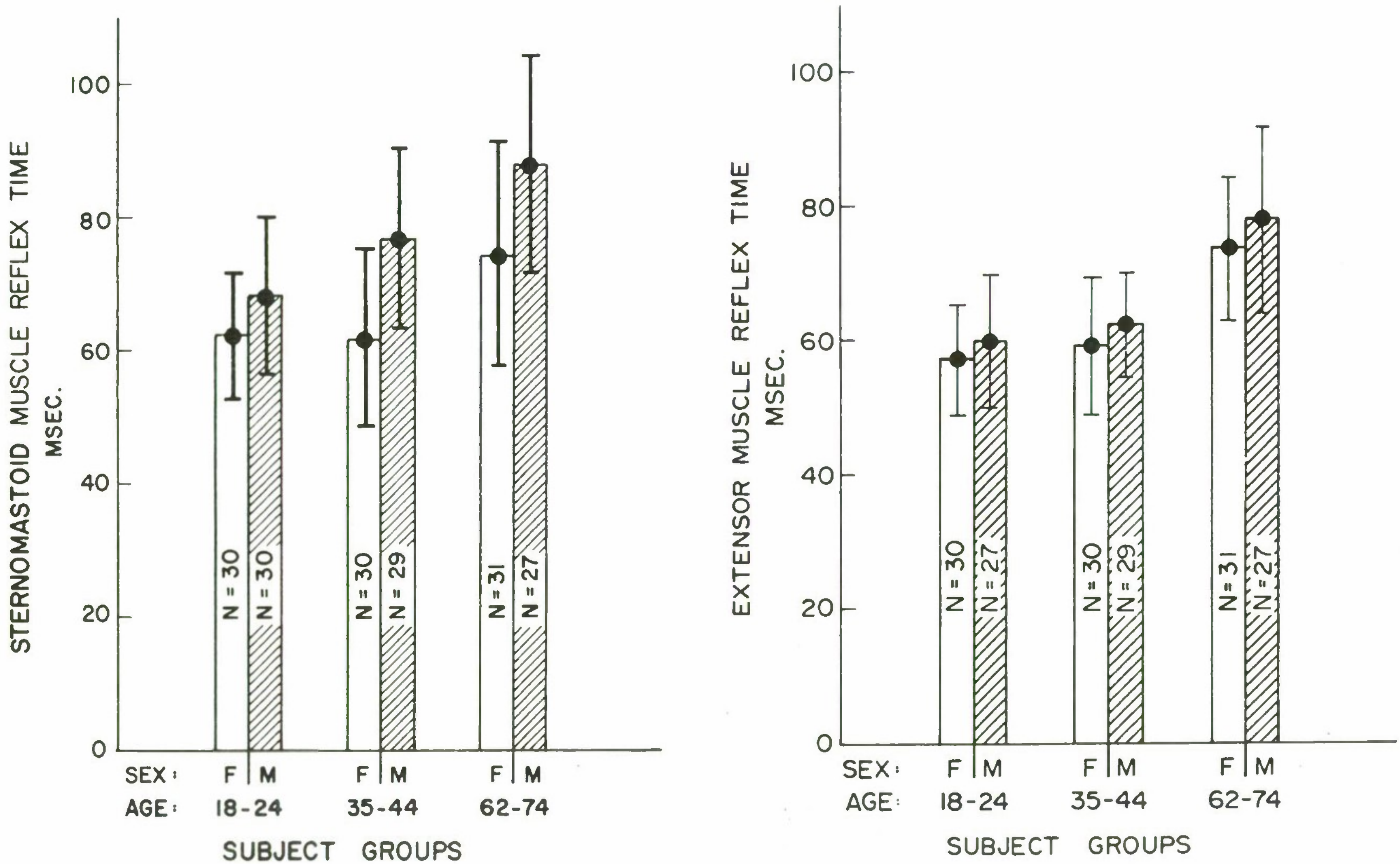

Fig. 3-4. Reflex Times of Neck Muscles. The flexor muscles (at left) show a gradual increase in reflex time with age and different responses for males and females. The extensor muscle reflexes (at right) show less degradation with age and similar responses in males and females. Extensor reflexes are slightly faster than flexors.

flexors. The same aging pattern as with flexors is also noted, though not to the same degree. Female extensor reflexes slow by 23% over the age spans measured, and males slow by 24%.

Extensor reflexes are faster than those of the flexors. In every category in Table 3-22 (except tall elderly males) the extensors have slightly-to-significantly shorter reflex times. Comparing the data for all subjects combined, extensors reflex 10% faster. The mean reflex times are significantly different at the $\alpha = .05$ level.

Coupled with reflex time is the muscle contraction, or force buildup, time. For this study contraction time was determined by subtracting reflex time from reaction time. Average contraction times, contained in Appendix E, show little difference. The range for flexors is from 50 to 69 ms (average 61 ms). For extensors, the range is from 60 to 76 ms (average 69 ms). Analysis of variance revealed no significant differences for any subject stratification for contraction times of either flexors or extensors. Apparently, sex, age, or muscle location have little effect on the rate at which muscles develop tension. It should be noted that this contraction time is not the time required for maximum muscle tension. The forces applied to the head were not enough to require a maximum muscle reaction effort.

As noted above, the reaction time was defined as the time from start of head acceleration to the point of maximum head deceleration (see Figure 2-16). Average reaction times for this study are shown in Table 3-23. They tend to follow the pattern established by reflex time, since contraction time was fairly constant for different subject groups. Statistical analysis of flexor muscle reaction times continues to show

Table 3-23

Neck Muscle Reaction Time

Subject Groups		FLEXORS* N	FLEXORS* $\bar{x}$	FLEXORS* S.D.	EXTENSORS* N	EXTENSORS* $\bar{x}$	EXTENSORS* S.D.
Females							
18-24	1-20%ile	10	114.7	8.3	10	125.4	3.0
	40-60%ile	9	122.1	7.7	10	133.5	15.0
	80-99%ile	9	121.8	12.4	8	133.0	13.2
35-44	1-20%ile	10	124.9	11.3	10	126.0	9.4
	40-60%ile	9	122.3	9.9	9	134.7	7.2
	80-99%ile	10	121.3	12.6	10	123.9	9.3
62-74	1-20%ile	10	142.5	17.0	10	142.0	10.5
	40-60%ile	10	139.6	13.6	10	142.0	5.8
	80-99%ile	11	140.5	14.8	11	140.4	9.0
Males							
18-24	1-20%ile	10	122.0	20.2	8	128.1	14.5
	40-60%ile	10	127.4	10.3	9	127.8	17.3
	80-99%ile	10	140.4	21.5	9	133.2	15.8
35-44	1-20%ile	10	136.4	19.9	9	129.6	15.2
	40-60%ile	10	136.1	13.8	10	137.3	9.9
	80-99%ile	10	135.7	17.1	10	128.7	10.1
62-74	1-20%ile	6	141.8	10.9	6	136.8	8.6
	40-60%ile	11	141.5	14.1	11	140.7	15.4
	80-99%ile	10	150.6	26.7	10	146.6	13.1
Females							
18-24		28	119.4	9.9	28	130.5	11.8
35-44		29	122.9	11.1	29	128.0	9.6
62-74		31	140.8	14.7	31	141.4	8.4
Males							
18-24		30	129.9	19.1	26	129.8	15.5
35-44		30	136.1	16.5	29	131.9	12.1
62-74		27	144.9	19.1	27	142.0	13.4
All Females		88	128.1	15.4	88	133.5	11.5
All Males		87	136.7	19.1	82	134.6	14.5
All Subjects		175	132.4	17.8	170	134.0	13.0

*Note: Dimensions are in milliseconds

significant differences among means for sex and age categories (α = .0005). However, for extensors, age is the only category in which means differ significantly (α = .0005). The contrasts of slower reflexes and faster contraction time for flexors and faster reflexes but slower contraction for extensors result in virtually identical reaction times overall for both groups of muscles. This means that the time from impulse to end of head motion is the same for both neck flexors and neck extensors.

In a sudden impulsive movement, it is probable that as the muscles react, they could easily over-correct, moving the head past the neutral position to one of instability in the direction opposite to the initial impulse. At this point it would be necessary for the antagonist muscle to react to compensate for the over-correction. Since both groups of neck muscles were continuously monitored by EMG, a limited investigation of the data was conducted to learn if this over-correction phenomenon occurred after low-level impulses. Data from the subgroup of 24 subjects used to develop EMG strength relationships (to be discussed in the following section) were examined. What was considered to be a reflex of the antagonist muscles was observed in at least one trial for thirteen of those subjects, indicating that even low-level forces could induce an antagonist reflex. The difference in times between the primary and antagonist reflexes was calculated. The results were inconclusive; difference times ranged from only 14 ms to over 90 ms with no obvious mode in the distribution.

2. Analysis of Electromyographic Data. Electromyograms are produced when a muscle fiber is activated. Whether caused by stretching of the muscle spindles in the stretch reflex loop or by voluntary action from higher central nervous system centers, when the motoneuron stimulates a

muscle fiber, depolarization of that fiber and a measurable electrical discharge occur. By recording the amplitude of the resulting EMG signal from the skin near the muscle, it is possible to estimate the forces exerted by the muscles. By noting the beginning and ending of an EMG epoch, it is possible to predict the length of a contraction period. The application of these two characteristics of EMG to the data gathered in this study will be discussed in this section.

The force developed in a muscle appears to be proportional to the amplitude of the summed muscle action potentials (EMG), as detected by electrodes on the skin located over the muscle's active tissue (Bigland and Lippold, 1954; Chapman and Troup, 1969; and Lippold, 1952). The quantitative relationship between a muscle's volitional force and the measured EMG amplitude varies, however, with several known factors. These factors include the state of strength training, the state of muscle fatigue, length of muscle, and the placement of the electrodes. A person who can develop high strengths requires proportionally fewer numbers of active motor units for a given load; hence, a smaller amplitude EMG develops at different submaximal loads than would occur with a weaker person. When a muscle fiber is fatigued, its ability to develop contractile tension upon further stimulation decreases. The result is that greater frequency of stimulation, together with recruitment of other motor units, is necessary to compensate for the loss of tension-producing capability in fatigued muscle fibers. For this reason fatigue causes an increase in the amplitude of the EMG. The maximum tension that can be developed by a muscle decreases as it is stretched or shortened relative to the normal resting length. This characteristic of the muscle modifies muscle fiber recruitment patterns and will affect the EMG signal. Lastly, the position of the electrodes will affect the EMG, because EMG amplitude is proportional to the distance between the muscle and the electrode.

With these factors in mind, the strength testing portion of the study was designed to measure the degree of muscle activity in the neck/head flexor muscles during isometric contractions at varying force levels. It was believed that if an acceptable quantitative relationship between EMG amplitude and muscle load could be obtained in the static tests, it could be used to predict the muscle tensions during controlled dynamic tests.

Muscle strength and corresponding EMG signals were obtained as described in Section 2.E. Data reduction involved determination of a mean force exerted by each subject for each requested level. The mean EMG power was obtained by a computerized algorithm. This required the EMG signal during the middle three seconds of exertion to be converted to amplitude levels A_i at intervals of every 6 ms, thus yielding 500 digital samples for each exertion epoch. These were then rectified (treated as positive values only) and were checked for excessive peak values which would indicate possible saturation of the amplifiers or FM tape recorder used to store the analog signals. Any DC offset was also subtracted from the values. The EMG_{RMS} amplitude over the three-second period was then computed as:

$$EMG_{RMS} = \sqrt{\frac{1}{500} \sum_{i=1}^{500} A_i^2}$$

A plot of the resulting EMG_{RMS} values for the various exertion levels is given in Figure 3-5 for the 35-44 age group of male volunteers in the study. The regressions indicate that the relationship can be treated as being linear, and a simple forced-zero intercept model is adequate.

What is also depicted in Figure 3-5 is a significant variance in the relationship between test results under identical conditions for different male subjects of similar age. This variance must be even further recognized when the total sample is considered, as depicted in Figure 3-6 by the forced-zero regression lines and their respective slope coefficients.

A co-variance analysis of these data indicated that neither sex, age, nor stature removed a significant amount of the variance in the relationship. Hence one must conclude that, even with good controls and standardized procedures, the use of EMG_{RMS} levels to predict precise muscle loadings for a given individual will not be possible without first calibrating the person's EMG_{RMS} level by use of a set of graded standardized loads in the position of interest. Once this is done, however, it is believed that the resulting EMG_{RMS} levels can be a useful research tool in constructing better biomechanical models. The basis for this is that for a given test session and individual the coefficient of variation usually averaged less than six percent in the tests just described. In other words, once an EMG_{RMS}/Force relationship has been developed for a given person during a test session, it is precise enough to allow subsequent EMG_{RMS} levels to be used as predictors of the muscle activation levels in subsequent tests.

The use of EMG to determine stretch reflex times of the neck flexor muscles was discussed in the previous section. However, when the EMG_{RMS}/force relationship was established for a subject, the EMG signal could also be used to estimate the force developed by the muscle during a reflex

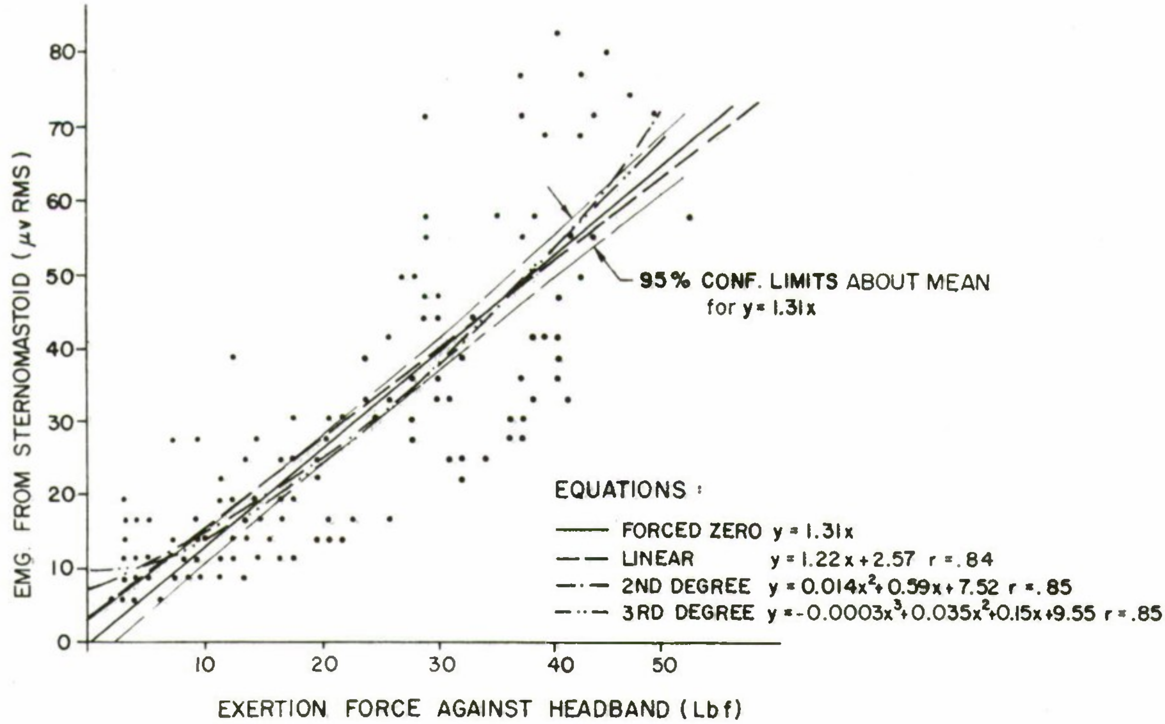

Figure 3-5. EMG_{RMS} of sternomastoid muscle vs. exertion force levels against headband by male subjects, age 35-44.

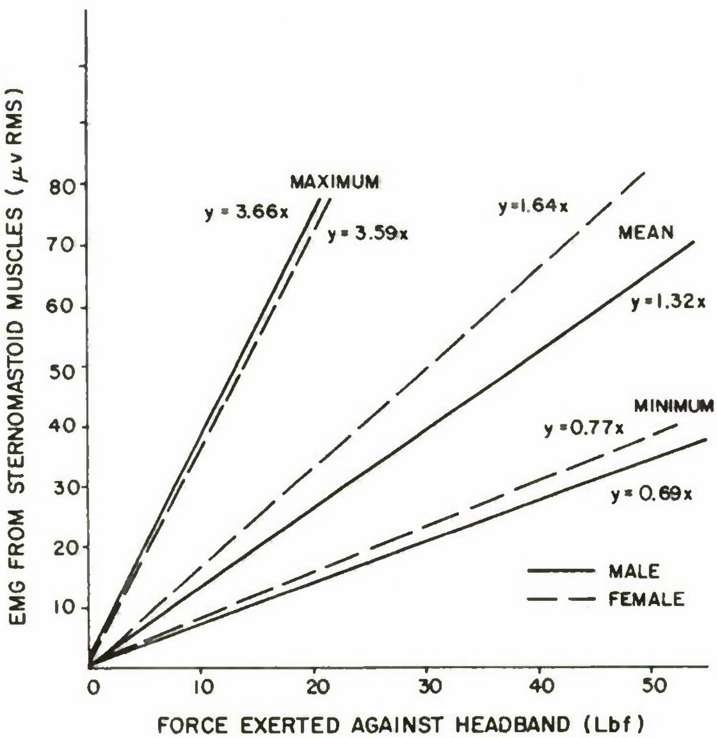

Figure 3- 6 . EMG_{RMS} forced-zero regressions versus exertion force levels for total subject group. The mean regression slopes are for all males and all females; the minimum and maximum slopes are the extremes for individual subjects.

test. As will be discussed in the next chapter, both the reflex time and the strength of muscle response can be important in mitigating the effects of a surprise rear-end collision.

The method for estimating muscle force during a reflex test was applied to a subgrouping of 24 subjects with representation from all sex, age,and stature groups. The procedure for estimating the dynamic muscle force response entailed digitizing the EMG signals obtained during the reflex tests and computing the RMS amplitudes of the EMG during the initial response to the head jerk. These amplitude values were compared to the values obtained during the static calibration tests, wherein the relationship $EMG_{RMS} \propto$ Static Load is assumed with the proportionality constant (a regression slope) given by the earlier static tests of the individual. Thus:

$$\text{Dynamic Muscle Load} = b(EMG_{RMS})$$

where

b: proportionality constant based on static tests of same subject.

EMG_{RMS}: RMS amplitude of EMG's during contraction following head jerk .

Dynamic Muscle Load: Prediction of load developed by active muscle contraction during jerk tests of individual.

Application of the technique is illustrated by the following two examples.

Example One: The one pound load used to jerk the head was dropped 6 inches, developing a peak acceleration (upper accelerometer) of 0.95 g. After 40 ms the sternomastoid muscles became active, and during the next 62 ms developed an EMG_{RMS} of 22.4 μv. Since this individual's static

EMG/Force relationship showed a regression slope of 3.6, it was estimated that the muscles then provided an average stopping force of 6.2 lbs, which was probably the major component providing deceleration of the head.

Example Two: The jerk load was dropped in a similar fashion as case one with a similar resulting head acceleration of 1.1 g. In this case, however, very little muscle response was observed. Subsequent analysis revealed that the muscles developed an EMG_{RMS} of 5.5 μv for a period of 24 ms. The static EMG/Force relationship for this individual had a regression slope of 7.1. In this case, the muscles were estimated to exert an average stopping force of only 1.1 lbs., indicating that the muscles were probably not the major decelerator of the head.

This technique was applied to the data from 16 subjects. The estimates ranged from a force of virtually zero (no active muscle reflex generated--all force dissipated in passive tissue) to as high as 26 lbs. The average force estimated was 5.6 lbs. for males and 9.6 lbs. for females. While the sample size was small and the variability between subjects was large, these limited results tend to indicate that females must exert a greater muscle force than males to adequately respond to a given impulse.

The force estimation method described above was combined with observations of the unprocessed EMG signal to assess whether dynamic and isometric muscle responses (as evidenced by EMG) are the same. The data from five subjects were used for the study. After the muscle force was calculated for a reflex test, the reflex and isometric test EMG signals were closely compared. Invariably, the signal characteristics (amplitude, apparent period, etc.) closely resemble each other at equivalent force levels. While this observation is certainly not proof, it is an indication that the response of a muscle detectable by EMG surface electrodes is the same whether the muscle is activated by dynamic (stretch reflex) conditions or by isometric (voluntary) conditions.

3. Acceleration Results. The accelerations recorded during the reflex tests were intended to be used only as indicators of head motion for the purpose of calculating stretch reflex time. Since the head motions involved were both translational and rotational, the two uniaxial accelerometers could not be expected to record the absolute linear and angular accelerations experienced by the subjects. However, the consistency of testing technique does allow the data to be used in a relative manner. Table 3-24 is a compilation of results of peak deceleration of the head as measured by the accelerometer at the top of the headpiece. The results indicate that relatively less deceleration force was experienced by taller subjects, in both flexor and extensor tests. Results are similar between males and females,nor is any consistent aging effect seen. It is notable that the overall average deceleration for both flexors and extensors was the same at 0.96 g as measured. This matches the similarity of reaction time results (132 ms for flexors, 134 ms for extensors). The corresponding results for acceleration of the head due to impulse loading by the weight were a peak of 0.77 g and time-to-peak of 38 ms (same for both muscle groups). The test procedures followed the guideline of dropping the weight the minimum distance (and thus applying the minimum force) necessary to achieve a definitive reflex. These results, then, indicate that the acceleration levels required to elicit the involuntary stretch reflex of the neck muscles are approximately the same for both flexors and extensors.

Table 3-24

Peak Deceleration of the Head during Reflex Test

Subject Groups		FLEXORS* N	$\bar{x}$	S.D.	EXTENSORS* N	$\bar{x}$	S.D.
Females							
18-24	1-20%ile	10	1.10	.24	10	1.05	.25
	40-60%ile	9	.97	.26	10	.92	.27
	80-99%ile	9	.85	.18	10	.81	.16
35-44	1-20%ile	10	.91	.14	10	1.07	.20
	40-60%ile	9	.97	.13	9	1.13	.21
	80-99%ile	11	.99	.23	10	1.06	.15
62-74	1-20%ile	10	1.11	.13	9	1.14	.20
	40-60%ile	9	.94	.18	10	.98	.16
	80-99%ile	11	.99	.18	11	.93	.17
Males							
18-24	1-20%ile	10	.98	.13	8	1.02	.09
	40-60%ile	10	.97	.23	10	.83	.15
	80-99%ile	10	.81	.31	10	.80	.22
35-44	1-20%ile	9	.99	.15	9	.92	.20
	40-60%ile	9	1.07	.17	10	.99	.16
	80-99%ile	10	.89	.11	10	.92	.20
62-74	1-20%ile	6	.94	.18	6	.86	.14
	40-60%ile	11	.95	.13	11	.94	.19
	80-99%ile	10	.92	.15	10	.84	.18
Females							
18-24		28	.98	.25	30	.92	.25
35-44		30	.96	.17	29	1.09	.18
62-74		30	1.01	.17	30	1.00	.19
Males							
18-24		30	.92	.24	28	.87	.19
35-44		28	.98	.16	29	.94	.18
62-74		27	.94	.14	27	.89	.18
All Females		88	.98	.20	89	1.00	.22
All Males		85	.95	.19	84	.90	.18
All Subjects		173	.96	.19	173	.95	.21

*Note: Dimensions in g's

CHAPTER 4

BIOMECHANICAL MODELING USING TEST RESULTS

A. Introduction and Objectives of Mathematical Modeling

The data gathered in this study were intended to be of practical use to other researchers and ultimately to designers of protective systems. The area of immediate application of the results is that of biomathematical modeling of cervical response. The objective of this portion of the study was to use the results with a specific model and explore the effects of body size, range of motion, and muscle strength on the body's response to a simulated rear-end collision.

There are several approaches to mathematical modeling of impact response. The region of the body that is to be studied may be isolated and its response calculated based on specified inputs. This method may be fairly simple or highly complex, depending on how much detail is included. Another method is whole-body response, in which the body region of interest is examined in its relation to the remainder of the body. Whole-body response modeling, even using fairly gross segmentation, is complex, since many joints and body segments must be incorporated. Finally, whole-body modeling with movement-restricting external surfaces is the most sophisticated. In this type of modeling, material properties of the surroundings as well as those of the occupant must be included.

In the case of the head and neck in hyperextension and rebound, impulsive forces must be transmitted by the seat through the torso to the base of the neck. Then, depending on vehicle interior surfaces and body restraints, the head may contact a seat or head restraint, the glass, instrument panel or steering wheel. These requirements suggest the use of the third type of model if gross body motion and possible contact with interior surfaces are to be examined. Such a model is the HSRI Two-Dimensional Crash Victim Simulator. The occupant simulator is composed of nine body segments and seven joints; vehicle components such as floor, seat, head restraint, instrument panel, and various belt restraint systems may be specified. This gross motion model was used by Robbins, et al (1974), to investigate injury susceptibility for different population groups. This investigation is discussed in the next section.

Gross motion simulation is necessarily limited in the amount of detail that can be incorporated, since computer costs for running such models rapidly become prohibitive. The detailed nature of some of these results would permit a closer study of neck response if an appropriate isolated head-neck model were available. Such a model is being developed based upon the results from this study. When complete, it will be published to supplement this report.

B. Simulations with HSRI 2-D Crash Victim Model

Some of the results of this research were used by Robbins, Snyder, Chaffin, and Foust (1974) for a study of how neck physical parameters might affect injury susceptibility for various population groups. The model used was the HSRI Two-Dimensional Crash Victim Simulator. This model simulates a seated occupant moving in the sagittal plane, with a single joint at the base of the neck to model head-neck motion, two joints in the spine, and joints at the shoulder, elbow, hip, and knee. Force generating contact circles are placed at head, thorax, hip, and on the extremities to provide interaction with the vehicle interior. Muscle forces are included as motion-resisting torques at the joints. The model run descriptions and results presented in this section are adapted from the paper by Robbins, et al (1974).

1. Input Data. Crash description, the vehicle interior description, and the occupant description are necessary input data for the model. For this study, the crash used is representative of a rear-end collision with a final velocity differential of 30 mph. This approximates a car-to-car rear-end collision with closing rate of 50-60 mph. The impact pulse is that described by Melvin and McElhaney (1972). The pulse, as shown in Figure 4-1, has two spikes with the peak acceleration of 15 g at 60 ms, decaying linearly to 0 g at 192 ms.

The vehicle interior consists of seat back, seat cushion, and floorboard. The seat back and seat cushion angles match those of the simulated auto seat from which the data were obtained. The seat force-deformation properties are those measured during verification tests for this model. A lap belt was included to prevent ramping up the seat back and to reduce body motion other than at the neck joint.

The basic occupant description is that of a 50th percentile male defined primarily from Air Force Studies (Hertzberg, 1954). Modifications from that baseline were made using the results of this study to specify eighteen separate population groups. Six stature groups were specified without regard to sex (short, average, and tall females, and short, average, and tall males). Body weight, cervical range of motion, and neck muscle strength were categorized by sex, age, and stature into 18 groups, as reported in Chapter 3. The average results for each category were used to define an occupant for model input. Occupant initial positions for the population stature extremes are shown in Figure 4-2.

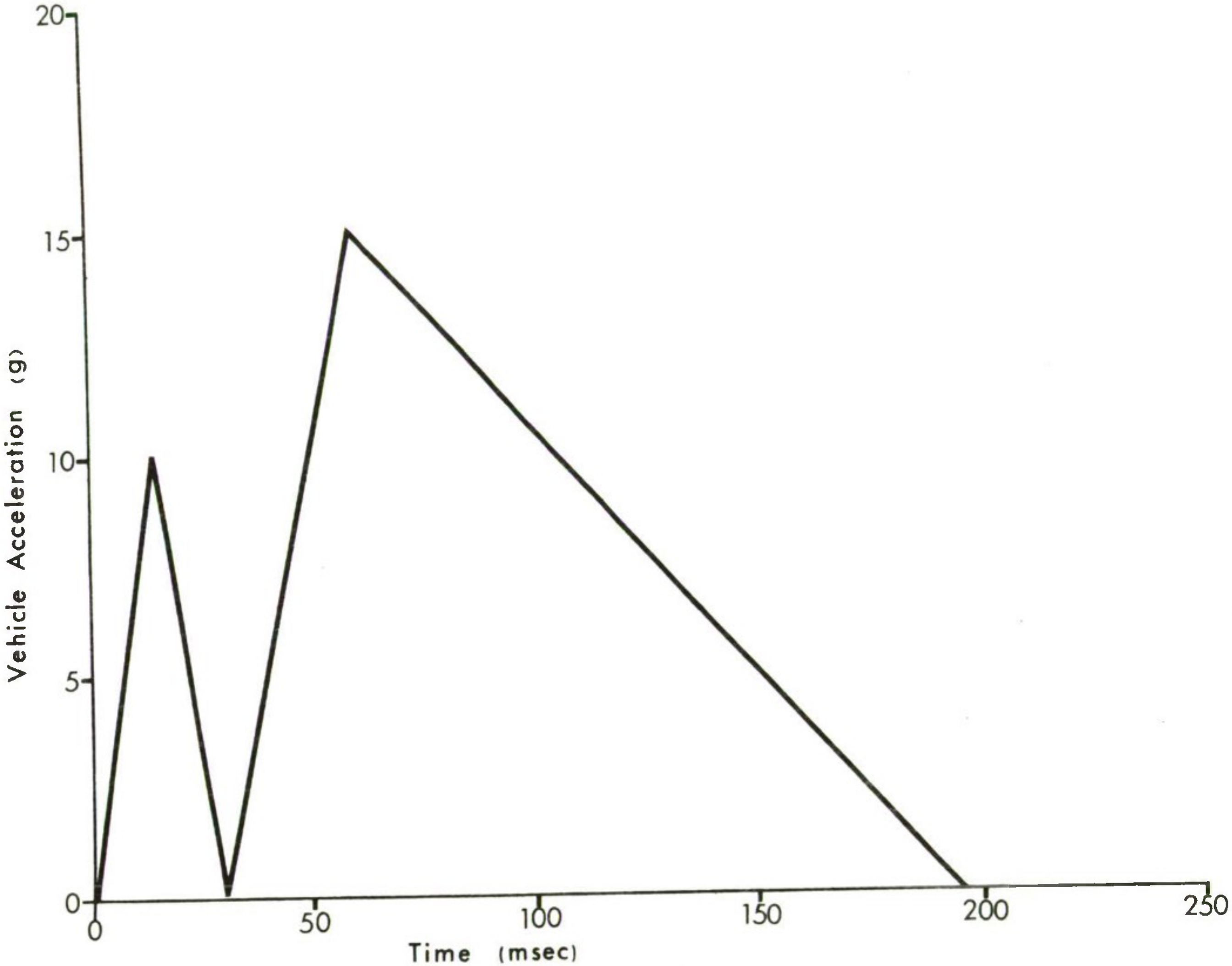

Figure 4-1. Vehicle acceleration input pulse.

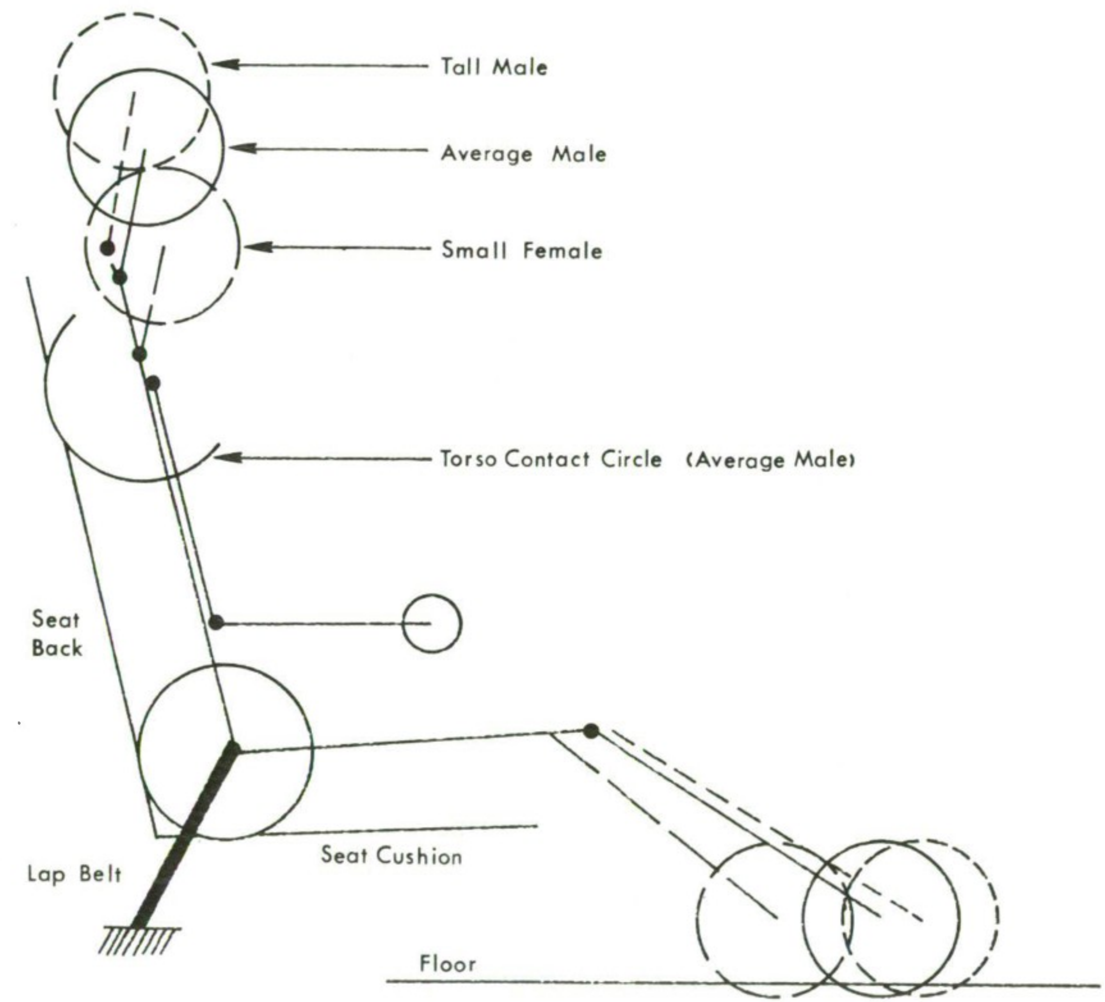

Figure 4-2. Comparison of initial configuration for three occupant sizes.

The computer exercises were designed to simulate response of the eighteen defined occupants for the 30 mph rear-end collision. Seat properties and crash conditions remained constant for these exercises; body weight, stature, range of motion, and neck muscle strength varied according to the population group. In addition, various degrees of surprise were simulated, with the neck muscles relaxed throughout the crash and with the muscles tensed at one-half the maximum voluntary force. (There is no provision in this model for muscle reflex and muscle force build-up. The muscles must either be tensed or relaxed.) All computer runs simulated rear-end collisions, with the head and neck initially hyperextending.

2. Results. Examination of the computer run results showed that two population groups represented the extremes in response. These were the 18-24 year male of tall stature (identified as "tall male") and the 62-74 year female of short stature ("small female"). The response of the 35-44 year male of average stature ("average male") was chosen as a reference to which the extremes could be compared. The results were reported only for these three occupants, since they demonstrate the full range of responses.

The model output produces many response parameters for which comparisons could be made, but the two which most graphically illustrate the human dynamics are head-torso relative angle and head resultant acceleration. The time history of these two quantities is plotted for each of the three occupant types defined above in Figures 4-3 through 4-10.

Two characteristics of the model which tend to affect interpretation of the results should be noted. First, in order to simulate normal seated position, an angulation between the head and torso segments must be established. Allowing 15° forward of vertical for normal geometrical relationships between head and torso masses and 13° rearward from vertical for seat back and torso angle, the initial head position is 28° forward of initial torso position. This 28° angle is reflected in the figures as the zero time value for head-torso relative angle. Second, the motion of the neck joint in this model is constrained to be symmetrical on either side of zero degrees. This means that the head will move as far forward as backward from a head-torso relative angle of 0°. For the purposes of these exercises, allowable extension of the neck was specified as one-half the total range of motion from zero degrees head-torso relative angle. This in effect adds approximately 22° to the extension range of motion (the initial head-torso relative angle less the amount by which extension range of motion normally exceeds flexion). The results are affected in that the greater extension allowed in the simulation permits higher head velocities and accelerations and should tend to diminish the influence of the neck muscles. As a practical matter, however, the net effect of the model characteristics probably produces a more realistic simulation. Observations of extension position X-rays reveal that the spinous processes of the vertebral column seldom meet point-to-point at the voluntary limit. A severe collision situation would tend to force them into point-to-point contact, adding significantly to the extension range of motion. The model results and conclusions reached are therefore probably quite close to a real-life situation.

Comparisions of responses from the three principal occupants are shown in Figures 4-3 and 4-4. In each case, the muscles are tensed to maximum voluntary strength throughout the response period, simulating the condition of no surprise and pre-tension. The effect of the neck musculature in limiting rearward head motion is easily seen in Figure 4-3. Subjects in the "average male" category were slightly stronger,

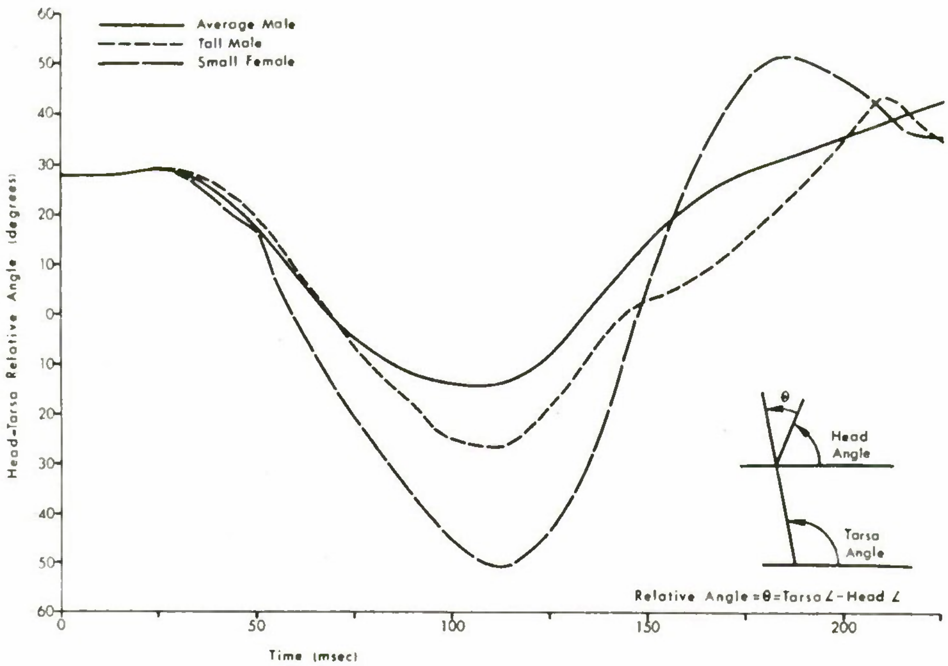

Figure 4-3. Head-torso relative angle for three occupants. Neck muscles are tensed to maximum voluntary levels. The average male, tall male, and small female represent the range of average results from the subject population in sex, age, stature, and muscle strength.

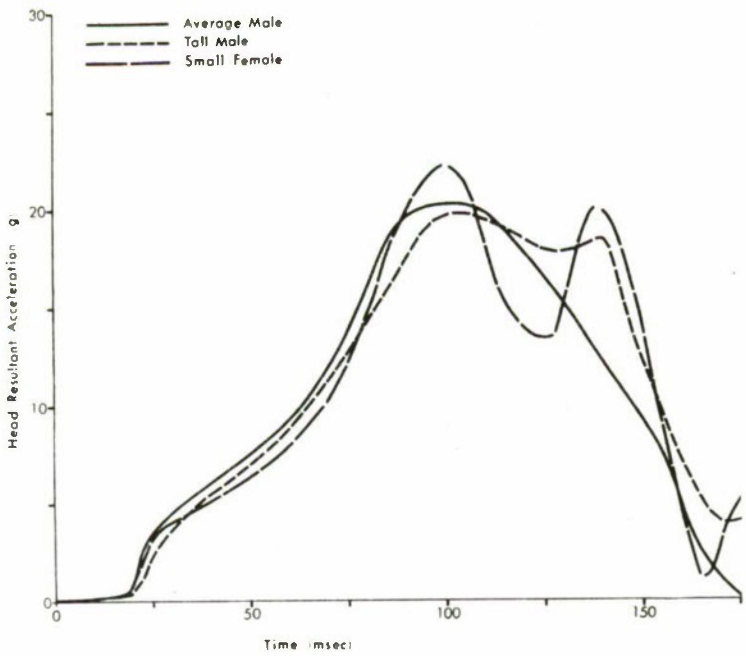

Figure 4-4. Head acceleration response for three occupants. These results are from the same computer runs as those for Figure 4-3.

on the average, than subjects in the "tall male" group. The "small female" group had the weakest neck muscles (Table 3-17). The figure shows that the head-torso angle during the simulated collision is directly proportional to muscle strength, with the small female hyper-extending about twice as much as the average male. One can conclude that these subjects have been able to influence their response in the crash situation, but to different degrees. The head resultant accelerations (Figure 4-4) for these same subjects are relatively similar, indicating that muscular tension mitigates acceleration effects.

The extent to which various degrees of muscle tension may affect head-neck response is shown in Figures 4-5 through 4-10. For each of the three occupants of interest, three levels of muscle tension are compared--completely untensed, tensed at one-half maximum voluntary level, and tensed at 100% of maximum voluntary level. Figure 4-5 shows that the average male with high neck muscle strength is able to prevent his head from reaching the range-of-motion limit, even with partial muscle tension. Only with muscles completely relaxed is the head driven into the stiff, motion-limiting stop (i.e., the assumed spinal limit) at the end of the range of motion. Figure 4-6 shows the effect of the average male's muscular tension on head resultant acceleration. A large acceleration spike is observed as the end of range of motion is reached, but the response is similar when the muscles are moderately active.

The combined beneficial effect of large range of motion and good muscle strength is shown in Figure 4-7 for the tall young male. For the completely untensed muscles, the range-of-motion limit is reached, but not as "violently" as in the previous case. Although the neck muscles of the tall male are not as strong as those of the average male,

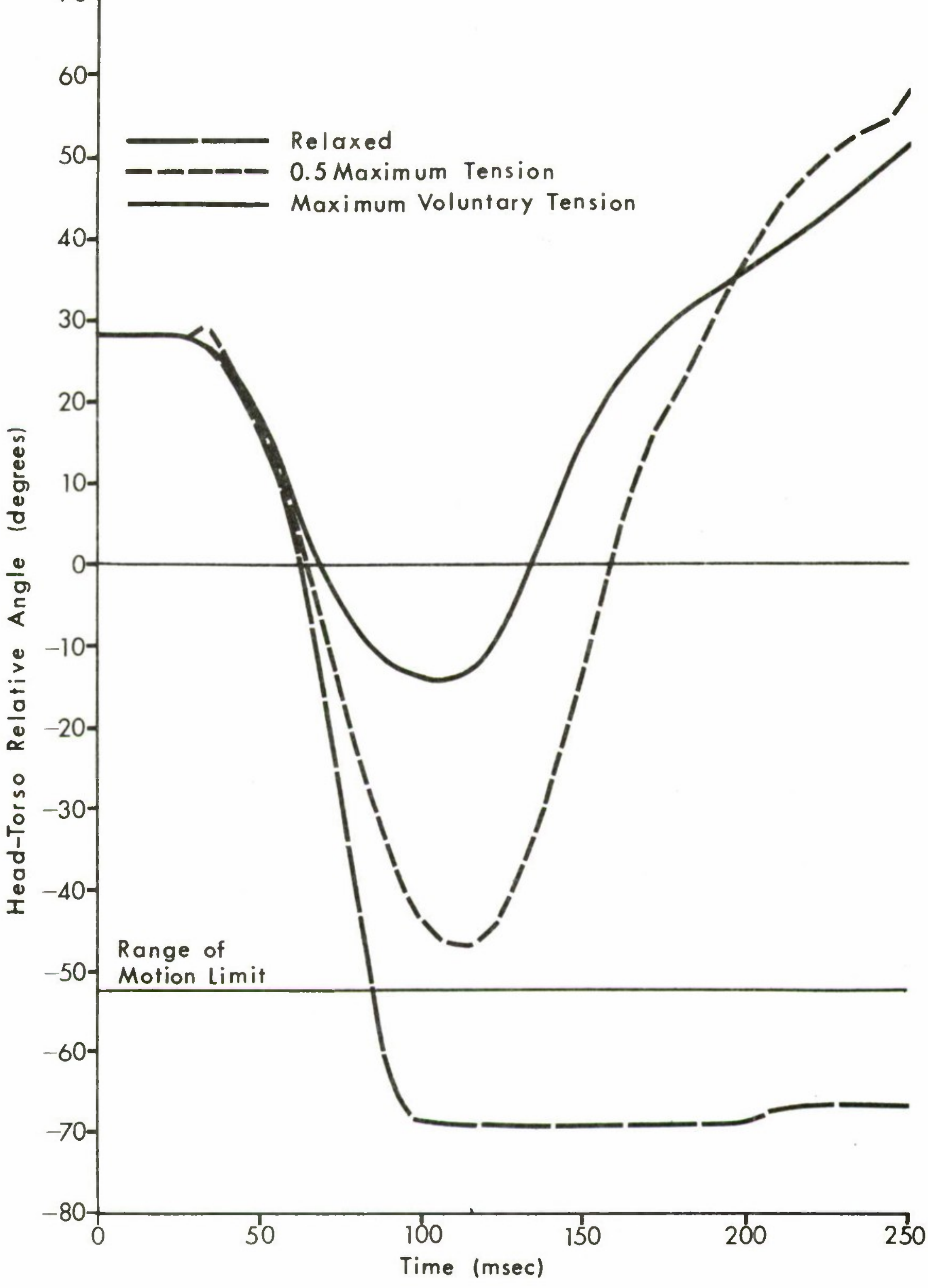

Figure 4-5. Effects of variation in neck muscle tension on head-torso relative angle (Average Male).

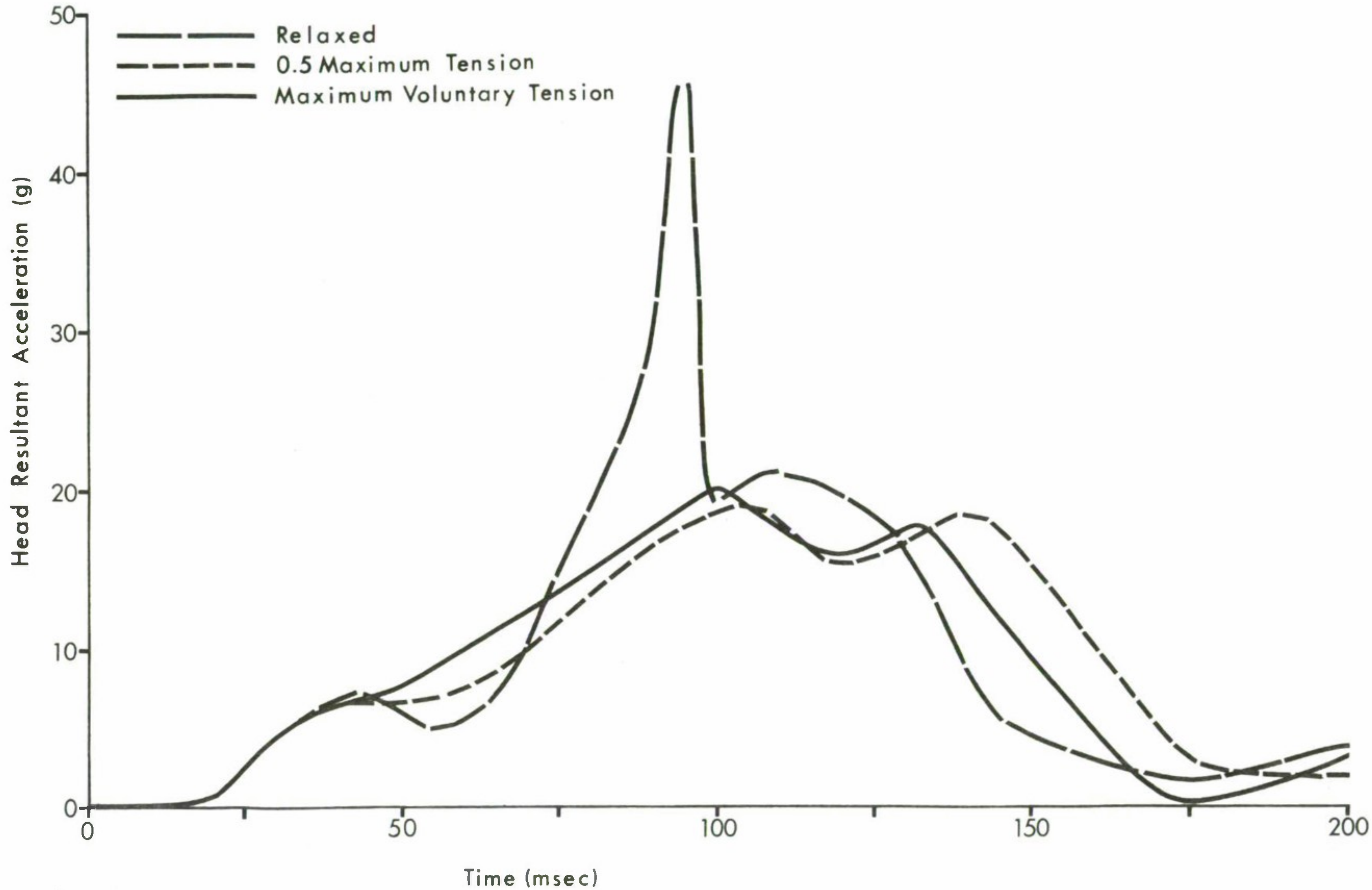

Figure 4-6. Head accelerations for varying muscle tension (Average Male).

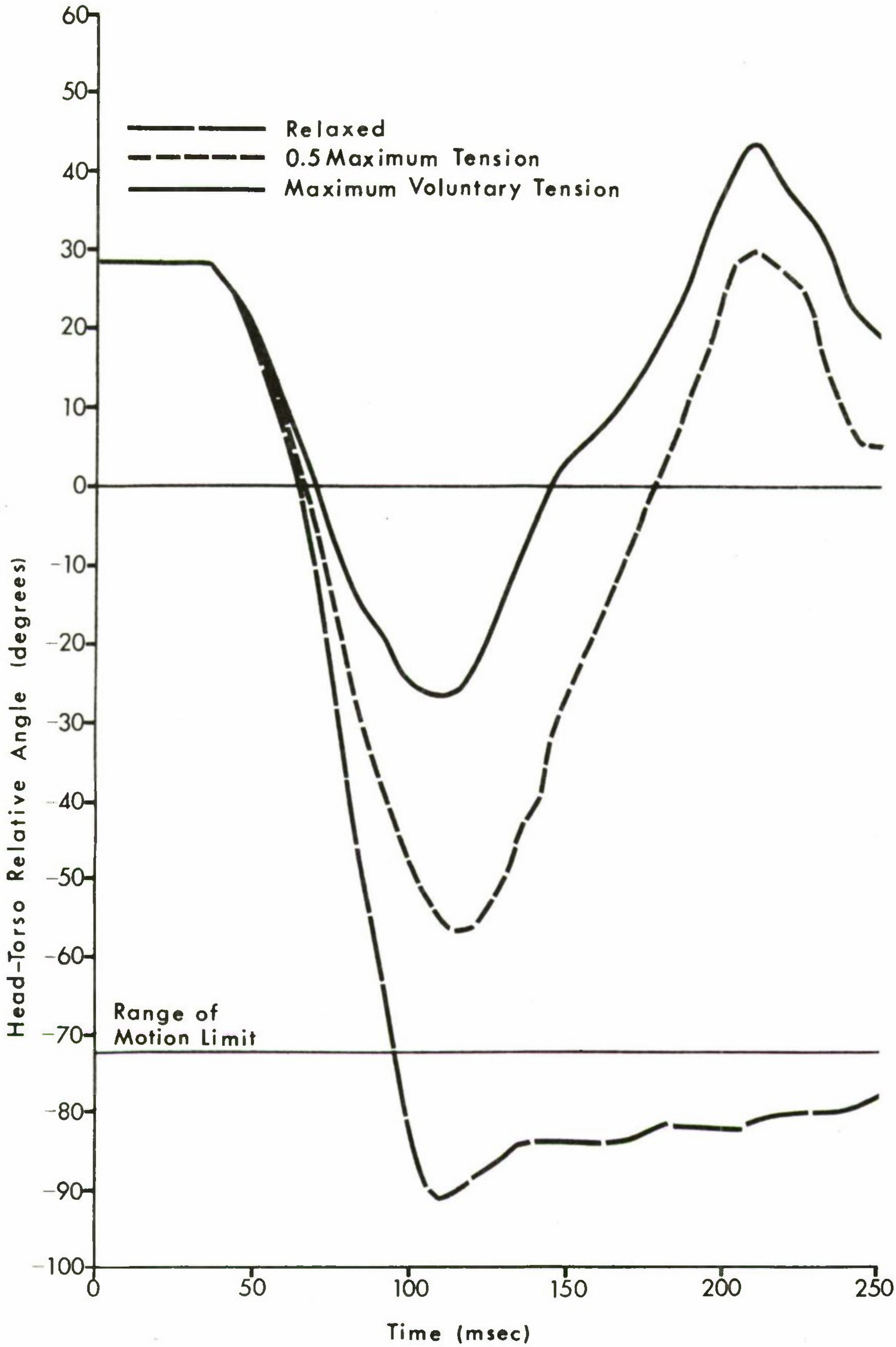

Figure 4-7. Effect of variation in neck muscle tension on head-torso relative angle (Tall Male).

the greater neck mobility prevents the range of motion limit from being closely approached for even half muscle tension. Figure 4-8 again shows the large acceleration spike that occurs when the stop is encountered, and the lower-level accelerations that are achieved when muscle tension is applied.

The population group that would appear to have the greatest disadvantage under this set of crash conditions is the small elderly female group. Figures 4-9 and 4-10 show that the dynamic behavior is distinctly different from the other two population segments. Low muscle strength and limited range of motion combine to allow the motion limit to be reached in all cases, though the head acceleration shows spikes only when the head remains at the limit for some period of time.

3. Summary and Conclusions. The three occupant sizes selected (young, tall male; middle-aged, average size male; elderly, short female) cover the range of dynamic responses observed from the entire subject population. Although average values for the major variables were used as input to the model, the range of responses is broad enough to point out population differences.

The dynamic predictions of the computer model show the effects of varying muscle strength and cervical range of motion on dynamic response of the head and neck. It would appear that the reduced mobility and strength of the older, small female would increase susceptibility to hyperextension injury, since even with muscles fully tensed, she could not prevent her head from reaching the limit of range of motion. These results may help to explain the increased incidence of these injuries to older persons and to females.

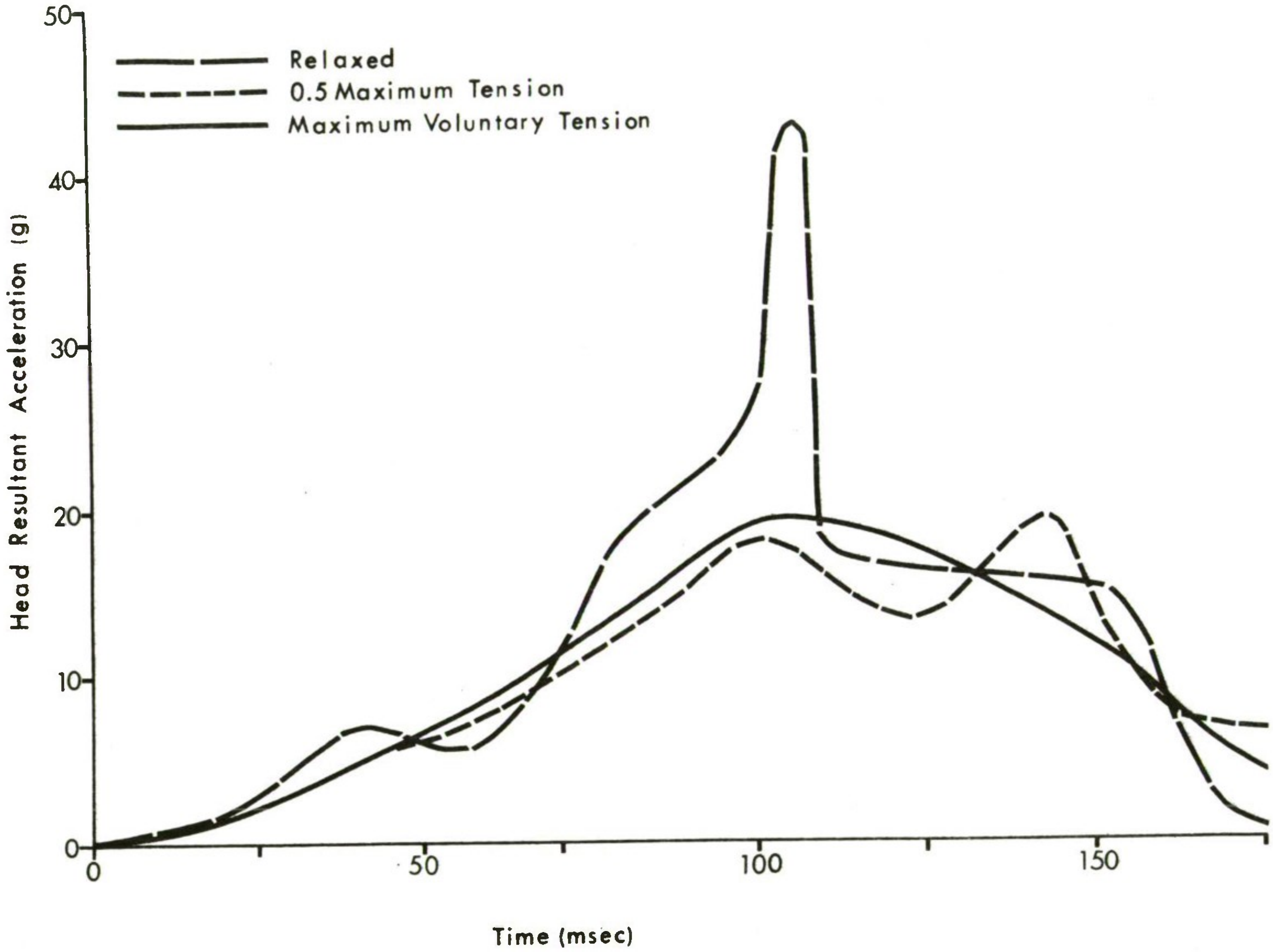

Figure 4-8. Head accelerations for varying muscle tension (Tall Male).

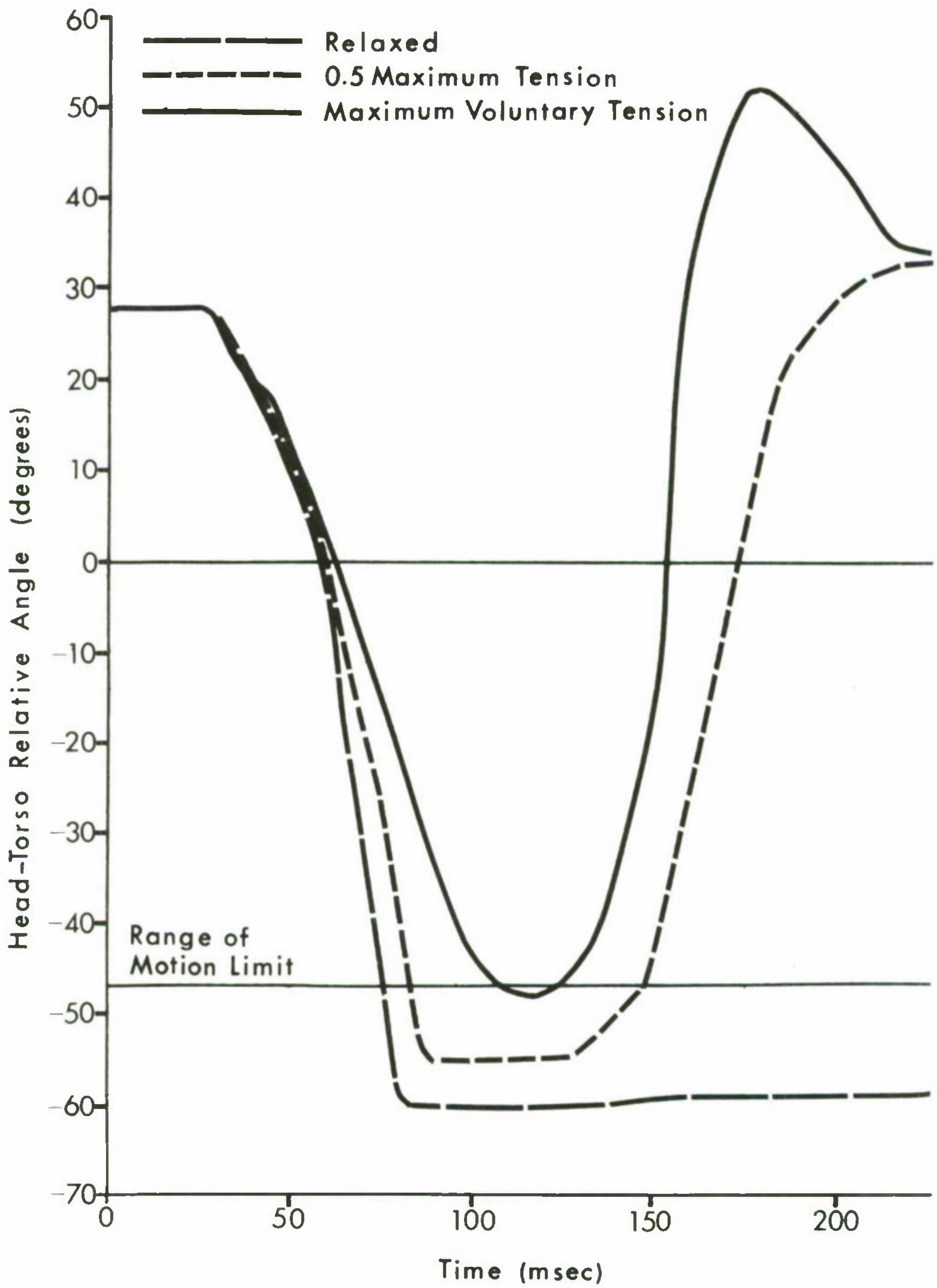

Figure 4-9. Effect of variation in neck muscle tension on head-torso relative angle (Small Female).

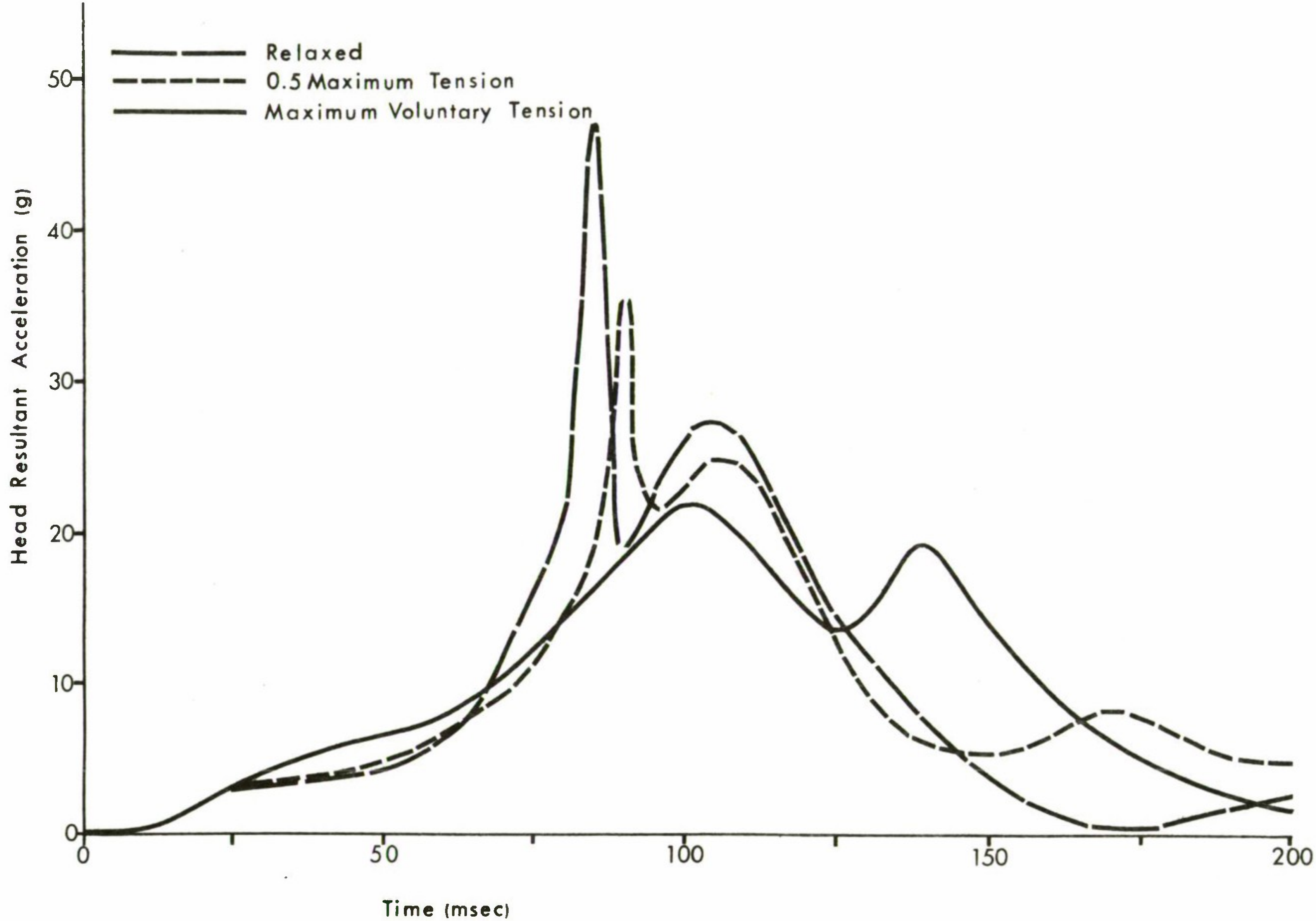

Figure 4-10. Head accelerations for varying muscle tension (Small Female).

Active neck muscular tension modifies head/neck dynamic response regardless of the population group. Even for the small elderly females, the muscle forces prevented sustained loading at the motion limit. For other portions of the population, the range of motion limit was not reached at all when the neck muscles were fully tensed. It may be concluded that strong neck muscles can reduce susceptibility to hyperextension injury.

The model does not predict injury levels. It is difficult to translate a sustained loading at the motion limit into damaged tissue, but it does seem probable that the high spikes of acceleration and long periods in hyperextension would lead to severe trauma of the neck structures. If one assumes that the spinous processes of the cervical vertebrae are contacting one another at these motion limits, one can hypothesize the possibility of fracture or ligamentous damage from severe rear impacts as simulated by the model.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

A. Introduction

The objectives of this study, as outlined in the original proposal, were ambitious. For a subject population of 180 volunteers stratified by sex, age, and stature to be representative of the entire U.S. adult population, it was intended to:

1) obtain comprehensive head and neck anthropometry;

2) measure sagittal plane range of motion of the head and neck;

3) impart a stimulus to the head to determine neck muscle reflex time in both flexion and extension; and

4) measure the strength of the neck flexor and extensor muscles.

Also, the effect of these measured biomechanical properties in the dynamic crash situation was to be assessed using a mathematical model of a crash victim.

Not only were all of the basic objectives accomplished, but the study also produced a great many other results. These include:

1) a comprehensive bibliography of literature related to all aspects of the cervical injury problem (Van Eck, et al, 1973, 2326 references);

2) additional anthropometry other than that directly related to the head and neck, including a comparison of measurements obtained from both internal structures and external landmarks for the same population;

3) a major study of cervical spine anthropometry and range of motion, using the x-rays that were obtained from each subject;

4) multiple test replications for each of the major variables, especially to assess repeatability in attaining voluntary range of motion positions;

5) the development of a sophisticated computerized data reduction system for multiple channels of data;

6) a significant substudy to use EMG as a predictor of muscle response time and strength; and

7) the data needed to explore, as a doctoral thesis, the interactions of passive and active neck tissues at low levels of acceleration, and the detailed modeling of neck musculature and the cervical spine.

B. Anthropometry

It is believed that the subject population was representative of those people whose state of health and neck characteristics could be called "normal" for their age. Normal arthritic degeneration with age was defined by the radiologist consultant to the study. Approximately one-third of those potential elderly subjects x-rayed were not allowed to complete the study--that is, to perform the reflex and strength tests--primarily because of degenerative arthritis. Only 5.5% of other subjects were unacceptable, most often because of unusual spine configuration. X-rays and photographs of these subjects are not included in the range-of-motion data presented herein, since strength and reflex time data were not obtained from them. While it is recognized that these persons constitute a proportion of the population exposed to possible injury in automobiles, it is not possible to assess their potentially different injury susceptibilities due to experimental safety considerations. It has already been noted, however, that one aspect of susceptibility--that of range of motion--was not conclusively affected by degenerative arthritis.

The experimental design for stature was based on the results of nationwide statistical sample of adults. The three stature groups selected were each intended to represent 20% of the population. As a practical matter, it was much easier to recruit tall subjects than short ones. Of those who volunteered, it seemed that much more than 20% of the population was "tall" and much less than 20% was "short", which may indicate something about the ethnic and socio-economic situation in the Ann Arbor, Michigan area.

The hypothesis that certain anthropometric measures would be good indicators of biomechanical properties was not supported by the results. Table 3-16 showed that external measurements of the neck were not highly correlated with range of motion of the neck. Table 3-18 showed similar results for anthropometry correlated with strength; while correlation coefficients were higher, they were not good enough for anthropometry to be a reliable predictor of strength. Kelkar (1973) also developed prediction equations for cervical spine range of motion using an exhaustive analysis of the coded x-ray data. He found that internal flexion and extension could be successfully predicted from externally measured range of motion, but that cervical spine range of motion could not be predicted from head, neck, or body anthropometry alone. Another interesting observation was that the two neck length measures devised for this study had very low correlation with stature. This demonstrates the difficulty in defining "the neck" from an anthropometric point of view; the neck has no easily-definable external landmarks.

The fact that certain of the anthropometric measurements were proportional to other measurements, with very little variance, is a potentially valuable tool for the biomechanical modeler. If the available data are limited to a few of the more basic (or more popular) measurements, it is still possible to define body segment sizes within reasonable accuracy limits by using proportions such as those presented in Table 3-10. Of course, this technique does not specify inertial properties for modeling of occupant dynamics, but limited data of that nature, related to anthropometry, are now becoming available (Chandler, et al, 1975).

The anthropometric measurements obtained in this study were a blend of applied measures and traditional more general measures. The validity of this subject population as being representative of the U.S. population was established by comparing three common measures. By extension it is assumed that other measures are likewise representative. There are several references available that would allow this assumption to be tested, particularly for the younger age group. Clauser, et al, Anthropometry of Air Force Women (1972) and Garrett and Kennedy A Collation of Anthropometry (1971), in particular, contain data for many measurements similar to those taken in this study, although the populations are not as sharply stratified.

C. Range of Motion

The combination of radiographic and photographic techniques to obtain range of motion data provided a unique opportunity to compare measurements from both internal structures and external landmarks for the same study population. This approach has not, to the authors' knowledge, been previously reported. The results indicate that, despite experimental precautions, much motion affecting the final position of the head in hyperflexion or hyperextension takes place in the upper torso. This accentuates the neck motion problem for designers of human analogs (dummies and mathematical models) since these devices are usually designed to produce all "neck" motion in the components above the torso. The kinematics of head and neck motion are therefore more difficult to reproduce.

Several interesting observations were made about head/neck movements in the sagittal plane. The first is that voluntary motion can be restricted to almost pure sagittal plane motion. Review of the front-view photographs indicated that the head turned very little as the subject moved into the extreme positions. A subsequent study of these and other positions by Schneider, et al (1975), using three-dimensional orthogonal photogrammetry with similar subjects, substantiated those observations. He measured average rotation of less than one degree in extension and less than five degrees in flexion.

Another observation about head motion was that the subjects were usually repeatable in achieving both initial and extreme positions. The initial head position and range of motion for a given subject were, as a rule, within a few degrees of each other for the four replications. The most variation was observed to occur between the x-ray results and the photographic results. The probable causes for this variation are that the subject was required to hold a position longer to allow the x-ray to be taken, could not be observed for changes in position immediately prior to the x-ray exposure, and moved from one laboratory to another with a short time lapse between the first and second replications. There was a slight "training" effect observed since the average range of motion tended to increase slightly with more replications. This was not statistically significant.

Third, the unpadded seat was found to be statistically no different from a padded seat of similar back and cushion angles insofar as initial head position was concerned. The effect of cushioning on torso and pelvic positioning in the seat while looking straight ahead, or of cushioning influence on range of motion, were beyond the scope of the study and were not explored.

This was not the first study of range of motion of the cervical spine. Some twenty-two have been previously reported in the English and non-English technical literature. Available results were summarized in the first two Technical Quarterly Reports (Snyder, Robbins, and Chaffin, March 1972; Snyder and Chaffin, June 1972). However, most of these studies either differed grossly in technique, were very limited as to study population, or used non-comparable landmarks. Only one study, that of Ferlic (1962), had a wide population age range and roughly comparable measurement methods. Ferlic summarized his results only by age and sex and for most groups the results were in excellent agreement. Only in the young female group, where Ferlic reported ten degrees greater range of motion, and for elderly females (Ferlic 24 degrees greater) were the results substantially different. For young females, the difference is possibly due to stature distribution. Ferlic reports no stature distribution, but a significant stature trend was noted in the young female group of this study. In fact, the tall young female results match Ferlic's almost exactly. For elderly females, Ferlic had a sample size of only 3, compared to 31 in this study, and the difference in range of motion is probably due largely to sample size differences. It is likely that the results of the present study are more representative of the effective range of motion of the seated automobile occupant.

The biomechanical modeling results suggest that limited range of motion is a factor in injury susceptibility. If this is true, then certain population segments would seem to be more susceptible to injury than others. In hyperflexion, elderly males and females have significantly restricted range. In hyperextension, individuals of short stature, males, and especially elderly persons are limited in mobility. Considering only range of motion results, the population group most likely to receive cervical injuries in a rear-end collision, then, are older persons and especially older males.

D. Neck Muscle Strength

Due to the positioning of the headband and force ring, the forces measured and reported in this study are effective forces generated by grouped neck muscles and applied through the center of gravity of the head. Because of the large numbers of muscles involved, it is impractical to distribute these forces among individual muscles and attempt by algebraic means to determine actual muscle fiber tensions. This problem is accentuated somewhat in the case of the sternomastoid muscle. Since the muscle is isolated and prominent, the EMG signal obtained from the flexor muscle is almost entirely due to sternomastoid action. However, the insertion of the sternomastoid is actually posterior to the occipital condyles--the point at which the skull pivots on the cervical spine. It is clear that the prevertebral muscles (and possibly muscles attached to the hyoid bone) must provide the tension to keep the head erect during a muscle flexor strength test, while the sternomastoids prevent extension in the cervical spine. The estimates of muscle force during a reflex test which are obtained from analysis of EMG amplitude are therefore subject to the same restrictions as other force measurements. The entire force cannot be attributed only to the sternomastoid muscles, but must be considered an effective force from several muscle groups.

The consistently higher strength of the extensor muscles is probably related to both increased muscle bulk and mechanical advantage. Cross-sectional anatomy references such as Eycleshymer (1970) show that there are more neck muscles of greater cross-sectional area to prevent flexion of the head than to prevent extension. The extensors are also located well posterior to the cervical spine and can exert a greater torque about the head-neck pivot than can the flexors, which are attached to the skull very near the superior portion of the cervical spine.

Marotzky (1972) reported that the force exerted through the head-neck joint was increased approximately 20% by pulling or pushing with the arms. It is unclear whether this increased force was due to increased stability or the influence of the long spinal muscles which extend well into the torso. However, it does relate to a question of interest to those who would simulate dynamic response, that of the difference between voluntary strength and absolute physiological ("panic") strength.

Chaffin and Baker (1970) cite studies that indicate demonstrated maximum strength is always somewhat less than absolute physiological capacity. This would seem especially true in the case of voluntary neck strength testing, since it is unlikely that test volunteers would want to induce neck muscle strain. Marotzky's measurements with arms braced, although still a voluntary effort, provide an estimate of this maximum capability. It is the present authors' opinion that the voluntary strength results represent about 70% of the maximum available strength capacity. As input to dynamic response models, a correction factor based on this percentage would seem reasonable in estimating muscle tensions for pre-tensed occupants.

E. Muscle Response and EMG

Robbins' work (1974) has indicated that neck muscles which are fully tensed can mitigate the effects of a rear-end collision. Knowing this, it then becomes important to know if the muscles can influence response in the surprise accident situation when the muscles are initially relaxed. For the crash pulse of Figure 4-1 and with the muscles completely relaxed, Robbins' results demonstrate that both peak resultant acceleration and peak angulation of the head occur 75-100 ms after the start of the pulse. The experimental results (Table 3-22) indicate that the muscles could be of little assistance. Only young males and females and middle-age females have average reflex times of less than 75 ms. Even if the muscles were able to generate maximum tension instantly, at least half the population still could not influence response prior to feeling the full effect of the impact. In reality however, additional time beyond reflex time is needed to build up maximum muscle tension. Approximately 60 ms of muscle force buildup time was measured from the subjects in this study but maximum tension was not needed to adequately respond to the head jerk. A limited experiment with two males age 32 demonstrated that 120 ms was needed from onset of muscle EMG to period of maximum force. Since the force buildup time was consistent throughout the subject population, it seems reasonable to allow 120 ms plus reflex time for total muscle reaction time.

The HSRI Crash Victim Simulator lacks the capability to include muscle reflex and reaction times in the simulation. However, subsequent work using a different model with that capability was performed by Bowman using data obtained similarly but in the lateral direction. He reported (Bowman, et al, 1975) that fast muscle reflex and force buildup was able to modify response compared to the completely relaxed case, provided the muscles were also strong. Younger subjects and males had this type of modified response. At the other extreme, elderly females having a combination of slowed reflexes and weak neck muscles were not able to limit head angulation. Again the increased injury susceptibility of this segment of the population was demonstrated.

The technical complexities of using the electromyogram as an estimator of muscle force have been discussed in Chapter 3. EMG_{RMS} amplitude has been demonstrated by several researchers to be proportional to muscle force, subject to certain limitations and constraints. In the experiments described, many important factors, such as fatigue, electrode position, and individual responses, were controlled. Other factors, especially the effects of tissue movement, could not be controlled in the dynamic experiments. While movement artifacts were occasionally noted, they took the form of baseline shifts rather than gross amplitude changes. Based on the results of the previous studies cited as to the effects of muscle movement on EMG amplitudes, it is believed that the movements were not sufficient in terms of magnitude and rate to greatly influence the resulting muscle force estimates.

As discussed in Section 3.E.2, muscle force estimates from EMG amplitudes are valid only for an individual. This implies that the major source of potential measurement error is due to what might be termed an individual's "electrical efficiency." This factor can easily account for a 5:1 difference in EMG amplitudes for a given load. The effect has been known for years, having been reported by Grossman and Weiner in 1966. It simply means that each individual must be carefully "calibrated" to determine his specific EMG amplitude output for a given load prior to performing various kinematic experiments. As illustrated, however, if such care is taken, the resulting data can be useful in furthering the understanding of musculoskeletal biomechanics. The demonstration of this procedure in this study is believed to be a contribution of a fundamental nature.

F. Suggestions for Future Work

The large amount of data collected in this study would be impractical, if not impossible, to analyze completely. With many disciplines involved, researchers from various fields may find that data of particular interest have not been presented. Anthropologists would find sufficient information to calculate Heath-Carter somatotypes or compare anthropometric measurements between populations, biomechanists could analyze for the components of head acceleration for low g-forces; biostatisticians could examine subtle relationships in the data. The original data are being preserved so that such analyses could be accomplished if thought desirable.

There is still much work that could be done with the x-rays. In particular, Kelkar's (1973) prediction equations could be reanalyzed to predict cervical spine range of motion relative to the Frankfort plane instead of the arbitrary skull plane. The so-called maximum physiological range of motion in extension and flexion could be better estimated for use as motion limiters in mathematical models. Also, the changes in vertebral body mid-sagittal size and shape due to age and arthritis could be summarized from the digitized data. All of these analyses have been beyond the scope of the project's resources, but they could provide valuable information to the researcher with a particular need.

The neck muscle reflex was elicited by jerking the head in the plane of its center of gravity. In an actual crash, however, the neck stretch reflex is induced by acceleration of the torso. The hypothesis used in designing the test protocol was that the neck responses would be similar in either case. Since the experiment could be controlled more closely by moving the head, that method was chosen. An interesting substudy would be to test that hypothesis with a selected group of volunteers by using the same instrumentation and moving the seat slightly to create the controlled low-level head jerk.

An important study currently being conducted is attempting to relate the low-level acceleration response from this general population to the relatively high-g sled tests of human volunteers currently being conducted by the Navy. These sled tests provide a means for improving our understanding of the complex reactions of the head and neck, but they must be conducted with a select population (young military males). A sophisticated biomechanical model (Bowman, et al, 1974) is being used to relate the low-level and high-level acceleration responses from an identical sample group. If definite relationships can be established, it may then be possible to predict the probable responses of other segments of the population which cannot be directly tested.

This study, in attempting to identify biomechanical properties of the neck which may be related to injury, has pointed up the need for a detailed parametric study using a mathematical model. The objective of such a study would be to pinpoint the biomechanical properties which influence the response of the model and to quantify the extent of that influence. However, in order to establish, for example, the percentage effect of increased joint stiffness on head resultant acceleration, it would be necessary to run many simulations, incrementally varying only that parameter. This type of study would be very expensive but would be most valuable because it would order parameters which could then be experimentally studied, thus gaining effective use of limited research funds.

G. General Conclusions and Applications

The purpose of this research was to measure certain characteristics of the human head and neck that were hypothesized to affect whether or not a person might be injured in a rear-end collision. Those quantities were measured for a given population and their effects were studied using a mathematical model. Each of the primary dependent variables (range of motion, reflex time, and strength) was found to influence injury susceptibility to a different degree. The effect of each was also found to be related to the three independent variables (sex, age, and stature), again to different degrees.

Of the three dependent variables, the results suggest that the neck muscle stretch reflexes are least likely to be effective in reducing or preventing cervical hyperextension. They only come into play during a surprise collision and then react too slowly to greatly alter the response. A large cervical range of motion is somewhat more beneficial but in a more passive sense. Range of motion does not change the response pattern so much as it allows the response to take place over a longer distance and time. The primary modifiers of head/neck response are the neck muscles. Strong neck muscles have a substantial mitigating effect on both forces and motion of the head, while weak neck muscles scarcely modify the response at all.

The results also suggest that certain portions of the U.S. adult population are more likely than others to sustain neck injuries in a given rear-end accident situation. Stature-related effects are minimal, except that range of motion is a factor for young adults. A person's sex may have a bearing on injury, and this effect is due to the average male's greater neck muscle strength. Females, who are not as strong, are observed to incur more cervical hyperextension injury than males, and this observation is supported by the modeling results. The elderly, it would appear, suffer the greatest risk of injury by virtue of the substantial degradation of reflex time, range of motion, and muscle strength. Based on these three biomechanical factors, it may be concluded that elderly females are the one population group at greatest risk during a rear-end collision.

Finally, the results suggest that provisions to account for aging and for sexual differences should be included in any human analog (dummy or computer model) in which dynamic humanlike response of the head and neck is desired. The losses of range of motion and muscle strength are probably sufficient to cause different responses in different population groups. These differences should be reflected in product testing.

The implications of these results are important to researchers who must assist in setting performance standards for occupant protection and to the designers who must translate research results to metal and padding. Since persons involved in a crash may neither react fast enough nor be strong enough to protect themselves from possible injury, occupant protection devices must be designed to accommodate the physiological limitations of the occupant and provide effective protection.

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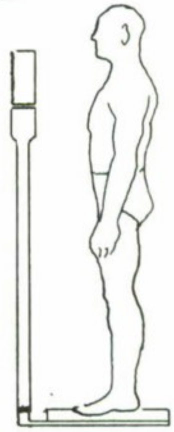
APPENDIX

APPENDIX A

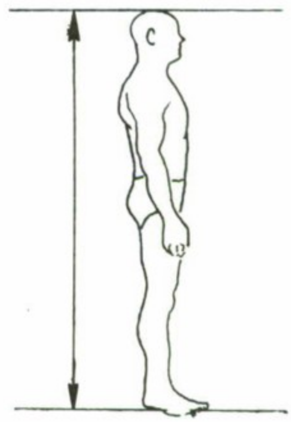
DESCRIPTION OF ANTHROPOMETRIC DIMENSIONS

A. SUBJECT IN STANDING POSITION (ERECT)

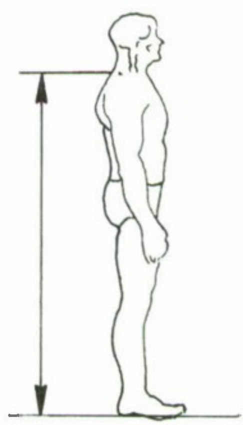
1. WEIGHT - Taken on standard medical type scale to nearest one-half pound. Subject unclothed except for shorts and sleeveless shirt.



2. STATURE - The subject maintains an erect standing posture, feet together, arms hanging at the side, looking straight ahead with head held in the Frankfort Plane.* The vertical distance is measured with the wall-mounted anthropometer from the floor to the highest point on the subject's head with the anthropometer arm firmly contacting the scalp. The measurement is taken at maximum normal inspiration.



3. CERVICALE - The subject maintains an erect posture, feet together, arms hanging at the side, looking straight ahead with head held in the Frankfort Plane. The vertical distance is measured with a wall-mounted anthropometer from the floor to the previously marked palpable spinous process of the seventh cervical vertebra.



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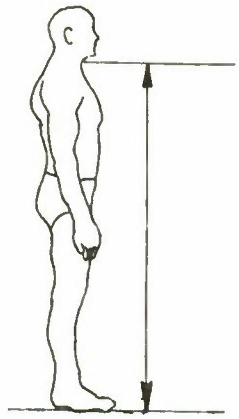
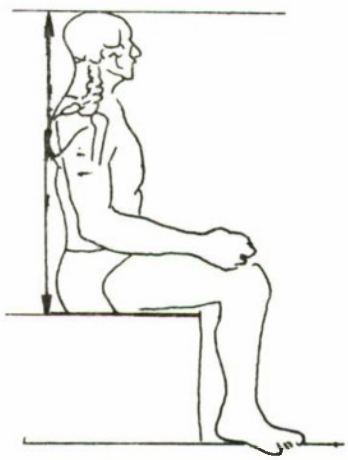
*See attached glossary (Section E) for all technical terms underlined in the measurement descriptions.

4. <u>CHIN-NECK INTERSECT</u> - The subject maintains an erect posture, feet together, arms hanging at the side, looking straight ahead with head held in the <u>Frankfort Plane</u>. The vertical distance is measured with a wall-mounted anthropometer from the floor to the <u>chin-neck intersect</u>. This intersection is located by observing the subject from the side and placing the point of the anthropometer arm at the highest point on the neck intersected by the chin.



B. SUBJECT IN SEATED POSITION (ERECT)

5. <u>SITTING HEIGHT (erect)</u> - The subject sits erect with arms hanging at sides, hands resting on upper legs, feet together and lower legs at right angles to upper legs. The head is held in the <u>Frankfort Plane</u>. The vertical distance is measured with an anthropometer from the sitting surface to <u>vertex</u> with the anthropometer arm firmly touching the scalp.

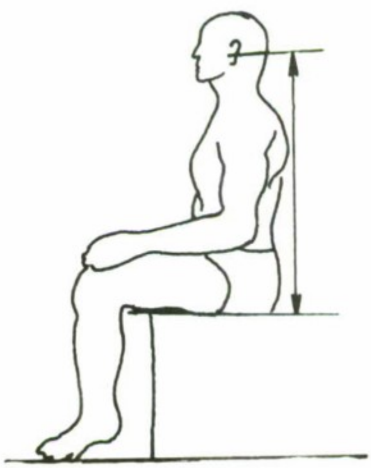


6. <u>SITTING CERVICALE HEIGHT</u> - The subject sits erect, with arms hanging at sides, hands resting on upper legs, feet together and lower legs at right angles to upper legs. The head is held in the <u>Frankfort Plane</u>. The vertical distance is measured with an anthropometer from the sitting surface to <u>cervicale</u>.

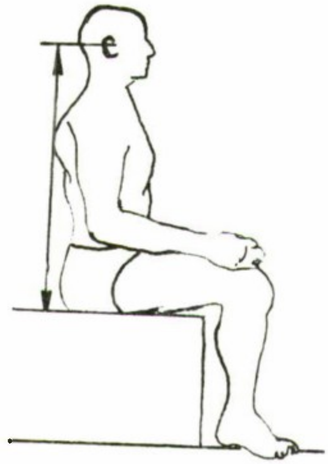
7. SITTING RIGHT SHOULDER (acromion) HEIGHT - The subject maintains an erect posture, with arms hanging at sides, hands resting on upper legs, feet together and lower legs at right angles to upper legs. The vertical distance is measured from behind the subject, with an anthropometer, from the sitting surface to the acromion.

8. SITTING LEFT SHOULDER (acromion) HEIGHT - The subject maintains an erect posture, with arms hanging at sides, hands resting on upper legs, feet together and lower legs at right angles to upper legs. The vertical distance is measured from behind the subject, with an anthropometer, from the sitting surface to the acromion.

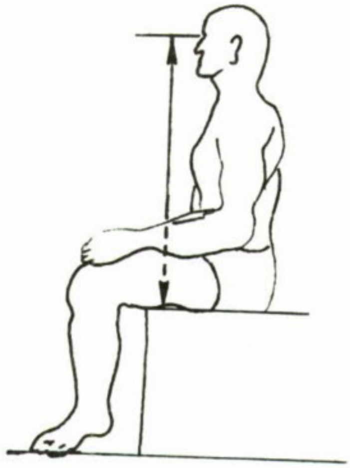
9. LEFT TRAGION - The subject maintains an erect posture, with arms hanging at sides, hands resting on upper legs, legs spread slightly, and head held in the Frankfort Plane. The vertical distance is measured with an anthropometer on the left side of the subject from the sitting surface to the left tragion.



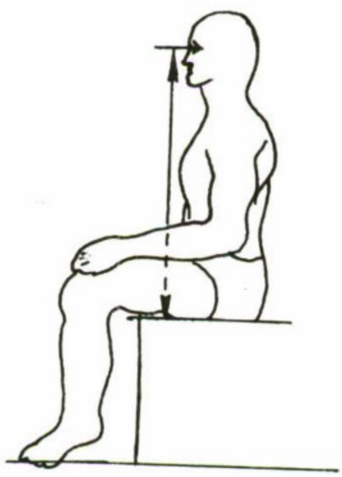
10. <u>RIGHT TRAGION</u> - The subject maintains an erect posture, with arms hanging at sides, hands resting on upper legs, legs spread slightly, and head held in the <u>Frankfort Plane</u>. The vertical distance is measured with an anthropometer on the right side of the subject from the sitting surface to the right <u>tragion</u>.



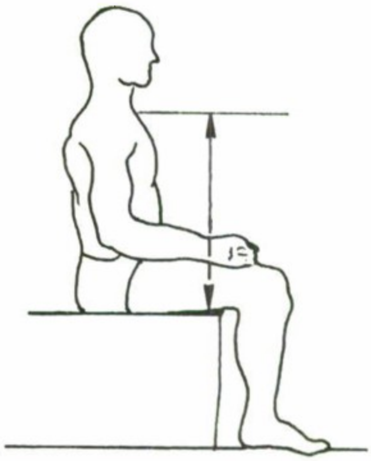
11. <u>NASAL ROOT DEPRESSION</u> - The subject maintains an erect posture, with arms hanging at sides, hands resting on upper legs, legs spread slightly, and head held in the <u>Frankfort Plane</u>. Facing the subject, the vertical distance is measured with an anthropometer from the sitting surface to <u>sellion</u>.



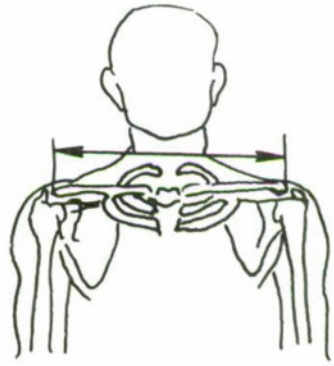
12. <u>SITTING LEFT EYE HEIGHT (erect)</u> - The subject sits erect, with arms hanging at sides, hands resting on upper legs, feet together, and lower legs at right angles to upper legs. The head is held in the <u>Frankfort Plane</u>. The vertical distance is measured with an anthropometer from the sitting surface to the inner corner (internal canthus) of the left eye.



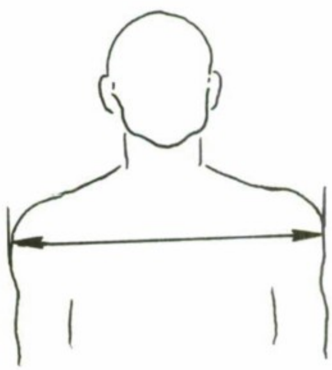
13. SITTING SUPRASTERNALE HEIGHT - The subject sits erect with arms at sides, hands resting on upper legs, legs spread slightly, and head held in the Frankfort Plane. Facing the subject, the vertical distance is measured with an anthropometer from the sitting surface to the suprasternale landmark.



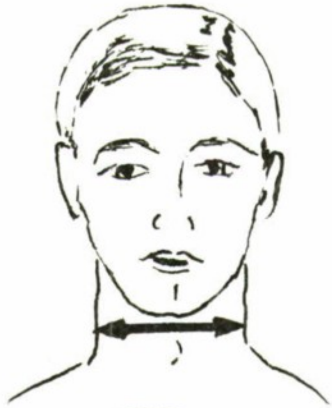
14. BIACROMIAL BREADTH - The subject maintains an erect posture, with arms hanging at side, hands resting on upper legs, looking straight ahead. From behind the subject, the horizontal distance is measured with an anthropometer between the acromion landmarks of the left and right scapulae.



15. SHOULDER BREADTH (bideltoid) - The subject sits erect, with arms hanging at sides, and hands resting on upper legs. Using the anthropometer, the horizontal distance is measured across the deltoid muscles.



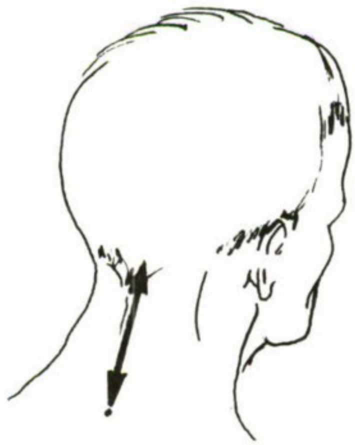
16. LATERAL NECK BREADTH (mid) - The subject is seated in erect posture, with head held in Frankfort Plane. The breadth is measured with anthropometer at mid-point of neck from left to right side.



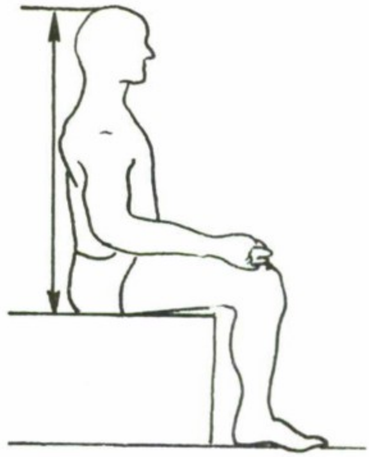
17. ANTERIOR-POSTERIOR NECK BREADTH (mid) - The subject is seated in erect posture, with head in Frankfort Plane. The breadth is measured with anthropometer at the level of the inferior aspect of the Adam's apple.

18. ANTERIOR NECK LENGTH - The subject is seated in erect posture, with head in Frankfort Plane. Distance from suprasternale to the chin-neck intersect is measured with sliding calipers.

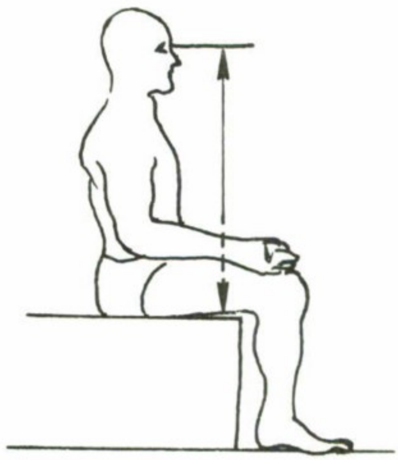
19. POSTERIOR NECK LENGTH - The subject is seated in erect posture, with head in Frankfort Plane. Distance is measured from cervicale to nuchale with sliding calipers.



C. SUBJECT IN SEATED (RELAXED) POSITION



20. SITTING HEIGHT (slumped) - The seated subject is allowed to assume normal slumped posture, with arms hanging at sides, hands resting on upper legs, feet together, and lower legs at right angles to upper legs. The vertical distance is measured from the sitting surface to top of head, with the anthropometer blade firmly touching the scalp.



21. LEFT SITTING EYE HEIGHT (slumped) - The seated subject is allowed to assume normal slumped sitting posture, with arms hanging at sides, hands resting on upper legs, feet together, and lower legs at right angles to upper legs. The vertical distance is measured from the sitting surface to the inner corner (internal canthus) of the left eye.

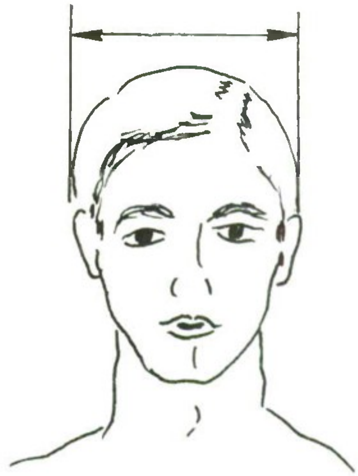
22. SUPERIOR NECK CIRCUMFERENCE - The subject is seated in relaxed posture. The circumference is measured with steel tape at the level of chin-neck intersect and nuchale.

23. <u>INFERIOR NECK CIRCUMFERENCE</u> - The subject is seated in relaxed posture. The circumference is measured with steel tape at the lowest anterior neck level.

24. <u>HEAD CIRCUMFERENCE</u> - The subject is seated in relaxed posture. The maximum circumference of the head is measured with a steel tape passing over the brow ridges and held perpendicular to the mid-sagittal plane (but not necessarily horizontally).

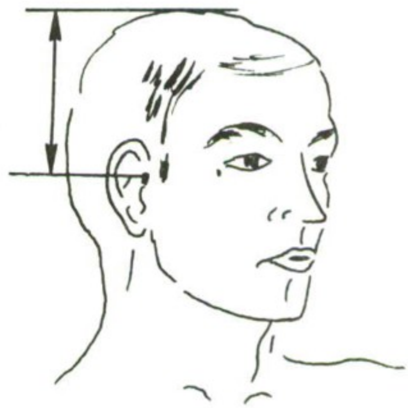
25. <u>HEAD ELLIPSE CIRCUMFERENCE (BENNETT)</u> - The subject is seated in relaxed posture. The head circumference from <u>menton</u> to point on back of head at maximum distance is measured with a steel tape.

26. <u>HEAD BREADTH</u> - The subject is seated in a relaxed posture. The maximum breadth of the head is measured with the spreading calipers perpendicular to the mid-sagittal plane of the head.

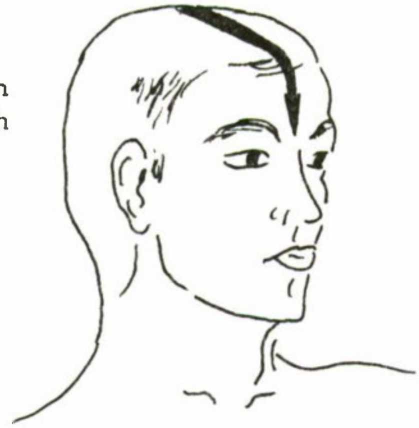


27. <u>HEAD LENGTH</u> - The subject is seated in a relaxed posture. The maximum length of the head is measured from <u>glabella</u> to the <u>occipital</u> region in the mid-sagittal plane of the head with the spreading calipers.

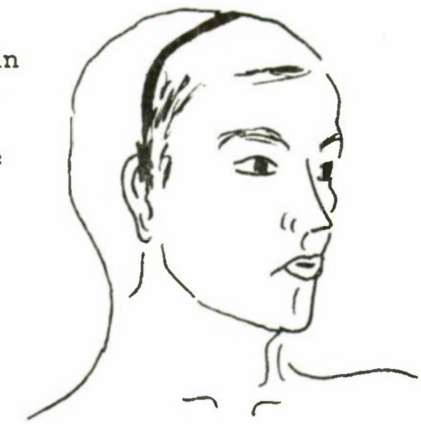
28. <u>HEAD HEIGHT</u> - The subject is seated in a relaxed posture. The vertical distance is measured from <u>tragion</u> to the highest point of the skull with the anthropometer.



29. SAGITTAL ARC - The subject is seated in a relaxed posture. The arc is measured with the steel tape in the mid-sagittal plane of the head, from glabella to inion.

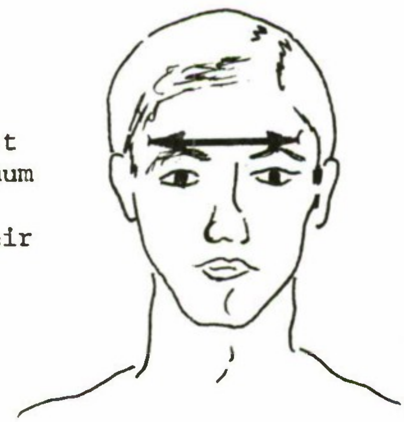


30. CORONAL ARC - The subject is seated in a relaxed posture, looking straight ahead. The arc is measured from right to left tragion over the top of the skull with the steel tape in a vertical plane.

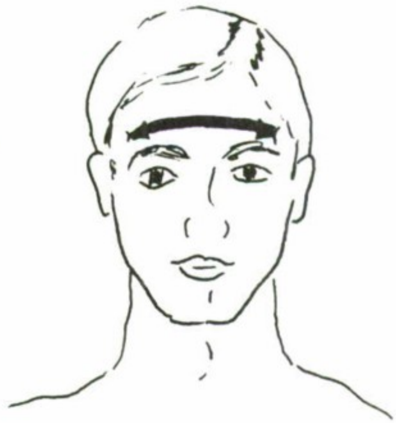


31. BITRAGION DIAMETER - The subject is seated in a relaxed posture. The diameter between right and left tragions is measured with light contact while holding the spreading calipers in a horizontal plane.

32. MINIMUM FRONTAL DIAMETER - The subject is seated in a relaxed posture. The minimum diameter is measured with the spreading calipers across the temporal crests at their point of greatest indentation. Care is taken that the measurement is made on the crests and not over the temporal muscles.



33. MINIMUM FRONTAL ARC - The subject is seated in a relaxed posture. A steel tape is used to measure the arc across the forehead, above the brow ridges, between the points of greatest indentation of the temporal crests.

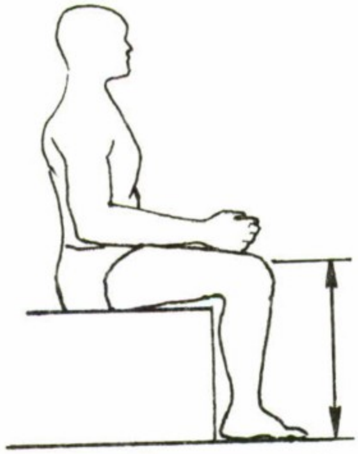


34. BITRAGION-MINIMUM FRONTAL ARC - The subject is seated in a relaxed posture. The arc is measured from right to left tragion with a steel tape at the level at which the minimum frontal arc was measured.

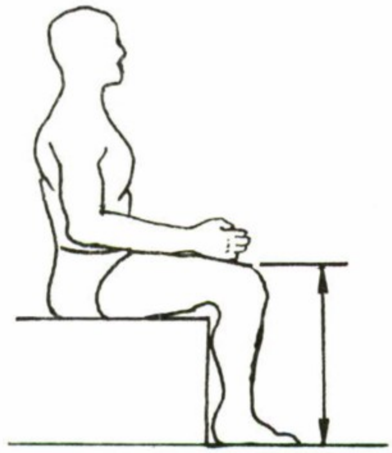
35. BITRAGION-INION ARC - The subject is seated in a relaxed posture. The arc is measured from right to left tragion with the steel tape passing over inion.

36. POSTERIOR ARC - The subject is seated in a relaxed posture. The arc is measured from right to left tragion with the steel tape passing over nuchale.

37. <u>SITTING KNEE-HEIGHT</u> - The subject sits in relaxed posture, hands resting on upper legs, feet together, and lower legs at a 90° angle to upper legs. The vertical distance is measured with an anthropometer from the floor to the superior aspect of the <u>patella</u>.



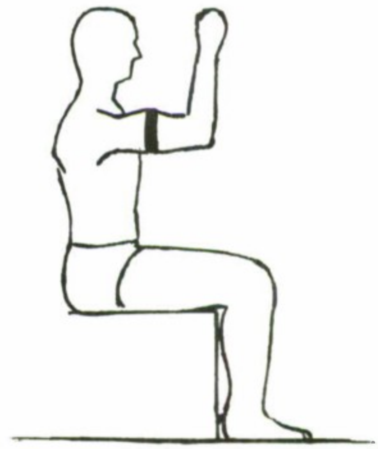
38. <u>SITTING KNEE-HEIGHT (maximal clearance)</u> - The subject sits in relaxed posture, hands resting on upper legs, feet together, and lower legs at a 90° angle to upper legs. The vertical distance is measured with an anthropometer from the floor to the highest point of the right knee. This point will be superior to that of the preceding measurement and provides maximum knee clearance distance.



39. <u>SEATED HEIGHT OF RIGHT ANTERIOR ILIAC SPINE</u> - The subject is seated in an erect posture. The vertical distance is measured with an anthropometer from the sitting surface to the anterior superior iliac spine of the right ilium.

40. SEATED HIP BREADTH - The subject is seated in an erect posture. The horizontal distance is measured with an anthropometer across the maximum breadth of the hips, applying only light contact pressure. Subject is lightly clothed.

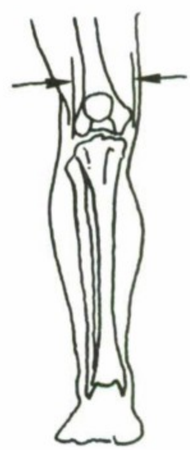
41. BICEPS FLEXED CIRCUMFERENCE (right) - The seated subject maintains a relaxed posture with his arms hanging freely at the side. The subject flexes his right arm at least 90°, makes a fist while holding his upper arm horizontal to the floor, and flexes his biceps to the maximum. The measurement is made with a steel tape at the maximum circumference of the upper right arm.



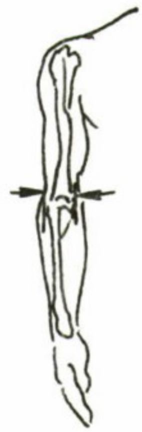
D. STANDING POSITION (RELAXED)

42. CALF CIRCUMFERENCE - The standing subject maintains a relaxed posture with the weight equally distributed on both feet, and legs slightly apart. The maximum circumference of the right calf is measured with a steel tape.

43. FEMORAL BIEPICONDYLAR DIAMETER - The subject maintains a relaxed posture with feet spread slightly apart. Using an anthropometer, the horizontal distance is measured between the medial and lateral epicondyles of the right femur.



44. <u>HUMERUS BIEPICONDYLAR DIAMETER</u> - The distance between the lateral and medial epicondyles of the right humerus is measured with a sliding caliper with the arm hanging freely at the side.



45. <u>RIGHT TRICEPS SKINFOLD</u> - The point of measurement is located on the dorsal aspect of the right arm of the standing subject, midway between the <u>acromion</u> and tip of the elbow (olecranon) when the forearm is flexed at 90°. The subject's arm is then extended to hang freely, the skinfold is lifted parallel to the long axis of the arm by firmly grasping a fold between the thumb and forefinger about one centimeter from the point to which the Lange caliper is applied. A reading is made within three seconds after application of the caliper, and the average is taken of several readings.

46. <u>RIGHT SUBSCAPULAR SKINFOLD</u> - This site is located on the standing subject below the inferior angle of the right scapula. The skinfold is lifted in a direction parallel to the ribs, with the skinfold angled upward medially and downward laterally at about 45° from the horizontal. A reading is made with the Lange caliper within three seconds after application of the caliper, and the average is taken of several readings.

47. <u>RIGHT SUPRAILIAC SKINFOLD</u> - This site is located on the standing subject superior to the lateral aspect of the iliac crest on the right side. The skinfold is lifted parallel to the pelvis and angled slightly upward medially. A reading is made with the Lange caliper within three seconds after application of the caliper, and the average is taken of several readings.

48. <u>RIGHT POSTERIOR MID-CALF SKINFOLD</u> - This site is located on the standing subject on the dorsal aspect of the lower leg, midway between the ankle and the knee. The skinfold is lifted parallel to the leg, and a tight skin adhesion is most commonly found here. A reading is made with the Lange caliper within three seconds after application of the caliper, and the average is taken of several readings.

E. Glossary of Anatomical Landmarks

Acromion - the superior lateral margin on the acromion process of the scapula.

Cervicale - the dorsal tip of the spinous process of the seventh cervical vertebra.

Chin-neck intersect - the most posterior projection of the chin upon the neck when viewed from the side.

Frankfort Plane - the head is oriented such that the tragion and the lowest point on the bony orbit of the eye form a horizontal plane parallel to the floor surface.

Glabella - the most anterior point on the brow ridge in the mid-sagittal plane.

Infraorbitale - the lowest point on the interior margin of the bony eye orbit.

Inion - the most posterior point on the external occipital protuberance in the mid-sagittal plane.

Menton - the point at the tip of the chin in the mid-sagittal plane.

Nuchale - the lowest point in the mid-sagittal plane of the occiput that can be palpated among the muscles in the posterior-superior part of the neck. This point is often visually obscured by hair.

Occipital - the posterior bone of the skull.

Patella - the knee cap.

Sellion - the point of greatest indentation where the bridge of the nose meets the forehead.

Suprasternale - the lowest point on the superior margin of the sternum.

Tragion - the anterior limit of the cartilaginous notch located superior to the tragus of the left ear.

Vertex - the highest point on the head in the mid-sagittal plane when the head is aligned in the Frankfort Plane.

APPENDIX B

ANTHROPOMETRY - DESCRIPTIVE STATISTICS

Summary descriptive statistics from the anthropometry portion of the study are contained in this appendix. These data are reported in the following order:

TABLE	
B.1	All Subjects Combined
B.2	Subjects grouped by Sex--Females
B.3	--Males
B.4	Subjects Grouped by Sex and Age--Females, 18-24
B.5	--Females, 35-44
B.6	--Females, 62-74
B.7	--Males, 18-24
B.8	--Males, 35-44
B.9	--Males, 62-74
B.10	Subjects Grouped by Sex, Age, and Stature --Females, 18-24, 1-20%ile
B.11	--Females, 18-24, 40-60%ile
B.12	--Females, 18-24, 80-99%ile
B.13	--Females, 35-44, 1-20%ile
B.14	--Females, 35-44, 40-60%ile
B.15	--Females, 35-44, 80-99%ile
B.16	--Females, 62-74, 1-20%ile
B.17	--Females, 62-74, 40-60%ile
B.18	--Females, 62-74, 80-99%ile
B.19	--Males, 18-24, 1-20%ile
B.20	--Males, 18-24, 40-60%ile
B.21	--Males, 18-24, 80-99%ile
B.22	--Males, 35-44, 1-20%ile
B.23	--Males, 35-44, 40-60%ile
B.24	--Males, 35-44, 80-99%ile
B.25	--Males, 62-74, 1-20%ile
B.26	--Males, 62-74, 40-60%ile
B.27	--Males, 62-74, 80-99%ile

The data tables are in the format produced by the University of Michigan Statistical Laboratory Michigan Interactive Data Analysis System (MIDAS). Each of the measurements is given a code name; the measurement name associated with the code names are identified on the following page. All dimensions are in centimeters unless otherwise noted.

CODE	MEASUREMENT NAME	MEAS. # (App. A)
WT(KG)	WEIGHT IN Kg	wt(lbs)/2.2
WT(LB)	WEIGHT IN LBS	1
STATURE	STATURE	2
PONDINDX	PONDERAL INDEX	stat(in)/ $\sqrt[3]{\text{wt(lbs)}}$
C7HT	CERVICAL HT	3
CHNKINT	CHIN-NECK INTERSECT HT	4
ERSITHT	ERECT SITTING HT	5
SITC7HT	SITTING CERVICALE HT	6
RTACR	SITTING RT ACROMION HT	7
LTACR	SITTING LT ACROMION HT	8
LTTRAG	LT TRAGION	9
RTTRAG	RT TRAGION	10
NASRTDEP	NASAL ROOT DEPRESSION	11
LTEYE	LT SITTING EYE HT(ERECT)	12
SUPSTREN	SITTING SUPRASTERNALE HT	13
BIACRBR	BIACROMIAL BREADTH	14
BIDELT	SHOULDER BREADTH (BIDELTOID)	15
LATNKBR	LATERAL NECK BREADTH	16
APNKBR	ANTERIOR-POSTERIOR NECK BREADTH	17
ANTNKLG	ANTERIOR NECK LENGTH	18
POSTNKLG	POSTERIOR NECK LENGTH	19
SLMPSIT	SLUMPED SITTING HT	20
SLLTEYE	LT SITTING EYE HT (SLUMPED)	21
SUPNKCIR	SUPERIOR NECK CIRCUMFERENCE	22
INFNKCIR	INFERIOR NECK CIRCUMFERENCE	23
HEADCIR	HEAD CIRCUMFERENCE	24
HEADELPS	HEAD ELLIPSE CIRCUMFERENCE	25
HEADBR	HEAD BREADTH	26
HEADLG	HEAD LENGTH	27
HEADHT	HEAD HT	28
SAGARC	SAGITTAL ARC	29
CORARC	CORONAL ARC	30
BITRGDI	BITRAGION DIAMETER	31

CODE	MEASUREMENT NAME	MEAS. # (App. A)
MINFRTDI	MINIMUM FRONTAL DIAMETER	32
MINFRTAR	MINIMUM FRONTAL ARC	33
BITRGMFA	BITRAGION-MINIMUM FRONTAL ARC	34
BITRGINA	BITRAGION-INION ARC	35
POSTARC	POSTERIOR ARC	36
SITKNEE	SITTING KNEE HT	37
KNEEMAX	SITTING KNEE HT (MAX CLEARANCE)	38
RTILACSP	SEATED HT OF RT ILIAC SPINE	39
HIPBR	SEATED HIP BREADTH	40
BICFLCIR	BICEPS FLEXED CIRCUMFERENCE	41
CALFCIR	CALF CIRCUMFERENCE	42
FEMDIA	FEMORAL BIEPICONDYLARIA-METER	43
HUMDIA	HUMERUS BIEPICONDYLAR DIAMETER	44
TRICEPSF	RT TRICEPS SKINFOLD	45
SUBSCPSF	RT SUBSCAPULAR SKINFOLD	46
SUPILSF	RT SUPRAILIAC SKINFOLD	47
CALFSF	RT POSTERIOR MID-CALF	48

The remaining measurements are the distances between the cervical vertibrae as measured from the X-rays, in inches.

C2 LINK	C1-C2 LINK DISTANCE (in inches)	
C3 LINK	C2-C3 LINK DISTANCE	
C4 LINK	C3-C4 LINK DISTANCE	
C5 LINK	C4-C5 LINK DISTANCE	
C6 LINK	C5-C6 LINK DISTANCE	
C7 LINK	C6-C7 LINK DISTANCE	
TOTLENG	TOTAL CERVICAL NECK LENGTH	

The following summary statistics are reported for each measurement:

Column Heading	Statistic
N	Number of Subjects in the Group
MINIMUM	Smallest Observation
MAXIMUM	Largest Observation
MEAN	Numerical Average
STD DEV	Standard Deviation
COEF VAR	Coefficient of Variation (Mean/Std Dev)
5TH %ILE	Fifth Percentile (Calculated)
50TH %ILE	Fiftieth Percentile (Calculated)
95TH %ILE	Ninety-fifth Percentile (Calculated)

Note: MIDAS specifies, as the percentile, the individual measurement which is closest to the requested percentile. For example; in a data set of 178 observations, the 9th smallest is called the 5th percentile, the 89th in rank is the 50th percentile and the 169th is the 95th percentile. This approach can cause misleading errors when small subsets of the data are analyzed; therefore, only the 50th percentile is included in Tables B.4 through B.9 and no percentiles are included for Tables B.10 through B.27.

TABLE B.1 ANTHROPOMETRY-ALL SUBJECTS COMBINED

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	5TH %ILE	50TH %ILE	95TH %ILE
.WT(KG)	178	44.091	121.14	68.382	14.472	21.164	49.545	65.682	97.955
.WT(LB)	178	97.000	266.50	150.44	31.839	21.164	109.000	144.500	215.500
.STATURE	178	144.80	195.00	167.01	10.076	6.033	150.700	167.100	184.200
.PONDINDX	178	10.559	13.692	12.447	.67573	5.429	11.089	12.439	13.512
.C7HT	178	122.90	169.70	142.53	9.1327	6.407	128.700	142.600	159.500
.CHNKINT	178	123.80	168.30	143.67	9.1650	6.382	129.300	143.700	160.500
.ERSITHT	178	76.000	97.900	87.296	4.7700	5.464	79.700	87.200	96.100
.SITC7HT	178	53.900	73.100	63.291	3.8411	6.069	57.600	63.200	70.400
.RTACR	178	48.300	65.700	56.712	3.9707	7.002	50.300	56.500	64.800
.LTACR	178	48.500	65.700	57.016	3.9320	6.896	50.500	56.800	63.700
.LTTRAG	178	62.900	84.400	74.110	4.5258	6.107	67.100	74.200	82.200
.RTTRAG	178	62.800	83.900	73.877	4.5374	6.142	66.700	73.600	82.100
.NASRTDEP	178	65.500	87.200	76.111	4.4095	5.794	63.400	75.600	83.900
.LTEYE	178	64.500	86.000	75.042	4.3933	5.854	67.900	74.500	83.200
.SUPSTREM	178	47.000	63.500	55.531	3.3593	6.049	49.800	55.500	61.800
.BIACRBR	178	31.000	45.100	37.535	2.8550	7.596	33.400	37.100	42.900
.BIDELT	178	34.000	54.000	43.734	4.1064	9.493	37.700	43.400	52.100
.LATNKBR	178	8.4000	13.200	10.620	1.0476	9.865	9.100	10.500	12.500
.APNKBR	178	8.0000	14.300	10.857	1.4064	12.954	8.900	10.600	13.500
.ANTNKLG	178	4.6000	13.100	8.8036	1.4691	16.684	6.200	8.800	11.000
.POSTNKLG	178	5.7000	15.200	10.201	1.6950	16.616	7.100	10.200	12.900
.SLMPSIT	178	73.300	96.000	84.640	4.5576	5.385	77.800	84.400	92.400
.SLLTEYE	178	62.700	85.300	72.593	4.3137	5.949	66.000	72.300	80.300
.SUPNKCIR	178	29.800	48.500	36.538	4.3971	12.034	30.700	36.100	45.300
.INFNKCIR	78	31.300	51.500	38.932	3.7242	9.566	33.500	38.700	45.500
.HEADCIR	178	50.500	64.500	56.810	2.1492	3.782	53.000	57.000	60.500
.HEADELPS	178	59.000	73.800	65.666	2.7256	4.151	61.200	65.800	70.100
.HEADBR	178	13.700	18.000	15.173	.68309	4.502	14.200	15.200	16.500

.HEADLG	178	16.300	22.300	18.492	.99342	5.372	16.800	18.500	20.000
.HEADHT	178	10.200	14.300	12.503	.71796	5.742	11.300	12.500	13.700
.SAGARC	178	29.700	41.500	35.546	1.9509	5.488	32.400	35.400	38.800
.CORARC	178	29.200	39.200	34.474	1.5286	4.434	32.300	34.200	37.000
.BITRGDI	178	11.800	15.500	13.660	.75535	5.522	12.500	13.600	15.000
.MINFRTDI	176	9.3000	11.900	10.548	.50290	4.768	9.700	10.500	11.500
.MINFRTAR	176	10.500	15.600	12.709	.87003	6.846	11.500	12.700	14.200
.BITRGMEA	178	26.400	34.500	29.758	1.3855	4.656	27.500	29.500	32.100
.BITRGINA	178	24.200	31.400	27.556	1.5159	5.501	25.000	27.600	30.200
.POSTARC	178	22.300	31.200	26.417	1.7953	6.794	23.600	26.800	29.500
.SITKNEE	178	42.300	61.300	50.338	3.7660	7.482	44.100	50.200	57.200
.KNEEMAX	178	44.500	64.100	52.512	3.7480	7.139	46.500	52.500	59.600
.BTILACSP	178	18.900	26.700	22.304	1.4606	6.548	20.100	22.100	25.200
.HIPBR	176	28.900	55.000	37.684	3.5495	9.419	33.300	37.300	44.000
.BICELCIR	178	24.000	41.500	30.584	3.7970	12.415	25.200	30.000	38.300
.CALFCIR	178	29.700	44.700	35.632	3.2601	9.149	31.000	35.500	42.000
.FEMDIA	178	8.0000	12.300	9.8293	.80922	8.224	8.600	9.800	11.400
.HUMDIA	178	5.3000	9.1000	6.7573	.77776	11.510	5.600	6.700	8.700
.TRICEPSF	178	.20000	3.6000	1.3343	.70399	52.762	.400	1.200	2.500
.SUBSCPSF	178	.60000	4.3000	1.6281	.79660	48.929	.700	1.400	3.400
.SUPILSF	178	.30000	4.3000	1.4770	.75568	51.164	.500	1.300	3.000
.CALFSF	178	.10000	3.5000	.95506	.72135	75.529	.100	.700	2.200
.C2 LINK	175	1.1567	1.9347	1.4457	.13203	9.133	1.228	1.423	1.660
.C3 LINK	176	.50233	.88767	.66161	.74103 -1	11.200	.542	.655	.781
.C4 LINK	176	.47767	.92767	.65151	.71384 -1	10.957	.543	.652	.770
.C5 LINK	176	.47233	.98500	.63527	.72317 -1	11.384	.532	.630	.755
.C6 LINK	176	.47767	.97500	.63238	.70897 -1	11.211	.515	.626	.741
.C7 LINK	152	.50267	.87567	.65227	.69732 -1	10.211	.562	.693	.807
.TOTLENG	151	3.7417	6.1030	4.6726	.41575	8.898	4.007	4.627	5.312

TABLE B.2 ANTHROPOMETRY BY SEX FEMALES

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	5TH %ILE	50TH %ILE	95TH %ILE
.WT(KG)	91	44.091	101.14	61.061	10.970	17.960	47.273	58.636	85.227
.WT(LB)	91	97.000	222.50	134.38	24.134	17.960	104.000	129.000	187.500
.STATURE	91	144.80	184.00	160.86	7.6707	4.769	149.100	160.400	174.100
.PONDINDX	91	10.559	13.62[illegible]	12.432	.71510	5.752	11.041	12.424	13.537
.C7HT	91	122.90	159.00	137.15	7.0421	5.135	126.000	136.800	150.000
.CHNKINT	91	123.80	160.90	138.30	7.1616	5.178	127.500	137.600	150.500
.ERSITHT	91	76.000	93.300	84.566	3.7110	4.388	78.900	84.500	90.900
.SITC7HT	91	52.900	69.600	61.205	2.6974	4.734	57.000	61.000	66.100
.RTACR	91	48.300	61.900	54.547	3.0451	5.583	49.700	54.700	60.600
.LTACR	91	48.800	61.600	54.769	2.8931	5.282	50.100	54.900	59.700
.LTTRAG	91	62.900	80.900	71.612	3.5667	4.981	66.500	71.200	78.200
.RTTRAG	91	62.800	80.300	71.396	3.6412	5.100	66.500	71.300	77.400
.NASRTOER	91	65.500	82.700	73.821	3.3725	4.569	67.800	74.100	79.600
.LTEYE	91	64.500	80.900	72.729	3.3512	4.608	67.000	73.200	78.600
.SUPSTREN	91	47.000	60.400	53.737	2.5338	4.818	49.500	53.800	57.600
.BIACRBR	91	31.000	43.200	35.708	2.1140	5.920	32.800	35.500	39.500
.BIDELT	91	34.000	48.800	40.946	2.4907	6.082	37.500	40.700	45.600
.LATNKBR	91	8.4000	11.500	9.8736	.60989	6.177	9.000	9.900	10.900
.APNKBR	91	8.0000	12.300	9.8868	.85946	8.693	8.800	9.700	11.500
.ANTNKLG	91	4.6000	11.700	8.7967	1.3482	15.326	6.500	8.700	11.000
.POSTNKLG	91	5.7000	12.900	9.7923	1.5640	15.972	7.000	9.800	12.500
.SLMPSIT	91	73.300	91.600	82.097	3.5054	4.270	76.200	81.600	87.800
.SLLTEYE	91	62.700	80.600	70.543	3.2739	4.641	64.900	70.400	75.500
.SUPNKCIR	91	29.800	44.800	33.451	2.6260	7.851	30.200	33.000	38.400
.INFNKCIR	91	31.300	44.200	36.278	2.3257	6.411	32.900	36.300	40.500
.HEADCIR	91	50.500	62.200	55.773	1.9515	3.499	52.400	55.800	58.800
.HEADELPS	91	59.000	72.400	63.995	2.1061	3.291	60.800	64.000	67.200
.HEADBR	91	13.700	16.400	14.835	.52332	3.528	14.100	14.800	15.600

.HEADLG	91	16.300	19.100	17.927	.69763	3.891	16.700	18.000	19.000
.HEADHT	91	10.200	13.700	12.235	.67477	5.493	11.200	12.400	13.500
.SAGARC	91	29.700	39.500	35.059	1.9474	5.555	31.500	35.000	38.100
.CORARC	91	29.200	39.200	34.058	1.5759	4.627	31.800	33.900	36.700
.BITRGDI	91	11.800	14.400	13.259	.55417	4.179	12.400	13.200	14.100
.MINERTDI	91	9.3000	11.700	10.404	.46498	4.469	9.700	10.400	11.200
.MINERTAR	91	10.500	15.400	12.491	.81030	6.487	11.400	12.400	13.800
.BITRGMEA	91	26.400	31.700	29.046	1.1156	3.841	27.400	29.000	31.000
.BITRGINA	91	24.200	30.200	26.892	1.3625	5.067	24.600	26.900	29.300
.POSTARC	91	22.300	29.800	25.562	1.5623	6.112	23.300	25.500	28.100
.SITKNEE	91	42.300	59.100	48.061	2.8599	5.948	43.700	48.200	52.800
.KNEEMAX	91	44.500	61.300	50.310	2.9267	5.817	45.300	50.500	54.600
.BTILACSP	91	19.900	25.500	21.758	1.1975	5.504	19.800	21.700	24.100
.HIPBR	91	32.100	55.000	38.579	3.8512	9.983	33.700	38.400	45.100
.BICELCIR	91	24.000	38.800	28.932	3.5091	12.129	24.800	28.300	36.700
.CALFCIR	91	29.700	43.200	34.526	2.8631	8.293	30.300	34.300	40.400
.FEMDIA	91	8.0000	12.800	9.6582	.84526	8.752	8.400	9.600	11.200
.HUMDIA	91	5.3000	9.1000	6.5154	.88906	13.646	5.400	6.300	8.800
.TRICEPSF	91	.70000	3.6000	1.7000	.76751	40.442	.700	1.700	2.600
.SUBSCPSF	91	.60000	4.8000	1.6462	.82291	49.990	.700	1.500	3.200
.SUPILSF	91	.30000	3.4000	1.3385	.64580	48.250	.500	1.200	2.500
.CALFSF	91	.10000	3.5000	1.1275	.87217	77.356	.100	1.100	2.700
.C2 LINK	90	1.1567	1.8543	1.3863	.11576	8.350	1.186	1.388	1.567
.C3 LINK	91	.51000	.87333	.62070	.59194 -1	9.537	.538	.621	.709
.C4 LINK	91	.47967	.92767	.61604	.67401 -1	10.941	.535	.614	.723
.C5 LINK	91	.47333	.83367	.60142	.60871 -1	10.121	.508	.588	.702
.C6 LINK	91	.47767	.80167	.60001	.61586 -1	10.264	.501	.601	.693
.C7 LINK	88	.50367	.81433	.65478	.60934 -1	9.306	.551	.655	.761
.TOTLENG	87	3.7417	6.1030	4.4778	.36997	8.262	3.891	4.471	5.051

TABLE B.3 ANTHROPOMETRY BY SEX MALES

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	5TH %ILE	50TH %ILE	95TH %ILE
WT(KG)	87	50.227	121.14	76.019	13.774	18.119	56.364	73.864	100.909
WT(LB)	87	110.50	265.50	167.24	30.303	18.119	124.000	162.500	222.000
STATURE	87	152.00	195.00	173.44	8.0927	4.666	162.200	173.300	187.100
PONDINDX	87	10.689	13.692	12.464	.63567	5.100	11.306	12.506	13.511
C7HT	87	129.30	169.70	148.16	7.5491	5.095	136.300	147.200	160.700
CHNKINT	87	129.60	168.30	149.30	7.5358	5.048	137.900	148.800	161.900
ERSITHT	87	78.900	97.900	90.152	4.0349	4.476	83.900	89.900	96.700
SITC7HT	87	57.900	73.100	65.472	3.4876	5.327	59.900	65.200	71.400
RTACR	87	50.300	65.700	58.976	3.5499	6.019	53.700	58.500	65.200
LTACR	37	48.500	65.700	59.370	3.4803	5.862	54.300	59.400	65.000
LTTRAG	97	66.800	84.400	76.723	3.9160	5.104	70.100	76.800	83.000
RTTRAG	87	65.700	83.800	76.472	3.8946	5.093	70.600	76.400	82.900
NASRTDER	87	66.900	87.200	78.507	4.0943	5.215	72.100	78.800	84.800
LTEYE	87	65.700	86.000	77.462	4.0474	5.225	70.900	77.600	83.600
SUPSTREN	87	48.600	63.500	57.407	3.0411	5.297	52.400	57.400	62.400
BIACRBR	37	35.500	45.100	39.548	2.1143	5.346	36.000	39.400	43.100
BIDELT	87	39.300	56.000	46.516	3.2370	7.006	42.400	46.500	52.800
LATNKBR	87	9.5000	13.200	11.400	.81526	7.151	10.000	11.400	12.800
APNKBR	87	9.6000	14.300	11.671	1.1230	9.460	10.100	11.800	13.600
ANTNKLG	87	5.0000	13.100	8.8149	1.5936	18.079	5.700	8.800	11.000
POSTNKLG	37	7.1000	15.200	10.629	1.7256	16.272	7.000	10.600	13.400
SLMPSIT	87	77.600	96.000	87.300	3.9861	4.566	80.800	87.200	94.500
SLLTEYE	87	63.500	85.300	74.733	4.2505	5.687	68.500	74.800	81.700
SUPNKCIR	87	32.200	48.500	39.767	3.4559	8.691	34.000	39.500	45.900
INFNKCIR	87	36.700	51.500	41.708	2.7633	6.625	37.500	41.500	46.200
HEADCIR	87	54.500	64.600	57.914	1.7748	3.065	54.900	57.800	60.800
HEADELPS	97	61.500	73.800	67.414	2.1449	3.182	63.700	67.500	71.000
HEADBR	87	14.000	18.000	15.526	.65316	4.207	14.600	15.500	16.800

.HEADLG	87	16.800	22.900	19.082	.91264	4.783	17.800	19.100	20.400
.HEADHT	87	10.900	14.300	12.732	.69341	5.446	11.700	12.800	13.800
.SAGARC	87	31.600	41.500	36.055	1.8308	5.078	33.500	36.000	39.100
.CORARC	87	32.400	38.400	34.903	1.3554	3.883	33.000	34.800	37.300
.BITRGDI	87	12.100	15.500	14.120	.68571	4.856	13.000	14.100	15.200
.MINFRTDI	85	9.5000	11.900	10.701	.49916	4.665	9.800	10.600	11.600
.MILFRTAR	85	11.000	15.600	12.942	.87578	6.767	11.600	12.900	14.300
.BITRCMEA	87	27.500	34.500	30.503	1.2447	4.081	28.800	30.500	32.300
.BITRGINA	87	24.600	31.400	28.249	1.3543	4.794	26.100	28.200	30.900
.POSTARC	87	24.200	31.200	27.722	1.3274	4.788	25.500	27.800	30.000
.SITKNEE	87	44.400	61.300	52.698	3.1000	5.883	48.000	52.400	58.100
.KNEEMAX	87	46.700	64.100	54.816	3.0754	5.610	50.000	54.600	60.300
.BTILACSP	87	20.300	26.700	22.576	1.4780	6.548	20.600	22.800	25.400
.HIPBR	85	28.800	43.700	36.726	2.9253	7.967	33.200	36.400	42.400
.BICELCIR	87	26.100	41.500	32.313	3.2978	10.206	27.300	32.000	38.600
.CALFCIR	87	29.800	44.700	36.791	3.2617	8.866	31.700	36.600	43.400
FEMDIA	87	8.6000	12.000	10.029	.72736	7.253	8.800	10.000	11.400
HUMDIA	87	5.7000	8.7000	7.0103	.53960	7.697	6.200	6.900	8.000
.TRICEPSF	87	.20000	2.4000	.85172	.43557	51.020	.400	.800	2.100
SUBSCPSF	87	.50000	4.3000	1.6092	.77244	48.001	.800	1.400	3.400
SUPILSF	87	.50000	4.3000	1.6218	.83505	51.488	.600	1.400	3.200
CALFSF	87	.20000	2.3000	.77471	.45882	59.225	.200	.600	1.700
C2 LINK	85	1.2947	1.9247	1.5086	.11885	7.878	1.332	1.493	1.712
C3 LINK	85	.50233	.89767	.70541	.62702 -1	8.889	.597	.712	.802
C4 LINK	85	.53667	.83500	.68949	.54093 -1	7.845	.601	.691	.771
C5 LINK	85	.53167	.93500	.67152	.55988 -1	8.827	.587	.671	.769
C6 LINK	85	.55067	.87500	.66704	.63695 -1	9.549	.577	.662	.761
C7 LINK	64	.54300	.87567	.72151	.62519 -1	8.665	.626	.718	.826
TOTLENG	64	4.1393	5.7013	4.9374	.31792	6.439	4.426	4.916	5.453

TABLE B.4 ANTHROPOMETRY BY SEX ANO AGE FEMALES 18-24

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STO OEV	COEF VAR	50TH %ILE
.WT(KG)	30	45.909	81.364	58.485	7.7618	13.272	57.500
.WT(LB)	30	101.00	179.00	128.67	17.076	13.272	126.500
.STATURE	30	144.80	184.00	162.68	8.8727	5.454	161.600
.PONDINDX	30	11.760	13.626	12.716	.53324	4.193	12.556
.C7HT	30	122.90	159.00	138.76	8.1204	5.852	137.700
.CHNKINT	30	123.80	160.90	139.92	8.3309	5.954	138.300
.ERSITHT	30	76.000	91.300	85.663	3.7435	4.370	85.100
.SITC7HT	30	53.900	66.200	61.653	2.9367	4.763	61.700
.RTACR	30	48.300	60.700	54.937	3.0244	5.505	55.100
.LTACR	30	48.800	60.300	55.157	2.8945	5.243	55.400
.LTTRAG	30	63.000	78.700	72.623	3.6091	4.970	72.600
.RTTRAG	30	63.100	79.000	72.487	3.7673	5.197	72.300
.NASRTOEP	30	65.500	79.800	74.580	3.8115	5.111	74.600
.LTEYE	30	64.500	78.700	73.437	3.7486	5.105	73.400
.SUPSTREV	30	47.000	58.900	54.320	2.7595	5.080	54.500
.8IACR8R	30	31.000	39.500	35.473	1.9983	5.633	35.900
.BIDELT	30	37.000	45.600	40.953	2.0779	5.074	40.900
.LATNK8R	30	8.4000	10.800	9.7567	.56427	5.783	9.800
.APNK8R	30	8.0000	10.600	9.3167	.54335	5.832	9.300
.ANTNKLG	30	6.0000	11.700	8.5667	1.4145	16.512	9.700
.POSTNKLG	30	6.7000	12.900	10.397	1.5635	15.033	10.300
.SLMPSIT	30	73.300	89.500	82.817	3.7395	4.515	82.300
.SLLTEYE	30	52.700	78.700	71.270	3.5911	5.039	70.600
.SUPNKCIR	30	29.800	35.700	32.110	1.4409	4.487	31.500
.INFNKCIR	30	32.500	40.000	35.830	1.8753	5.234	35.700
.HEADCIR	30	52.400	59.000	55.480	1.7205	3.101	55.500
.HEAOELPS	30	60.800	67.200	63.813	1.7180	2.692	63.500
.HEAO8R	30	13.700	15.600	14.633	.45283	3.095	14.600

.HEADLG	30	16.400	18.900	17.793	.63514	3.570	17.900
.HEADHT	30	10.900	13.400	12.160	.53473	4.397	12.000
.SAGARC	30	32.500	38.400	35.110	1.4342	4.095	34.900
.CORARC	30	31.600	37.400	33.673	1.3214	3.924	33.600
.BITRGDI	30	12.300	14.000	13.103	.38906	2.969	13.100
.MINFRTDI	30	9.4000	11.700	10.313	.54503	5.285	10.200
.MINFRTAR	30	11.200	13.800	12.393	.68225	5.505	12.200
.BITRGMFA	30	26.600	31.000	28.777	.98530	3.424	28.800
.BITRGINA	30	24.600	29.800	26.923	1.3069	4.854	26.700
.POSTARC	30	23.800	29.800	26.090	1.5984	6.126	25.600
.SITKNEE	30	42.300	58.100	48.767	3.3082	6.784	48.500
.KNEEMAX	30	45.200	61.300	50.983	3.3181	6.508	50.700
.RTILACSP	30	18.900	25.500	21.653	1.2412	5.732	21.600
.HIPBR	30	33.700	42.300	37.430	2.2121	5.910	37.200
.BICFLCIR	30	24.500	30.900	27.173	1.8154	6.681	27.100
.CALFCIR	30	31.300	41.400	34.687	2.4524	7.070	33.800
.FEMDIA	30	8.3000	10.800	9.4333	.56406	5.979	9.400
.HUMDIA	30	5.3000	9.1000	6.5267	1.0680	16.364	6.300
.TRICEPSF	30	.90000	3.6000	1.8133	.57759	31.852	1.800
.SUBSCPSF	30	.70000	3.2000	1.5567	.58879	37.824	1.500
.SUPILSF	30	.50000	3.4000	1.3600	.64786	47.637	1.200
.CALFSF	30	.10000	3.5000	1.6600	.86885	52.340	1.700
.C2 LINK	30	1.1660	1.6860	1.3613	.11729	3.616	1.362
.C3 LINK	30	.51000	.78533	.63257	.62354 -1	9.857	.634
.C4 LINK	30	.47967	.80067	.62587	.67992 -1	10.864	.618
.C5 LINK	30	.50600	.79700	.61380	.63165 -1	10.291	.600
.C6 LINK	30	.48667	.79200	.62103	.56141 -1	9.040	.616
.C7 LINK	29	.50367	.81433	.65799	.66103 -1	10.046	.656
.TOTLENG	29	3.8913	5.5560	4.4984	.37291	8.290	4.466

TABLE B.5 ANTHROPOMETRY BY SEX AND AGE FEMALES 35-44

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.WT(KG)	30	44.091	101.14	59.447	13.008	21.881	57.045
.WT(LB)	30	97.000	222.50	130.78	28.617	21.881	125.500
.STATURE	30	148.40	172.90	161.43	6.4473	3.994	161.000
.PONDINDX	30	10.789	13.580	12.611	.69072	5.477	12.708
.C7HT	30	125.30	146.10	137.10	6.0737	4.430	136.400
.CHNKINT	30	126.80	149.60	138.78	5.8154	4.190	138.500
.ERSITHT	30	79.600	91.500	85.380	2.8839	3.378	85.200
.SITC7HT	30	57.000	66.100	61.590	2.5357	4.117	61.100
.RTACR	30	50.300	60.800	55.457	2.4723	4.458	55.300
.LTACR	30	50.700	61.600	55.757	2.5397	4.555	55.400
.LTTRAG	30	67.500	78.200	72.453	2.5859	3.569	72.500
.RTTRAG	30	66.700	77.500	72.307	2.5522	3.530	72.800
.NASRTDEP	30	69.200	79.800	74.537	2.2298	2.992	74.400
.LTEYE	30	68.000	78.600	73.500	2.2402	3.048	73.600
.SUPSTREV	30	49.500	57.500	54.187	2.0149	3.718	54.100
.BIACRBR	30	32.500	42.900	35.747	2.0910	5.849	35.200
.BIDELT	30	34.000	48.800	40.760	3.1335	7.688	40.100
.LATNKBR	30	9.0000	11.000	9.8433	.55627	5.651	9.900
.APNKBR	30	8.8000	12.200	9.6900	.70091	7.233	9.500
.ANTNKLG	30	4.6000	11.400	8.9300	1.6056	17.980	8.700
.POSTNKLG	30	8.1000	12.500	10.123	.97828	9.664	10.000
.SLMPSIT	30	78.300	90.000	82.873	2.8147	3.396	82.600
.SLLTEYE	30	64.900	74.800	71.013	2.3744	3.344	71.400
.SUPNKCIR	30	30.000	40.500	32.620	2.0845	6.390	32.200
.INFNKCIR	30	31.300	44.200	35.833	2.4718	6.898	35.400
.HEADCIR	30	52.100	58.500	55.843	1.5620	2.797	56.000
.HEADELPS	30	60.200	67.000	63.680	1.6014	2.515	63.800
.HEADBR	30	13.700	16.300	14.880	.54608	3.670	14.800

.HEAOLG	30	16.300	19.100	17.940	.77397	4.314	18.000
.HEAOHT	30	10.200	13.500	12.287	.73143	5.953	12.500
.SAGARC	30	30.400	39.300	35.443	2.1375	6.031	35.300
.CORARC	30	29.200	38.500	33.950	1.6412	4.834	33.800
.BITRGOI	30	11.800	14.400	13.263	.59624	4.495	13.200
.MINFRTDI	30	9.3000	11.600	10.423	.46586	4.469	10.400
.MINFRTAR	30	10.500	15.400	12.367	.95496	7.722	12.300
.BITRGMFA	30	26.400	31.700	28.870	1.0652	3.690	28.800
.BITRGINA	30	24.400	29.800	26.677	1.3746	5.153	26.400
.POSTARC	30	22.300	28.600	25.177	1.5292	6.074	24.800
.SITKNEE	30	43.500	51.500	47.683	2.3492	4.927	47.300
.KNEEMAX	30	45.200	54.600	50.100	2.4962	4.982	49.800
.RTILACSP	30	19.700	24.100	21.607	1.1135	5.154	21.600
.HIPBR	30	33.500	55.000	38.207	4.7607	12.460	37.500
.BICFLCIR	30	24.800	38.700	28.593	3.4539	12.079	28.000
.CALFCIR	30	30.000	43.200	34.290	3.1037	9.051	34.200
.FEMOIA	30	8.0000	12.800	9.6233	.97013	10.081	9.300
.HUMOIA	30	5.4000	8.9000	6.5300	.92257	14.128	6.300
.TRICEPSF	30	.80000	3.6000	1.8300	.65345	35.708	1.700
.SUBSCPSF	30	.60000	4.2000	1.5633	.96828	61.937	1.100
.SUPILSF	30	.40000	3.0000	1.3133	.70110	53.383	1.100
.CALFSF	30	.10000	2.8000	1.2433	.81566	65.603	1.300
.C2 LINK	30	1.1567	1.5410	1.3793	.84742 -1	6.144	1.386
.C3 LINK	30	.52800	.67900	.61983	.44060 -1	7.103	.622
.C4 LINK	30	.54267	.68867	.61797	.43791 -1	7.086	.627
.C5 LINK	30	.52633	.69667	.61048	.49041 -1	8.033	.621
.C6 LINK	30	.50067	.69300	.61086	.47528 -1	7.781	.614
.C7 LINK	30	.53767	.76100	.66561	.49845 -1	7.489	.665
.TOTLENG	30	3.8060	4.8977	4.5040	.26731	5.935	4.585

TABLE B.6 ANTHROPOMETRY BY SEX AND AGE FEMALES 62-74

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
WT(KG)	31	50.682	88.864	65.176	10.606	16.273	63.182
.WT(LB)	31	111.50	195.50	143.39	23.333	16.273	139.000
.STATURE	31	146.30	174.20	158.54	7.1418	4.505	158.100
.PONDINDX	31	10.559	13.376	11.983	.69081	5.765	11.975
.C7HT	31	123.20	150.00	135.64	6.6655	4.914	135.300
.CHNKINT	31	124.90	150.50	136.26	6.8514	5.028	135.200
.ERSITHT	31	76.500	93.300	82.716	3.7848	4.576	82.200
.SITC7HT	31	54.900	69.600	60.400	3.1008	5.134	60.200
.RTACR	31	48.900	61.900	53.290	3.2336	6.068	53.300
.LTACR	31	48.900	60.400	53.439	2.7966	5.233	53.500
.LTTRAG	31	62.900	80.900	69.819	3.7494	5.370	69.800
.RTTRAG	31	62.800	80.300	69.458	3.7230	5.360	68.600
.MASRTDEP	31	66.700	82.700	72.394	3.4754	4.801	71.400
.LTEYE	31	65.400	80.900	71.297	3.4702	4.867	70.500
.SUPSTREN	31	47.600	60.400	52.739	2.6923	5.105	52.300
.BIACRBR	31	32.800	43.200	35.897	2.2863	6.369	35.700
.BIDELT	31	37.600	47.800	41.119	2.2075	5.368	40.700
.LATNKBR	31	9.5000	11.500	10.016	.68804	6.869	10.000
.APNKBR	31	9.4000	12.300	10.629	.72305	6.803	10.600
.ANTNKLG	31	7.2000	10.900	8.8503	.97303	10.945	8.800
.POSTNKLG	31	5.7000	12.200	8.8871	1.6518	18.587	8.800
.SLMPSIT	31	75.100	91.600	80.648	3.5211	4.365	80.600
.SLLTEYE	31	62.900	80.500	69.354	3.4758	5.014	69.100
.SUPNKCIR	31	31.000	44.800	35.552	2.7263	7.669	35.400
.INFNKCIR	31	32.100	42.400	37.142	2.3982	6.457	37.200
.HEADCIR	31	50.500	62.200	55.957	2.4630	4.399	56.100
.HEADELPS	31	59.000	72.400	64.474	2.7579	4.278	64.100
.HEADBR	31	14.100	16.400	14.987	.51616	3.457	14.900

.HEADLG	31	16.500	19.100	18.045	.67717	3.753	18.200
.HEADHT	31	11.200	13.700	12.403	.73643	5.937	12.500
.SAGARC	31	29.700	39.500	34.639	2.1540	6.219	34.600
.COPARC	31	31.200	39.200	34.535	1.6622	4.813	34.000
.BITRGDI	31	12.100	14.200	13.406	.62018	4.626	13.500
.MINFRTDI	31	9.7000	11.300	10.474	.37145	3.546	10.400
.MINFRTAR	31	11.500	15.400	12.706	.75186	5.917	12.700
.BITRGMFA	31	27.000	31.200	29.477	1.1843	4.018	29.400
.BITRGINA	31	24.200	30.200	27.071	1.4183	5.239	27.200
.POSTARC	31	22.600	27.800	25.423	1.4646	5.761	25.900
.SITKNEE	31	43.000	54.400	47.803	2.8132	5.885	47.700
.KNEEMAX	31	44.500	56.200	49.861	2.8852	5.786	50.200
.PTILACSP	31	19.400	24.400	22.006	1.2315	5.596	21.700
.HIPBR	31	32.100	46.000	40.052	3.7624	9.394	40.200
.BICELCIR	31	24.000	38.800	30.961	3.8418	12.409	30.700
.CALFCIR	31	29.700	41.100	34.574	3.0628	8.854	34.600
.FEMDIA	31	8.3000	12.000	9.9097	.89939	9.076	9.900
.HUMDIA	31	5.4000	8.8000	6.4903	.66701	10.277	6.300
.TRICEPSF	31	.20000	3.3000	1.4645	.77182	52.701	1.400
.SUBSCPSF	31	.60000	4.8000	1.8129	.86400	47.658	1.700
.SUPILSF	31	.30000	2.5000	1.3419	.60760	45.278	1.400
.CALFSF	31	.10000	1.7000	.50000	.45314	90.627	.200
.C2 LINK	30	1.1593	1.8543	1.4183	.13576	9.572	1.408
.C3 LINK	31	.51367	.87333	.61006	.67959 -1	11.140	.604
.C4 LINK	31	.47967	.92767	.60467	.84096 -1	13.908	.587
.C5 LINK	31	.47333	.83867	.58067	.65223 -1	11.232	.577
.C6 LINK	31	.47767	.80167	.56917	.67866 -1	11.924	.570
.C7 LINK	29	.52367	.60737	.64037	.65124 -1	10.171	.638
.TOTLENG	28	3.7417	6.1030	4.4284	.45966	10.380	4.384

TABLE B.7 ANTHROPOMETRY BY SEX AND AGE MALES 18-24

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.WT(KG)	30	50.227	111.14	71.394	14.106	19.758	68.182
.WT(LB)	30	110.50	244.50	157.07	31.034	19.758	150.000
.STATURE	30	162.40	189.90	174.86	8.5583	4.894	174.600
.PONOINOX	30	11.789	13.639	12.833	.49189	3.833	12.880
.C7HT	30	136.30	163.30	148.96	8.1797	5.491	147.900
.CHNKINT	30	137.70	165.20	150.80	7.9374	5.264	150.200
.ERSITHT	30	85.100	97.900	91.063	3.7941	4.166	91.600
.SITC7HT	30	59.600	73.100	65.423	3.3600	5.136	65.200
.RTACR	30	53.700	65.700	59.340	3.5815	6.036	58.700
.LTACR	30	54.100	65.500	59.617	3.3948	5.694	59.400
.LTTRAG	30	70.800	83.400	77.543	3.4025	4.388	78.000
.RTTRAG	30	71.800	83.800	77.253	3.4162	4.422	77.100
.NASRTOEP	30	72.200	86.000	79.300	3.7367	4.712	79.200
.LTEYE	30	70.700	85.000	78.277	3.7093	4.739	78.100
.SUPSTREN	30	52.400	62.400	57.307	2.5653	4.476	57.100
.BIACRBR	30	35.600	45.100	39.900	2.2638	5.674	39.500
.BIDELT	30	39.300	55.700	46.787	3.3231	7.103	46.600
.LATNKBR	30	10.000	13.200	11.420	.80361	7.037	11.200
.APNKBR	30	9.6000	13.000	10.903	.77526	7.110	10.700
.ANTNKLG	30	7.3000	13.100	9.7700	1.1771	12.048	9.700
.POSTNKLG	30	7.5000	14.700	11.403	1.5475	13.571	11.400
.SLMPSIT	30	80.700	95.300	87.717	3.9260	4.476	88.100
.SLLTEYE	30	68.500	84.000	74.997	3.9692	5.293	74.600
.SUPNKCIR	30	32.200	43.000	36.873	2.5045	6.792	36.900
.INFNKCIR	30	36.700	46.000	40.760	2.4410	5.989	40.200
.HEADCIR	30	54.600	62.500	57.663	1.6868	2.925	57.500
.HEADELPS	30	61.500	73.800	67.240	2.5109	3.734	67.000
.HEADBR	30	14.000	16.000	15.110	.48732	3.225	15.200

.HEADLG	30	16.800	22.300	19.033	1.0090	5.301	19.000
.HEADHT	30	11.700	14.300	12.840	.63713	4.962	12.900
.SAGARC	30	33.500	39.400	36.807	1.6723	4.543	36.900
.COPARC	30	32.400	37.400	34.863	1.3379	3.838	34.500
.BITRGDI	30	12.100	15.100	13.700	.66384	4.846	13.700
.MINFRTOI	28	9.7000	11.900	10.525	.44690	4.246	10.500
.MINFRTAR	28	11.400	14.800	12.836	.96464	7.515	12.700
.BITRGMFA	30	27.500	32.100	30.107	1.2026	3.994	29.800
.BITRGINA	30	24.600	31.000	28.123	1.5290	5.437	28.100
.POSTAPC	30	24.200	30.800	27.353	1.3718	5.015	27.500
.SITKNEE	30	47.200	59.100	52.977	3.3359	6.297	52.400
.KNEEMAX	30	49.500	61.200	55.013	3.4458	6.264	54.700
.RTILACSP	30	20.300	25.400	22.470	1.3872	6.173	22.200
.HIPBR	28	28.800	43.400	35.339	2.9792	8.430	35.000
.BICFLCIR	30	26.100	39.600	31.197	3.2159	10.308	30.600
.CALFCIR	30	31.100	44.300	36.847	2.8213	7.657	36.600
.FEMDIA	30	8.8000	11.800	9.7867	.68669	7.017	9.800
.HUMDIA	30	5.7000	8.7000	7.0100	.57676	8.228	6.900
.TRICEPSF	30	.30000	1.7000	.87000	.38160	43.862	.800
.SUBSCPSF	30	.60000	2.9000	1.2733	.49196	38.625	1.200
.SUPILSF	30	.50000	3.2000	1.2867	.68367	53.125	1.100
.CALFSF	30	.20000	2.3000	.96000	.47168	49.133	.900
.C2 LINK	30	1.3070	1.9347	1.4976	.11396	7.610	1.476
.C3 LINK	30	.58467	.88767	.71200	.66359 -1	9.320	.708
.C4 LINK	30	.55067	.83500	.69879	.53430 -1	7.646	.693
.C5 LINK	30	.60567	.98500	.68958	.74400 -1	10.789	.675
.C6 LINK	30	.57200	.97500	.68511	.79063 -1	11.540	.681
.C7 LINK	24	.62600	.87567	.72265	.62264 -1	8.616	.710
.TOTLENG	24	4.3720	5.5350	4.9374	.29122	5.393	4.913

TABLE B.8 ANTHROPOMETRY 8Y SEX ANO AGE MALES 35-44

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STO OEV	COEF VAR	50TH %ILE
.WT(KG)	30	61.364	121.14	83.447	13.977	16.750	79.773
.WT(LB)	30	135.00	266.50	183.58	30.750	16.750	175.500
.STATURE	30	153.00	195.00	173.92	8.3540	4.803	174.000
.PONOINOX	30	10.689	13.512	12.107	.67666	5.589	12.140
.C7HT	30	129.30	169.70	148.59	8.0504	5.418	148.300
.CHNKINT	30	129.60	168.30	149.54	7.6490	5.115	149.700
.ERSITHT	30	83.100	97.100	90.473	4.0314	4.456	89.700
.SITC7HT	30	59.100	72.700	65.770	3.6966	5.621	65.400
.RTACR	30	52.100	64.900	59.320	3.4275	5.778	58.700
.LTACR	30	54.300	65.700	60.060	3.2192	5.360	59.700
.LTTRAG	30	70.100	84.400	76.933	3.9194	5.095	76.700
.RTTRAG	30	70.600	83.600	76.793	3.9694	5.169	76.400
.NASRTDEP	30	71.400	85.700	78.743	3.9962	5.075	78.900
.LTEYE	30	70.100	84.500	77.713	3.8132	4.907	77.800
.SUPSTPEN	30	52.800	63.500	57.913	3.0366	5.243	57.700
.BIACRBR	30	35.600	44.000	39.717	2.1143	5.324	39.400
.BIDELT	30	44.300	56.000	48.813	3.1060	6.363	47.400
.LATNKBR	30	9.5000	12.800	11.687	.77046	6.593	11.700
.APNKBR	30	10.500	13.900	12.183	.93110	7.642	12.000
.ANTNKLG	30	5.0000	10.800	7.8267	1.6101	20.572	7.700
.POSTNKLG	30	7.1000	13.700	10.323	1.5622	15.133	10.500
.SLMPSIT	30	80.900	93.100	87.513	3.4188	3.907	87.200
.SLLTEYE	30	69.500	81.700	75.080	3.3874	4.512	75.000
.SUPNKCIR	30	36.100	48.000	41.183	3.1124	7.557	40.300
.INFNKCIR	30	38.700	51.500	43.207	2.9118	6.739	43.000
.HEADCIR	30	55.200	64.600	58.243	2.0003	3.434	57.600
.HEADELPS	30	63.500	72.300	67.893	2.0621	3.037	68.000
.HEADBR	30	14.700	18.000	15.800	.67976	4.302	15.700

.HEADLG	30	17.000	22.900	19.050	.96338	5.057	19.000
.HEADHT	30	11.300	14.100	12.810	.65197	5.090	12.900
.SAGARC	30	32.600	41.500	36.097	1.8663	5.170	36.200
.CORARC	30	33.100	38.400	35.430	1.3742	3.879	35.200
.BITRGDI	30	13.200	15.500	14.373	.58246	4.052	14.400
.MINFRTDI	30	9.7000	11.800	10.877	.52040	4.785	10.900
.MINFRTAR	30	11.300	14.400	13.033	.79712	6.116	12.900
.BITRGMFA	30	29.000	34.500	30.870	1.3308	4.311	30.700
.BITRGINA	30	26.000	31.400	28.403	1.3077	4.604	28.200
.POSTARC	30	25.400	31.200	28.023	1.3811	4.928	27.900
.SITKNEE	30	46.500	61.300	53.040	3.1445	5.929	53.000
.KNEEMAX	30	49.800	64.100	55.367	2.9152	5.265	55.200
.RTILACSP	30	20.500	26.700	23.127	1.6396	7.090	22.500
.HIPBR	30	33.300	43.700	37.897	2.7818	7.340	37.200
.BICFLCIR	30	27.300	41.500	34.300	3.3373	9.730	34.300
.CALFCIR	30	33.500	44.700	38.507	3.5073	9.108	38.100
.FEMDIA	30	9.1000	12.000	10.263	.70245	6.844	10.200
.HUMDIA	30	6.1000	8.2000	7.0733	.54071	7.644	7.000
.TRICEPSF	30	.50000	2.4000	1.1267	.54198	48.105	1.100
.SUBSCPSF	30	.90000	4.3000	2.1300	.94692	44.456	2.200
.SUPILSF	30	.80000	4.8000	2.1933	.94611	43.136	2.000
.CALFSF	30	.20000	2.2000	.84000	.50556	60.185	.700
.C2 LINK	30	1.3307	1.8670	1.4981	.12419	8.290	1.469
.C3 LINK	30	.50233	.81767	.70342	.64240 -1	9.133	.715
.C4 LINK	30	.56133	.79600	.67847	.51151 -1	7.539	.672
.C5 LINK	30	.54933	.77800	.66628	.53809 -1	8.076	.663
.C6 LINK	30	.55067	.76067	.67459	.48450 -1	7.182	.674
.C7 LINK	21	.64367	.81367	.73202	.48751 -1	6.660	.721
.TOTLENG	21	4.4873	5.7013	4.9720	.31685	6.373	4.952

TABLE B.9 ANTHROPOMETRY BY SEX AND AGE MALES 62-74

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
WT(KG)	27	50.682	89.545	72.904	9.4493	12.961	72.727
WT(LB)	27	111.50	197.00	160.59	20.788	12.961	160.000
STATURE	27	152.00	184.20	171.33	7.0631	4.122	169.800
PONDINOX	27	11.450	13.692	12.451	.50150	4.028	12.465
C7HT	27	129.70	159.50	146.81	6.2253	4.240	146.800
CHNKINT	27	130.10	160.50	147.36	6.7648	4.591	146.000
ERSITHT	27	78.900	96.500	88.781	4.0790	4.594	88.400
SITC7HT	27	57.900	72.400	65.136	3.4950	5.361	65.100
RTACP	27	50.300	65.700	58.189	3.6524	6.277	58.200
LTACP	27	48.500	63.700	58.330	3.7293	6.393	58.800
LTTRAG	27	66.900	83.000	75.578	4.2996	5.689	75.700
RTTRAG	27	65.700	83.300	75.248	4.1474	5.512	75.400
NASRTDEP	27	66.900	87.200	77.363	4.4624	5.768	77.000
.LTEYE	27	65.700	86.000	76.278	4.5083	5.910	75.800
.SUPSTREN	27	43.600	63.500	56.956	3.5279	6.194	57.400
.BIACRBR	27	35.500	42.700	38.970	1.8872	4.843	38.800
.BIDELT	27	40.300	47.900	44.952	2.1169	4.709	45.400
.LATNKBR	27	9.7000	12.300	11.059	.77473	7.005	11.100
.APNKBR	27	10.600	14.300	12.600	.88839	7.051	12.500
.ANTNKLG	27	6.7000	12.100	8.8519	1.3351	15.083	8.800
.POSTNKLG	27	7.8000	15.200	10.107	1.8491	18.295	9.800
.SLMPSIT	27	77.600	96.000	86.600	4.6438	5.362	86.600
.SLLTEYE	27	63.500	85.300	74.070	5.3587	7.235	73.900
.SUPNKCIR	27	36.900	48.500	41.407	2.6332	6.359	41.100
.INFNKCIR	27	37.200	46.200	41.096	2.2664	5.515	41.100
.HEADCIR	27	54.500	60.800	57.926	1.6052	2.776	57.900
.HEADFLPS	27	63.500	70.500	67.074	1.7386	2.592	67.200
.HEADBR	27	14.800	16.800	15.685	.56412	3.537	15.600

.HEADLG	27	17.300	21.000	19.170	.75642	3.946	19.300
.HEADHT	27	10.900	14.200	12.526	.77390	6.178	12.600
.SAGARC	27	31.600	39.100	35.174	1.6195	4.604	35.000
.CORARC	27	32.400	36.700	34.378	1.1683	3.398	34.600
.BITRGDI	27	13.300	15.400	14.304	.61047	4.268	14.300
.MINERTDI	27	9.5000	11.700	10.639	.47583	4.452	10.600
.MINERTAR	27	11.000	15.600	12.952	.88377	6.824	12.900
.BITRGMEA	27	28.400	33.000	30.537	1.0955	3.587	30.800
.BITRGINA	27	26.100	30.500	28.219	1.2270	4.348	28.200
.POSTARC	27	25.200	29.500	27.796	1.1551	4.156	27.900
.SITKNEE	27	44.400	57.600	52.007	2.7614	5.310	51.800
.KNEEMAX	27	46.700	59.300	53.985	2.7297	5.056	53.700
.PTILACSP	27	20.400	26.000	23.048	1.4086	6.112	23.000
.HIPBR	27	30.800	41.900	36.863	2.4773	6.720	36.300
.BICELCIR	27	27.000	35.900	31.344	2.2469	7.169	31.600
.CALFCIR	27	29.800	38.500	34.822	2.2728	6.527	35.000
.FEMDIA	27	8.6000	11.700	10.037	.73649	7.338	10.000
.HUMDIA	27	6.1000	8.2000	6.9407	.50631	7.295	6.800
.TRICEPSF	27	.20000	2.3000	.84815	.48546	57.237	.700
SUBSCPSF	27	.80000	2.5000	1.4037	.46532	33.150	1.300
SUPILSF	27	.50000	2.6000	1.3593	.45679	33.606	1.200
CALFSF	27	.20000	1.0000	.49630	.19510	39.311	.400
C2 LINK	25	1.2947	1.7917	1.5245	.11982	7.743	1.558
C3 LINK	25	.57133	.80233	.69989	.57983 -1	8.285	.709
C4 LINK	25	.53667	.77133	.69156	.58016 -1	8.389	.695
C5 LINK	25	.53167	.78500	.65613	.66065 -1	10.069	.637
C6 LINK	25	.55000	.77167	.63631	.48439 -1	7.613	.622
C7 LINK	19	.54300	.85533	.70844	.75992 -1	10.727	.722
TOTLENG	19	4.1393	5.6153	4.8990	.36178	7.385	4.916

TABLE B.10 ANTHROPOMETRY BY SEX, AGE AND STATURE FEMALES 18-24 1-20%11e

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
WT(KG)	10	45.909	63.636	52.909	5.6110	10.605
WT(LB)	10	101.00	140.00	116.40	12.344	10.605
STATURE	10	144.80	157.60	153.54	4.0465	2.635
PONDINDX	10	11.906	12.896	12.402	.28684	2.313
C7HT	10	122.90	134.00	130.47	3.6749	2.817
CHNKINT	10	123.80	135.90	131.77	3.7205	2.824
ERSITHT	10	76.000	85.700	82.140	3.0064	3.660
SITC7HT	10	53.900	62.300	58.930	2.6700	4.531
RTACR	10	48.300	55.700	52.630	2.5184	4.785
LTACR	10	48.800	57.200	53.180	2.6195	4.926
LTTRAG	10	63.000	73.100	69.510	3.1003	4.460
RTTRAG	10	63.100	72.800	68.940	2.9949	4.344
NASRTOEP	10	65.500	75.700	71.030	3.6170	5.092
LTEYE	10	64.500	73.900	70.020	3.2910	4.700
.SUPSTREN	10	47.000	55.600	51.950	2.7432	5.280
.BIACRBR	10	31.000	37.600	34.170	2.1019	6.151
BIDELT	10	37.000	43.400	39.740	2.0662	5.199
.LATNKBR	10	8.4000	10.800	9.4500	.77639	8.216
.APNKBR	10	8.0000	10.600	9.2100	.74304	8.068
.ANTNKLG	10	6.0000	9.4000	7.6900	1.3093	17.026
.POSTNKLG	10	9.4000	12.100	10.210	.91585	8.970
.SLMPSIT	10	73.300	84.700	79.900	3.1774	3.977
.SLLTEYE	10	62.700	73.900	68.770	3.3496	4.871
.SUPNKCIR	10	29.800	35.700	31.720	1.9171	6.044
.INFNKCIR	10	33.400	39.900	35.680	2.1837	6.120
.HEADCIR	10	53.700	58.000	55.150	1.3632	2.472
.HEADELPS	10	61.000	66.200	63.360	1.6153	2.549
.HEADBR	10	13.700	15.300	14.420	.48717	3.378

.HEADLG	10	17.100	18.900	17.860	.55418	3.103
.HEAOHT	10	11.300	12.700	12.130	.48086	3.964
.SAGARC	10	34.000	36.500	34.950	.97211	2.781
.COPARC	10	31.800	34.200	33.210	.90609	2.728
.BITPGOI	10	12.400	13.300	12.870	.24060	1.869
.MINFRTDI	10	9.6000	11.400	10.180	.54324	5.336
.MINFRTAR	10	11.600	13.800	12.350	.73974	5.990
.BITRGMEA	10	27.600	29.400	28.610	.64196	2.244
.BITRGINA	10	25.100	29.800	26.770	1.3417	5.012
.POSTARC	10	24.000	29.800	25.820	1.7738	6.870
.SITKNEE	10	42.300	48.100	45.400	1.7436	3.840
.KNEEMAX	10	45.200	50.100	47.690	1.4510	3.043
.RTILACSP	10	18.900	23.200	21.380	1.2044	5.633
.HIPBR	10	33.700	39.400	36.860	1.9352	5.250
.BICFLCIR	10	25.200	29.800	26.790	1.3626	5.086
.CALFCIR	10	31.300	35.600	33.670	1.5188	4.511
.FEMDIA	10	8.3000	9.8000	9.0400	.41150	4.552
.HUMDIA	10	5.6000	9.1000	6.7000	1.5283	22.810
.TRICEPSF	10	1.1000	2.5000	1.8200	.50067	27.509
.SUBSCPSF	10	1.0000	3.2000	1.8500	.76775	41.500
.SUPILSF	10	.50000	3.4000	1.4400	.81268	56.436
.CALFSF	10	.10000	3.5000	1.8600	1.1007	59.178
.C2 LINK	10	1.1660	1.3860	1.2709	.85291 -1	6.711
.C3 LINK	10	.54200	.64967	.60143	.35805 -1	5.953
.C4 LINK	10	.47967	.66133	.58827	.62400 -1	10.607
.C5 LINK	10	.55000	.66100	.59663	.34848 -1	5.841
.C6 LINK	10	.48667	.63267	.58187	.42513 -1	7.306
.C7 LINK	10	.50367	.71433	.61930	.58465 -1	9.441
.TOTLENG	10	3.8913	4.5547	4.2584	.21990	5.164

TABLE B.11 ANTHROPOMETRY BY SEX, AGE ANO STATURE FEMALES 18-24 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STO DEV	COEF VAR
.WT(KG)	10	50.000	72.273	60.000	7.0516	11.753
.WT(LB)	10	110.00	159.00	132.00	15.513	11.753
.STATURE	10	158.20	164.40	161.52	1.7409	1.078
.PONDINOX	10	11.760	13.395	12.524	.47773	3.814
.C7HT	10	136.50	139.20	137.77	.96730	.702
.CHNKINT	10	136.90	141.50	138.90	1.6344	1.177
.ERSITHT	10	83.000	87.800	85.240	1.5869	1.862
.SITC7HT	10	60.500	62.600	61.410	.79505	1.295
.RTACR	10	52.000	56.400	54.220	1.6383	3.022
.LTACR	10	51.000	56.500	54.300	1.9125	3.522
.LTTRAG	10	69.400	74.200	72.030	1.7166	2.383
.RTTRAG	10	69.600	74.400	72.120	1.6240	2.252
.NASRTDEP	10	71.800	77.300	74.470	1.6104	2.163
.LTEYE	10	70.700	76.500	73.120	1.8624	2.547
.SUPSTREN	10	51.900	55.300	54.070	1.1156	2.063
.BIACRBR	10	31.400	37.500	35.520	1.7587	4.951
.BIOELT	10	38.200	45.100	40.950	1.8603	4.543
.LATNKBR	10	9.3000	10.800	9.9500	.46963	4.720
.APNKBR	10	8.4000	9.8000	9.3000	.46667	5.018
.ANTNKLG	10	6.5000	9.9000	8.2600	.97205	11.768
.POSTNKLG	10	6.7000	12.700	10.180	1.8023	17.705
.SLMPSIT	10	79.900	84.800	81.980	1.5676	1.912
.SLLTEYE	10	68.500	72.900	70.320	1.5985	2.273
.SUPNKCIR	10	30.800	34.400	32.640	1.2607	3.862
.INFNKCIR	10	32.500	40.000	36.570	1.9488	5.329
.HEADCIR	10	53.000	59.000	55.510	1.8651	3.360
.HEADELPS	10	61.500	67.200	64.050	1.8069	2.821
.HEADBR	10	14.100	15.300	14.580	.31198	2.140

.HEAOLG	10	16.400	18.800	17.810	.74454	4.180
.HEADHT	10	11.600	13.400	12.290	.61364	4.993
.SAGARC	10	34.000	38.400	35.240	1.4721	4.177
.CORARC	10	32.500	37.400	33.870	1.6439	4.953
.BITRGOI	10	12.300	13.500	13.020	.40222	3.089
.MINFRTOI	10	9.8000	11.200	10.330	.41647	4.032
.MINFRTAR	10	11.600	13.500	12.500	.67165	5.373
.BITRGMFA	10	27.300	30.800	28.860	1.0276	3.561
.BITRGINA	10	24.600	28.400	26.790	1.3279	4.957
.POSTARC	10	23.800	27.800	25.810	1.3008	5.040
.SITKNEE	10	47.700	49.400	48.610	.53009	1.091
.KNEEMAX	10	49.100	52.000	50.830	.87439	1.720
.RTILACSP	10	19.800	22.500	21.090	.89125	4.226
.HIPBR	10	34.200	42.300	38.400	2.3930	6.232
.BICFLCIR	10	24.600	30.900	27.570	1.9293	6.998
.CALFCIR	10	32.100	41.400	35.870	2.8810	8.032
.FEMDIA	10	8.4000	10.200	9.4700	.52292	5.522
.HUMDIA	10	5.3000	6.9000	6.0300	.59638	9.890
.TRICEPSF	10	.90000	3.6000	1.8200	.73454	40.360
.SUBSCPSF	10	.90000	2.0000	1.5000	.37118	24.746
.SUPILSF	10	.70000	2.4000	1.3700	.64987	47.436
.CALFSF	10	.20000	3.1000	1.4600	.92880	63.616
.C2 LINK	10	1.2437	1.6860	1.3735	.12098	8.808
.C3 LINK	10	.51000	.75900	.63747	.72462 -1	11.367
.C4 LINK	10	.55367	.80067	.63823	.71966 -1	11.276
.C5 LINK	10	.50600	.70400	.60463	.61231 -1	10.127
.C6 LINK	10	.54667	.79200	.62597	.67941 -1	10.854
.C7 LINK	10	.59500	.81433	.66797	.62869 -1	9.412
.TOTLENG	10	4.0067	5.5560	4.5478	.42548	9.356

TABLE B.12 ANTHRDPOMETRY BY SEX, AGE AND STATURE FEMALES 18-24 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	10	56.364	81.364	62.545	7.5832	12.124
.WT(LB)	10	124.00	179.00	137.60	16.683	12.124
.STATURE	10	166.50	184.00	172.99	4.6734	2.702
.PONOINOX	10	12.437	13.626	13.222	.41320	3.125
.C7HT	10	140.40	159.00	148.03	5.0104	3.385
.CHNKINT	10	138.00	160.90	149.08	6.2396	4.185
.ERSITHT	10	85.900	91.300	89.610	1.5162	1.692
.SITC7HT	10	62.400	66.200	64.620	1.3935	2.156
.RTACR	10	55.000	60.700	57.960	1.9518	3.367
.LTACR	10	55.400	60.300	57.990	1.5495	2.672
.LTTRAG	10	72.600	78.700	76.330	1.7276	2.263
.RTTRAG	10	72.500	79.000	76.400	1.7269	2.260
.NASRTOEP	10	74.500	79.800	78.240	1.4946	1.910
.LTEYE	10	73.200	78.700	77.170	1.5528	2.012
.SUPSTREN	10	53.900	58.900	56.940	1.3525	2.375
.BIACRBR	10	35.100	39.500	36.730	1.3081	3.561
.BIDELT	.0	40.400	45.600	42.170	1.7036	4.040
.LATNKBR	10	9.5000	10.100	9.8700	.20575	2.085
.APNKBR	10	8.9000	9.9000	9.4400	.38930	4.124
.ANTNKLG	10	8.1000	11.700	9.7500	1.1287	11.576
.POSTNKLG	10	7.9000	12.900	10.800	1.8756	17.366
.SLMPSIT	10	80.600	89.500	86.570	2.5738	2.973
.SLLTEYE	10	69.500	78.700	74.720	2.5703	3.440
.SUPNKCIP	10	30.700	33.200	31.970	.96038	3.004
.INFNKCIR	10	33.000	37.100	35.240	1.3209	3.748
.HEADCIR	10	52.400	58.400	55.780	.9949	3.576
.HEADELPS	10	60.800	66.700	64.030	1.8148	2.834
.HEADBR	10	14.300	15.600	14.900	.43970	2.951

.HEADLG	10	16.700	18.400	17.710	.65226	3.683
.HEADHT	10	10.900	12.600	12.060	.53166	4.408
.SAGARC	10	32.500	37.700	35.140	1.8620	5.299
.CORARC	10	31.600	36.100	33.940	1.3201	3.890
.BITRGOI	10	13.100	14.000	13.420	.29740	2.216
.MINFRTO	10	9.4000	11.700	10.430	.67338	6.456
.MINFRTAR	10	11.200	13.600	12.330	.69450	5.633
.BITRGMFA	10	26.600	31.000	28.860	1.2703	4.402
.BITRGINA	10	24.800	29.500	27.210	1.3428	4.935
.POSTARC	10	24.000	29.000	26.640	1.6998	6.381
.SITKNEE	10	49.900	58.100	52.290	2.3516	4.497
.KNEEMAX	10	51.900	61.300	54.430	2.7072	4.974
.RTILACSP	10	21.400	25.500	22.490	1.2270	5.456
.HIPBR	10	33.700	40.700	37.030	2.1705	5.862
.BICFLCIR	10	24.500	30.000	27.160	2.1686	7.984
.CALFCIR	10	31.900	40.600	34.520	2.4571	7.118
.FEMDIA	10	9.0000	10.800	9.7900	.51737	5.285
.HUMDIA	10	6.2000	8.8000	6.8500	.74870	10.930
.TRICEPSF	10	.90000	2.5000	1.8000	.53333	29.630
.SUBSCPSF	10	.70000	2.3000	1.3200	.47796	36.209
.SUPILSF	10	.60000	2.3000	1.2700	.50343	39.640
.CALFSF	10	1.1000	2.7000	1.6600	.51897	31.263
.C2 LINK	10	1.3307	1.5673	1.4395	.79849	5.547
.C3 LINK	10	.54100	.78533	.65880	.64241 -1	9.751
.C4 LINK	10	.56600	.75700	.65110	.58095 -1	8.923
.C5 LINK	10	.55600	.79700	.64013	.81860 -1	12.788
.C6 LINK	10	.62033	.69500	.65527	.26439 -1	4.035
.C7 LINK	9	.56200	.78133	.68989	.62141 -1	9.007
.TOTLENG	9	4.1983	5.3073	4.7102	.32115	6.818

TABLE B.13 ANTHROPOMETRY BY SEX, AGE AND STATURE FEMALES 35-44 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	10	44.091	59.318	52.932	5.6147	10.607
.WT(LB)	10	97.000	130.50	116.45	12.352	10.607
.STATURE	10	148.40	157.20	154.23	3.1163	2.021
.PONDINDX	10	11.535	13.403	12.465	.51109	4.100
.C7HT	10	125.30	134.10	130.31	3.0175	2.316
.CHNKINT	10	126.80	137.60	132.46	3.3948	2.563
.ERSITHT	10	79.600	85.200	82.760	1.8179	2.197
.SITC7HT	10	57.000	61.500	59.340	1.3134	2.213
.RTACR	10	50.300	55.400	53.450	1.7784	3.327
.LTACR	10	50.700	56.800	53.970	1.6540	3.065
.LTTRAG	10	67.500	72.700	70.070	1.6820	2.400
.RTTRAG	10	66.700	72.800	69.990	1.9564	2.795
.NASRTOEP	10	69.200	74.300	72.510	1.7540	2.419
.LTEYE	10	68.000	73.200	71.360	1.7684	2.478
.SUPSTREN	10	49.500	55.400	52.730	1.8809	3.567
.BIACRBR	10	32.900	42.900	35.220	2.8224	8.014
.BIDELT	10	37.000	44.000	39.690	2.1074	5.310
.LATNKBR	10	9.0000	10.300	9.6400	.47656	4.944
.APNKBR	10	9.0000	10.400	9.5700	.47387	4.952
.ANTNKLG	10	6.5000	11.300	8.5200	1.4950	17.547
.POSTNKLG	10	9.5000	12.500	10.450	1.0102	9.667
.SLMPSIT	10	78.300	83.000	80.310	1.7052	2.123
.SLLTEYE	10	64.900	71.500	69.090	2.1100	3.054
.SUPNKCIR	10	30.300	34.700	31.970	1.3695	4.284
.INFNKCIR	10	31.900	37.500	34.650	1.7011	4.910
.HEADCIR	10	52.100	57.100	55.220	1.5569	2.819
.HEADELPS	10	60.200	65.500	63.180	1.6144	2.555
.HEADBR	10	13.700	15.300	14.730	.45717	3.104

.HEADLG	10	16.700	19.000	17.890	.80062	4.475
.HEADHT	10	10.200	13.400	12.010	.87490	7.285
.SAGARC	10	30.400	39.300	34.800	2.8414	8.165
.CORARC	10	29.200	38.500	33.800	2.4308	7.192
.BITRGDI	10	11.800	14.000	12.910	.65566	5.079
.MINFRTDI	10	9.3000	10.900	10.320	.49844	4.830
.MINFRTAF	10	10.500	15.400	12.370	1.2711	10.276
.BITRGMFA	10	26.400	31.000	28.480	1.3415	4.710
.BITRGINA	10	24.400	27.400	25.870	1.0605	4.099
.POSTARC	10	22.300	25.500	24.070	.95574	3.971
.SITKNEE	10	43.500	46.300	45.050	1.0124	2.247
.KNEEMAX	10	45.200	48.700	47.330	1.1490	2.428
.RTILACSP	10	19.700	22.300	20.900	.96379	4.611
.HIPBR	10	33.500	39.600	36.070	2.4572	6.812
.BICFLCIR	10	24.800	32.600	28.260	2.7714	9.807
.CALFCIR	10	30.000	36.500	33.580	1.8820	5.604
.FEMDIA	10	8.0000	11.200	9.3100	.93862	10.082
.HUMDIA	10	5.5000	8.7000	6.4100	.89499	13.962
.TRICEPSF	10	.80000	2.5000	1.7600	.64670	36.744
.SUBSCPSF	10	.70000	2.6000	1.4400	.64670	44.910
.SUPILSF	10	.40000	2.3000	1.2300	.62725	50.996
.CALFSF	10	.10000	2.8000	1.3400	.86049	64.216
.C2 LINK	10	1.2563	1.4090	1.3215	.44260 -1	3.349
.C3 LINK	10	.54133	.64133	.59113	.33966 -1	5.746
.C4 LINK	10	.54267	.65133	.58703	.40329 -1	6.870
.C5 LINK	10	.52633	.68400	.59663	.56543 -1	9.477
.C6 LINK	10	.53600	.66033	.58907	.45303 -1	7.691
.C7 LINK	10	.60433	.72833	.64787	.42809 -1	6.608
.TOTLENG	10	4.0963	4.6517	4.3332	.21689	5.005

TABLE B.14 ANTHROPOMETRY BY SEX, AGE ANO STATURE FEMALES 35-44 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STO OEV	COEF VAR
.WT(KG)	9	47.273	69.091	57.374	7.0803	12.341
.WT(LB)	9	104.00	152.00	126.22	15.577	12.341
.STATURE	9	157.70	164.40	161.17	2.1036	1.305
.PONOINDX	9	11.842	13.481	12.688	.51153	4.032
.C7HT	9	133.80	139.50	136.98	1.8397	1.343
.CHNKINT	9	135.70	142.10	139.21	2.2071	1.585
.ERSITHT	9	82.100	87.900	84.944	1.7889	2.106
.SITC7HT	9	58.900	63.600	61.244	1.5915	2.599
.RTACR	9	51.600	58.800	55.689	2.5295	4.542
.LTACR	9	52.000	59.700	55.689	2.5790	4.631
.LTTRAG	9	69.600	76.300	72.367	1.9474	2.691
.RTTRAG	9	69.200	75.900	72.278	1.9766	2.735
.NASRTOER	9	72.200	76.900	74.411	1.3119	1.763
.LTEYE	9	71.700	76.200	73.511	1.2722	1.731
.SUPSTREN	9	51.800	57.000	54.022	1.8109	3.352
.BIACRBR	9	32.500	37.300	35.322	1.5164	4.293
.BIDELT	9	34.000	46.100	40.033	3.6861	9.208
.LATNKBR	9	9.0000	10.600	9.6444	.56372	5.845
.APNKBR	9	8.8000	10.800	9.6111	.64700	6.732
.ANTNKLG	9	6.6000	11.000	9.1556	1.4406	15.735
.POSTNKLG	9	9.0000	12.100	10.200	1.0210	10.010
.SLMPSIT	9	79.800	85.200	82.356	1.5059	1.829
.SLLTEYE	9	69.100	74.400	70.878	1.7130	2.417
.SUPNKCIR	9	30.000	34.500	32.200	1.8028	5.599
.INFNKCIR	9	31.300	39.500	35.944	2.4709	6.874
.HEADCIR	9	52.500	57.100	55.778	1.4114	2.530
.HEADELPS	9	60.500	65.300	63.600	1.5207	2.391
.HEAOBR	9	13.800	15.600	14.800	.55678	3.762

.HEADLG	9	16.700	19.100	17.944	.75019	4.181
.HEADHT	9	11.100	13.400	12.111	.73390	6.060
.SAGARC	9	33.000	36.800	34.811	1.3541	3.890
.CORARC	9	32.300	34.600	33.567	.84113	2.506
.BITRGDI	9	12.700	14.400	13.344	.49018	3.673
.MINFRTDI	9	9.8000	11.000	10.333	.36056	3.489
.MINFRTAR	9	11.000	13.800	12.267	.81854	6.673
.BITRGMFA	9	28.000	30.000	28.911	.62539	2.163
.BITRGINA	9	25.000	29.300	26.967	1.4045	5.208
.POSTARC	9	23.600	27.500	25.200	1.4133	5.608
.SITKNEE	9	46.000	48.800	47.556	.87337	1.837
.KNEEMAX	9	48.600	51.100	50.011	.96882	1.937
.RTILACSP	9	20.100	22.700	21.389	.87242	4.079
.HIPBR	9	33.600	39.800	37.433	2.3596	6.303
.BICFLCIR	9	24.900	33.000	27.711	2.8812	10.397
.CALFCIR	9	30.000	38.200	33.689	3.0424	9.031
.FEMDIA	9	8.9000	9.9000	9.4333	.35707	3.785
.HUMDIA	9	5.4000	8.9000	6.4889	.98036	15.108
.TRICEPSF	9	.80000	2.5000	1.6778	.56519	33.687
.SUBSCPSF	9	.60000	2.8000	1.3778	.79338	57.584
.SUPILSF	9	.50000	2.4000	1.2444	.68394	54.960
.CALFSF	9	.10000	2.2000	1.0222	.81972	80.193
.C2 LINK	9	1.3157	1.4543	1.3929	.48828 -1	3.506
.C3 LINK	9	.54900	.66700	.63715	.36760 -1	5.769
.C4 LINK	9	.56800	.66100	.62170	.33531 -1	5.393
.C5 LINK	9	.54033	.64733	.60070	.37064 -1	6.170
.C6 LINK	9	.54067	.69300	.61011	.41620 -1	6.822
.C7 LINK	9	.58633	.76100	.66870	.48485 -1	7.251
.TOTLENG	9	4.2273	4.6840	4.5312	.15005	3.312

TABLE B.15 ANTHROPOMETRY BY SEX, AGE AND STATURE FEMALES 35-44 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	11	51.136	101.14	67.066	17.665	26.339
.WT(LB)	11	112.50	222.50	147.55	38.862	26.339
.STATURE	11	164.10	172.90	168.19	2.4664	1.466
.PONDINDX	11	10.789	13.580	12.680	.95253	7.512
.C7HT	11	138.10	146.10	143.36	2.6082	1.819
.CHNKINT	11	138.20	149.60	144.18	3.4058	2.362
.ERSITHT	11	85.700	91.500	88.118	1.8170	2.062
.SITC7HT	11	59.700	66.100	63.918	1.9838	3.104
.RTACR	11	54.600	60.800	57.091	1.6574	2.903
.LTACR	11	53.400	61.600	57.436	2.1500	3.743
.LTTRAG	11	72.500	78.200	74.691	1.6177	2.166
.RTTRAG	11	72.100	77.500	74.436	1.4009	1.882
.NASRTOEP	11	75.300	79.800	76.482	1.4105	1.844
.LTEYE	11	74.200	78.600	75.436	1.3193	1.749
.SUPSTREN	11	53.200	57.500	55.645	1.2160	2.185
.BIACRBR	11	34.700	39.600	36.573	1.5749	4.306
.BIDELT	11	38.700	48.800	42.327	3.0473	7.199
.LATNKBR	11	9.4000	11.000	10.191	.47844	4.695
.APNKBR	11	9.1000	12.200	9.8636	.91353	9.262
.ANTNKLG	11	4.6000	11.400	9.1182	1.8846	20.668
.POSTNKLG	11	8.1000	11.100	9.7636	.87667	8.979
.SLMPSIT	11	83.600	90.000	85.627	1.8412	2.150
.SLLTEYE	11	69.800	74.800	72.873	1.5736	2.159
.SUPNKCIR	11	31.300	40.500	33.555	2.6021	7.755
.INFNKCIR	11	33.400	44.200	36.818	2.7842	7.562
.HEADCIR	11	53.000	58.500	56.464	1.5762	2.792
.HEADELPS	11	61.000	67.000	64.200	1.6395	2.554
.HEADBP	11	14.300	16.300	15.082	.59635	3.954

.HEADLG	11	16.300	19.000	17.982	.84002	4.672
.HEADHT	11	12.100	13.500	12.682	.39451	3.111
.SAGARC	11	33.600	38.100	36.545	1.5514	4.245
.CORARC	11	32.400	36.700	34.400	1.2450	3.619
.BITRGDI	11	12.900	14.300	13.518	.49964	3.696
.MINFRTDI	11	9.8000	11.600	10.591	.50290	4.748
.MINFRTAR	11	11.400	14.000	12.445	.79920	6.422
.BITRGMFA	11	28.000	31.700	29.191	1.0445	3.578
.BITRGINA	11	25.500	29.800	27.173	1.3756	5.062
.POSTARC	11	24.100	28.600	26.164	1.4369	5.492
.SITKNEE	11	49.000	51.500	50.182	.80971	1.614
.KNEEMAX	11	50.800	54.600	52.691	1.0329	1.960
.RTILACSP	11	21.100	24.100	22.427	.93176	4.155
.HIPBR	11	34.000	55.000	40.782	6.5909	16.161
.BICFLCIR	11	24.800	38.700	29.618	4.3676	14.746
.CALFCIR	11	30.400	43.200	35.427	3.8846	10.965
.FEMDIA	11	8.8000	12.800	10.064	1.2209	12.132
.HUMDIA	11	5.6000	8.8000	6.6727	.96963	14.531
.TRICEPSF	11	1.1000	3.6000	2.0182	.73596	36.466
.SUBSCPSF	11	.80000	4.2000	1.8273	1.3100	71.693
.SUPILSF	11	.60000	3.0000	1.4455	.81653	56.490
.CALFSF	11	.10000	2.1000	1.3364	.81397	60.909
.C2 LINK	11	1.1567	1.5410	1.4206	.10849	7.636
.C3 LINK	11	.52800	.67900	.63176	.47544 -1	7.526
.C4 LINK	11	.55033	.68867	.64303	.39210 -1	6.098
.C5 LINK	11	.53267	.69667	.63106	.47481 -1	7.524
.C6 LINK	11	.50067	.68667	.63127	.48827 -1	7.735
.C7 LINK	11	.53767	.74433	.67921	.56110 -1	8.261
.TOTLENG	11	3.8060	4.8977	4.6370	.31239	6.737

TABLE B.16 ANTHROPOMETRY BY SEX, AGE AND STATURE FEMALES 62-74 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	10	50.909	80.682	61.000	10.027	16.438
.WT(LB)	10	112.00	177.50	134.20	22.060	16.438
STATURE	10	146.30	153.30	151.02	2.3021	1.524
PONDINOX	10	10.559	12.441	11.670	.58144	4.982
C7HT	10	123.20	131.30	128.78	2.5525	1.982
.CHNKINT	10	124.90	133.50	129.66	2.6484	2.043
ERSITHT	10	76.500	81.600	79.670	1.7231	2.163
.SITC7HT	10	54.900	61.400	58.210	2.0588	3.537
.RTACR	10	48.900	55.600	51.380	2.2439	4.367
.LTACR	10	48.900	54.500	51.720	2.1735	4.202
.LTTRAG	10	62.900	69.800	67.000	1.8944	2.828
.RTTRAG	10	62.800	68.200	66.480	1.7422	2.621
.NASRTDEP	10	66.700	71.300	69.540	1.6661	2.396
.LTEYE	10	65.400	70.900	68.440	1.6827	2.459
.SUPSTREN	10	47.600	53.500	50.680	1.8648	3.679
.BIACRBR	10	32.800	42.900	35.220	2.8557	8.108
.BIDELT	10	37.900	43.900	40.220	1.7002	4.227
.LATNKBR	10	8.5000	11.100	9.8800	.80250	8.122
.APNKBR	10	9.4000	12.300	10.620	.79415	7.478
.ANTNKLG	10	7.2000	10.500	8.6900	1.0785	12.411
.POSTNKLG	10	5.8000	12.200	9.2100	1.3681	20.284
.SLMPSIT	10	75.100	81.000	77.780	2.0010	2.573
.SLLTEYE	10	62.900	71.700	66.660	2.7273	4.091
.SUPNKCIR	10	21.000	44.800	35.430	3.6468	10.357
.INFNKCIR	10	32.100	42.100	36.310	3.1388	8.644
.HEADCIR	10	51.800	58.100	54.340	1.8100	3.331
.HEADFLPS	10	59.000	66.100	62.220	1.8978	3.050
.HEADBR	10	14.100	15.200	14.670	.36225	2.469

.HEADLG	10	16.500	18.300	17.500	.53635	3.049
.HEADHT	10	11.400	12.700	11.970	.50343	4.206
.SAGARC	10	30.400	36.300	33.290	2.0469	6.149
.CORARC	10	31.200	35.500	33.520	1.2173	3.632
.BITRGDI	10	12.100	14.200	13.030	.73794	5.663
.MINFRTDI	10	9.7000	10.900	10.390	.43063	4.145
.MINFRTAR	10	11.500	13.500	12.460	.71523	5.740
.BITRGMEA	10	27.000	31.000	28.720	1.2770	4.445
.BITRGINA	10	24.200	29.200	26.730	1.5924	5.957
.POSTARC	10	23.000	27.300	24.960	1.3484	5.402
.SITKNEE	10	43.000	47.500	44.710	1.4510	3.245
.KNEEMAX	10	44.500	48.900	46.630	1.6634	3.567
.PTILACSP	10	19.400	23.800	21.090	1.2671	6.009
.HIPBR	10	35.200	45.300	39.550	3.8004	9.585
.BICFLCIP	10	27.000	38.800	31.910	4.8525	15.255
.CALFCIP	10	29.700	39.100	33.380	2.8557	8.555
.FEMDIA	10	8.3000	11.200	9.4700	.88826	9.380
.HUMDIA	10	5.8000	6.8000	6.2700	.34335	5.476
.TRICEPSF	10	.30000	3.3000	1.4200	.84953	59.829
.SUBSCPSF	10	1.1000	4.8000	1.8700	1.0791	57.708
.SUPILSF	10	.70000	2.1000	1.3200	.46619	35.317
.CALFSF	10	.10000	1.7000	.57000	.47152	82.723
.C2 LINK	10	1.2000	1.5107	1.3600	.98433 -1	7.238
.C3 LINK	10	.54300	.65700	.58783	.35140 -1	5.978
.C4 LINK	10	.53567	.63167	.58947	.29956 -1	5.082
.C5 LINK	10	.47333	.61133	.56470	.43686 -1	7.736
.C6 LINK	10	.50333	.60733	.56810	.33177 -1	5.840
.C7 LINK	9	.53367	.68733	.63241	.48421 -1	7.657
.TOTLENG	9	3.8160	4.6077	4.2900	.25825	6.020

TABLE B.17 ANTHROPOMETRY BY SEX, AGE AND STATURE FEMALES 62-74 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	10	61.364	71.818	66.705	3.8958	5.840
.WT(LB)	10	135.00	158.00	146.75	8.5708	5.840
.STATURE	10	155.40	159.60	157.44	1.6534	1.050
.PONDINOX	10	11.319	12.191	11.762	.29119	2.476
.C7HT	10	132.00	137.50	134.55	1.9851	1.475
.CHNKINT	10	130.80	137.30	134.38	2.3925	1.780
.ERSITHT	10	79.200	84.500	82.000	1.7776	2.168
.SITC7HT	10	57.900	61.600	59.720	1.1858	1.986
.RTACR	10	49.600	54.900	52.450	1.9733	3.762
.LTACR	10	49.300	55.600	52.970	2.0838	3.934
.LTTRAG	10	67.000	71.800	68.920	1.5164	2.200
.RTTRAG	10	66.600	71.100	68.690	1.4985	2.182
.NASRTOEP	10	69.900	74.600	71.620	1.6123	2.251
.LTEYE	10	69.100	73.600	70.510	1.5765	2.236
.SUPSTREN	10	50.900	54.400	52.500	1.2211	2.326
.BIACRBR	10	34.300	43.200	36.320	2.5995	7.157
.BIDELT	10	39.900	43.700	41.560	1.3640	3.282
.LATNKBR	10	9.3000	11.300	10.130	.59824	5.906
.APNKBR	10	9.7000	12.000	10.700	.76594	7.158
.ANTNKLG	10	7.3000	9.9000	8.4200	.77143	9.162
.POSTNKLG	10	5.7000	11.500	8.3000	1.9624	23.644
.SLMPSIT	10	77.500	81.600	80.070	1.2517	1.563
.SLLTEYE	10	67.100	72.600	69.020	1.6844	2.441
.SUPNKCIR	10	32.300	37.300	35.440	1.4439	4.074
.INFNKCIR	10	34.600	40.500	37.380	1.5725	4.207
.HEADCIR	10	53.800	59.500	56.710	1.9740	3.481
.HEADELPS	10	62.300	69.600	65.220	2.1322	3.269
.HEADBR	10	14.400	16.400	15.140	.59666	3.941

.HEADLG	10	16.800	19.100	18.180	.74506	4.099
.HEADHT	10	11.200	13.700	12.410	.89250	7.192
.SAGARC	10	29.700	37.500	35.180	2.3612	6.712
.CORARC	10	31.800	39.200	35.100	2.1715	6.187
.BITRGOI	10	12.700	14.100	13.510	.49542	3.667
.MINFRTDI	10	9.9000	11.300	10.510	.39285	3.738
.MINFRTAR	10	12.100	13.300	12.760	.40332	3.161
.BITRGMFA	10	27.400	31.000	29.590	1.0472	3.539
.BITRGINA	10	25.400	30.200	27.630	1.4561	5.270
.POSTARC	10	22.600	27.500	25.710	1.5758	6.129
.SITKNEE	10	46.600	49.400	47.770	.84334	1.765
.KNEEMAX	10	48.800	51.400	49.950	.83964	1.681
.PTILACSP	10	21.200	24.200	22.210	.95853	4.315
.HIPBR	10	37.300	44.500	40.440	2.2036	5.449
.BICELCIR	10	26.800	35.300	31.200	2.1899	7.019
.CALFCIR	10	33.800	37.400	36.080	1.2309	3.412
.FEMDIA	10	8.6000	10.600	10.110	.66908	6.619
.HUMDIA	10	6.2000	8.8000	6.8200	.79554	11.665
.TRICEPSF	10	.20000	2.2000	1.4200	.73151	51.515
.SUBSCPSF	10	1.7000	3.0000	2.2000	.45947	20.885
.SUPILSF	10	.80000	2.4000	1.6300	.43218	26.514
.CALFSF	10	.10000	1.2000	.45000	.42492	94.426
.C2 LINK	9	1.1593	1.6077	1.3980	.11996	8.581
.C3 LINK	10	.53000	.71000	.60420	.59746 -1	9.888
.C4 LINK	10	.50100	.74333	.57973	.66606 -1	11.489
.C5 LINK	10	.50800	.65700	.56973	.42057 -1	7.382
.C6 LINK	10	.47767	.71067	.55183	.70186 -1	12.719
.C7 LINK	10	.54600	.72333	.63027	.56621 -1	8.984
.TOTLENG	9	3.3773	5.1393	4.3519	.36856	8.469

TABLE 8.18 ANTHROPOMETRY BY SEX, AGE AND STATURE FEMALES 62-74 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	11	50.682	88.864	57.583	14.393	21.297
.WT(LB)	11	111.50	195.50	148.68	31.665	21.297
.STATURE	11	160.70	174.20	166.36	4.5491	2.734
.PONDINDX	11	10.903	13.376	12.469	.80257	6.436
.C7HT	11	137.70	150.00	142.86	4.2695	2.989
.CHNKINT	11	138.50	150.50	143.97	4.1027	2.850
.ERSITHT	11	82.100	93.300	86.136	3.8469	4.466
.SITC7HT	11	59.200	69.600	63.009	3.3192	5.268
.PTACR	11	50.600	61.900	55.791	3.4783	6.235
.LTACR	11	52.000	50.400	55.427	2.7893	5.032
.LTTRAG	11	70.000	80.900	73.20(	3.9428	5.386
.RTTRAG	11	68.900	80.300	72.864	3.8226	5.246
.NASRTOEP	11	71.900	82.700	75.691	3.2706	4.32'
.LTEYE	11	70.800	80.900	74.609	3.2393	4.342
.SUPSTREN	11	52.000	60.400	54.827	2.8601	5.217
.BIACRBR	11	34.400	38.700	36.127	1.2507	3.462
.BIDELT	11	37.600	47.800	41.536	3.0247	7.282
.LATNKBR	11	9.2000	11.500	10.036	.69753	6.950
.APNKBR	11	9.5000	11.500	10.573	.68131	6.444
.ANTNKLG	11	8.5000	10.900	9.5000	.76681	8.072
.POSTNKLG	11	7.9000	11.000	9.1273	1.0326	11.313
.SLMPSIT	11	80.500	91.600	83.782	3.5802	4.273
.SLLTEYE	11	68.900	80.600	72.191	3.2922	4.560
.SUPNKCIR	11	33.200	39.800	35.764	2.6508	7.412
.INFNKCIR	11	33.900	42.400	37.682	2.2565	5.988
.HEADCIR	11	50.500	62.200	56.827	2.7807	4.893
.HEADELPS	11	61.500	72.400	65.845	2.7890	4.236
.HEADBR	11	14.400	16.000	15.136	.46749	3.089

.HEADLG	11	17.400	18.900	18.336	.54639	2.980
.HEAOHT	11	11.600	13.700	12.791	.57351	4.484
.SAGARC	11	33.300	39.500	35.373	1.5576	4.403
.CORARC	11	33.300	36.500	34.945	1.0848	3.104
.BITRGDI	11	12.900	14.200	13.655	.47194	3.456
.MINFRTDI	11	10.000	11.000	10.518	.31247	2.971
.MINFRTAR	11	11.600	15.400	12.882	.99581	7.730
.BITRGMFA	11	29.000	31.200	30.064	.88800	2.954
.BITRGINA	11	25.000	28.200	26.873	1.1714	4.359
.ROSTARC	11	23.300	27.800	25.582	1.4965	5.850
.SITKNEE	11	49.100	54.400	50.645	1.6591	3.276
.KNEEMAX	11	51.000	56.200	52.718	1.5562	2.952
.RTILACSR	11	21.500	24.400	22.655	.96681	4.263
.HIPBR	11	32.100	46.000	40.064	4.9786	12.427
.BICFLCIR	11	24.000	35.900	29.973	4.1132	13.723
.CALFCIR	11	30.300	41.100	34.345	3.9609	11.533
.FEMDIA	11	8.4000	12.000	10.127	1.0140	10.012
.HUMDIA	11	5.4000	7.8000	6.3909	.70065	10.963
.TRICEPSF	11	.50000	3.0000	1.5455	.80295	51.956
.SUBSCPSF	11	.60000	3.4000	1.4091	.81787	58.042
.SURILSF	11	.30000	2.5000	1.1000	.77201	70.183
CALFSF	11	.10000	1.4000	.48182	.49562	102.864
.C2 LINK	11	1.2283	1.8543	1.4879	.15527	10.435
C3 LINK	11	.51367	.87333	.63561	.91022 -1	14.321
.C4 LINK	11	.47967	.92767	.64115	.11874	18.520
C5 LINK	11	.48367	.83867	.60512	.91761 -1	15.164
C6 LINK	11	.48367	.80167	.58591	.88224 -1	15.058
C7 LINK	10	.55067	.80733	.55763	.86027 -1	13.081
TOTLENG	10	3.7417	6.1030	4.6218	.62230	13.464

TABLE B.19 ANTHROPOMETRY BY SEX, AGE AND STATURE MALES 18-24 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	10	50.227	68.182	59.364	6.4173	10.810
.WT(LB)	10	110.50	150.00	130.60	14.118	10.810
.STATURE	10	162.40	167.70	165.36	1.7161	1.038
.PONDINDX	10	12.076	13.639	12.864	.49471	3.846
.C7HT	10	136.30	142.90	140.33	2.1541	1.535
.CHNKINT	10	137.70	144.70	142.28	2.1735	1.528
.ERSITHT	10	85.100	89.900	86.970	1.6083	1.849
.SITC7HT	10	59.600	63.800	62.140	1.3697	2.204
.RTACP	10	53.700	60.500	56.470	2.3847	4.223
.LTACR	10	54.100	62.000	56.730	2.4887	4.387
.LTTRAG	10	70.800	76.400	73.890	1.7891	2.421
.RTTRAG	10	71.800	76.700	73.840	1.7167	2.325
.NASRTDEP	10	72.200	79.600	75.590	2.3053	3.050
.LTEYE	10	70.700	78.700	74.500	2.3561	3.163
.SUPSTREN	10	52.400	58.800	55.080	1.9037	3.456
.BIACRBR	10	35.600	40.900	38.270	1.5413	4.027
.BIDELT	10	39.300	46.300	44.340	2.1603	4.872
.LATNKBR	10	10.000	11.700	10.860	.57774	5.320
.APNKBR	10	9.6000	10.900	10.310	.45326	4.396
.ANTNKLG	10	7.3000	11.600	9.2200	1.4428	15.649
.POSTNKLG	10	7.5000	13.300	10.880	1.5317	14.078
.SLMPSIT	10	80.700	86.900	84.100	1.8779	2.233
.SLLTEYE	10	69.700	76.800	71.950	2.2863	3.178
.SUPNKCIR	10	32.200	37.000	34.650	1.5494	4.471
.INFNKCIR	10	36.700	40.500	38.910	1.5617	4.014
.HEADCIR	10	54.600	58.400	56.630	1.2685	2.240
.HEADELPS	10	61.500	68.500	65.210	2.1620	3.315
.HEADBR	10	14.300	15.300	14.780	.38528	2.607

.HEADLG	10	16.800	22.300	19.010	1.4051	7.391
.HEADHT	10	11.900	13.200	12.450	.45522	3.656
.SAGARC	10	33.500	38.700	35.640	1.5827	4.441
.CORARC	10	32.400	37.400	34.220	1.4006	4.093
.BITRGOI	10	12.100	13.800	13.110	.49989	3.813
.MINFRTDI	9	9.7000	10.700	10.233	.36056	3.523
.MINFRTAR	9	11.400	14.000	12.389	.90753	7.325
.BITRGMFA	10	27.500	30.800	29.150	.94310	3.235
.BITRGINA	10	24.600	29.500	27.250	1.6880	6.195
.POSTARC	10	24.200	28.000	26.320	1.1689	4.441
.SITKNEE	10	47.200	51.500	49.580	1.2444	2.510
.KNEEMAX	10	49.500	53.300	51.640	1.1834	2.292
.RTILACSP	10	20.300	23.300	21.630	.92141	4.260
.HIPBR	10	28.800	36.200	33.310	2.1997	6.604
.BICFLCIR	10	26.100	32.800	28.920	2.1301	7.365
.CALFCIR	10	31.100	38.700	34.850	2.4204	6.945
.FEMOIA	10	8.8000	9.9000	9.2400	.43256	4.681
.HUMOIA	10	5.7000	7.0000	6.5200	.39665	6.084
.TRICEPSF	10	.30000	1.4000	.76000	.40332	53.069
.SUBSCPSF	10	.60000	1.5000	1.0500	.27988	26.655
.SUPILSF	10	.50000	1.8000	.96000	.41952	43.700
.CALFSF	10	.20000	1.8000	.86000	.43767	50.892
.C2 LINK	10	1.3070	1.4920	1.4049	.52550 -1	3.740
.C3 LINK	10	.59800	.74700	.67493	.44313 -1	6.565
.C4 LINK	10	.55067	.70467	.66163	.46180 -1	6.980
.C5 LINK	10	.60833	.70467	.65343	.32037 -1	4.903
.C6 LINK	10	.57200	.71467	.64917	.42142 -1	6.492
.C7 LINK	9	.62600	.77633	.70385	.47641 -1	6.769
.TOTLENG	9	4.3720	5.0413	4.7660	.20828	4.370

TABLE B.20 ANTHROPOMETRY BY SEX, AGE AND STATURE MALES 18-24 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
WT(KG)	10	56.364	86.364	69.591	9.0376	12.987
WT(LB)	10	124.00	190.00	153.10	19.883	12.987
STATURE	10	171.10	176.20	174.18	1.7479	1.003
PONDINOX	10	12.021	13.511	12.861	.49009	3.811
C7HT	10	144.90	151.20	147.79	2.1304	1.442
CHNKINT	10	146.30	152.10	149.81	2.0915	1.396
ERSITHT	10	87.600	94.100	91.450	1.7213	1.882
SITC7HT	10	62.200	68.000	65.380	1.5789	2.415
RTACR	10	55.500	65.700	59.970	3.3410	5.571
LTACR	10	55.700	65.500	60.350	2.9714	4.924
LTTRAG	10	74.800	79.500	77.970	1.4392	1.846
RTTRAG	10	73.500	79.500	77.430	1.6432	2.122
NASRTDEP	10	76.000	84.300	79.860	2.0555	2.574
LTEYE	10	75.400	82.000	78.820	1.7650	2.239
SUPSTREN	10	54.800	60.200	57.320	1.6811	2.933
BIACRBR	10	37.800	42.000	39.580	1.2665	3.200
BIDELT	10	42.800	49.800	46.990	2.4655	5.247
LATNKBR	10	10.800	12.400	11.500	.58119	5.054
APNKBR	10	9.9000	11.900	10.980	.68767	6.263
ANTNKLG	10	8.8000	10.700	9.8200	.66466	6.768
POSTNKLG	10	9.1000	14.700	11.670	1.5420	13.214
SLMPSIT	10	80.800	91.000	87.950	3.2705	3.719
SLLTEYE	10	68.500	78.700	75.160	3.7071	4.932
SUPNKCIR	10	35.000	40.000	37.180	1.6240	4.368
INFNKCIR	10	37.500	44.200	40.780	2.2866	5.607
HEADCIR	10	56.600	58.600	57.570	.76165	1.323
HEADELPS	10	66.000	69.100	67.400	1.1547	1.713
HEADBR	10	14.000	15.600	15.190	.46296	3.048

.HEAOLG	10	17.800	20.000	18.850	.72763	3.860
.HEADHT	10	12.500	13.800	13.110	.43063	3.285
.SAGARC	10	34.400	39.300	37.110	1.4310	3.856
.CORARC	10	33.800	36.500	34.980	1.0315	2.949
.BITRGOI	10	12.900	14.600	13.970	.51865	3.713
.MINFRTOI	10	10.100	11.900	10.540	.52536	4.984
.MINFRTAR	10	11.700	14.000	12.670	.75137	5.930
.BITRGMFA	10	29.200	31.000	30.080	.66131	2.199
.BITRGINA	10	26.400	31.000	28.350	1.2545	4.425
.POSTARC	10	25.800	28.800	27.470	1.0924	3.977
.SITKNEE	10	50.200	53.800	52.720	1.0881	2.064
.KNEEMAX	10	51.700	56.000	54.500	1.2175	2.234
.RTILACSP	10	21.000	25.200	22.410	1.1657	5.202
.HIPBR	9	33.200	37.200	34.967	1.5158	4.335
.BICFLCIR	10	28.000	34.200	31.040	2.5118	8.092
.CALFCIR	10	34.200	39.600	36.610	1.4670	4.007
.FEMDIA	10	8.9000	10.800	9.8100	.59151	6.030
.HUMDIA	10	6.6000	7.4000	7.0400	.31340	4.452
.TRICEPSF	10	.40000	1.7000	1.0300	.40838	39.649
.SUBSCPSF	10	.70000	2.2000	1.2600	.46476	36.886
.SUPILSF	10	.50000	2.3000	1.2800	.54324	42.441
.CALFSF	10	.50000	1.7000	1.0700	.40014	37.396
.C2 LINK	10	1.4127	1.6047	1.4978	.57987 -1	3.871
.C3 LINK	10	.58467	.76767	.68747	.55456 -1	8.067
.C4 LINK	10	.64633	.74600	.69100	.29919 -1	4.330
.C5 LINK	10	.60567	.70767	.65950	.34290 -1	5.199
.C6 LINK	10	.57700	.71933	.65543	.45621 -1	6.960
.C7 LINK	8	.62833	.73033	.69571	.44142 -1	6.345
.TOTLENG	8	4.5197	5.0987	4.8549	.20429	4.208

TABLE B. 21 ANTHROPOMETRY BY SEX, AGE AND STATURE MALES 18-24 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	10	70.455	111.14	85.227	11.885	13.946
.WT(LB)	10	155.00	244.50	187.50	26.148	13.946
.STATURE	10	177.90	189.90	185.04	3.7512	2.027
.PONDINOX	10	11.789	13.624	12.773	.53740	4.207
.C7HT	10	150.70	163.30	158.75	3.9554	2.492
.CHNKINT	10	154.20	165.20	160.30	3.4477	2.151
.ERSITHT	10	91.600	97.900	94.770	2.6051	2.749
.SITC7HT	10	65.400	73.100	68.750	2.7806	4.044
.RTACR	10	57.900	65.400	61.580	3.0521	4.956
.LTACR	10	58.600	65.300	61.770	2.6654	4.315
.LTTRAG	10	78.000	83.400	80.770	2.3305	2.885
.RTTRAG	10	77.100	83.800	80.490	2.7086	3.365
.NASRTOEP	10	77.600	86.000	82.450	2.9640	3.595
.LTEYE	10	76.400	85.000	81.510	2.8065	3.443
.SUPSTREN	10	57.100	62.400	59.520	1.9498	3.276
.BIACRBR	10	37.300	45.100	41.850	2.2897	5.471
.BIDELT	10	42.600	55.700	49.030	3.5425	7.225
.LATNKBR	10	10.400	13.200	11.900	.89318	7.506
.APNKBR	10	10.400	13.000	11.420	.75100	6.576
.ANTNKLG	10	9.0000	13.100	10.270	1.1509	11.206
.POSTNKLG	10	8.8000	13.400	11.660	1.5925	13.655
.SLMPSIT	10	88.100	95.300	91.100	2.8515	3.130
.SLLTEYE	10	73.100	84.000	77.880	3.4950	4.488
.SUPNKCIR	10	34.300	43.000	38.790	2.3440	6.043
.INFNKCIR	10	39.800	46.000	42.590	2.0019	4.700
.HEADCIR	10	55.800	62.500	58.790	2.0910	3.557
.HEADELPS	10	66.100	73.800	69.110	2.4113	3.489
.HEADBR	10	14.600	16.000	15.360	.45265	2.947

.HEADLG	10	17.900	20.400	19.240	.83160	4.322
.HEADHT	10	11.700	14.300	12.960	.80581	6.218
.SAGARC	10	35.200	39.400	37.670	..4197	3.769
.CORARC	10	33.100	37.300	35.390	1.3996	3.955
.BITRGOI	10	13.500	15.100	14.020	56529	4.032
.MINFRTOI	9	10.400	11.200	10.800	.22913	2.122
.MINFRTAR	9	11.800	14.800	13.467	.98742	7.332
.BITRGMFA	10	29.300	32.100	31.090	1.1140	3.583
.BITRGINA	10	27.300	31.000	28.770	1.3191	4.585
.POSTARC	10	27.200	30.800	28.270	1.1700	4.139
.SITKNEE	10	51.600	59.100	56.630	2.3243	4.104
.KNEEMAX	10	53.200	61.200	58.900	2.3781	4.038
.RTILACSP	10	21.200	25.400	23.370	1.5181	6.496
.HIPBR	9	34.800	43.400	37.967	3.0241	7.965
.BICFLCIR	10	30.000	39.600	33.630	3.1798	9.455
.CALFCIR	10	36.500	44.300	39.080	2.7575	7.056
.FEMDIA	10	9.5000	11.800	10.310	.58775	5.701
.HUMDIA	10	6.7000	8.7000	7.4700	.55986	7.495
.TRICEPSF	10	.40000	1.2000	.82000	.30840	37.610
.SUBSCPSF	10	.80000	2.9000	1.5100	.60636	40.156
.SUPILSF	10	.50000	3.2000	1.6200	.89044	54.966
.CALFSF	10	.40000	2.3000	.95000	.58357	61.429
.C2 LINK	10	1.4763	1.9347	1.5899	.12927	8.131
.C3 LINK	10	.69933	.88767	.77360	.52333 -1	6.765
.C4 LINK	10	.67167	.83500	.74373	.48220 -1	6.483
.C5 LINK	0	.67033	.98500	.75580	.91129 -1	12.057
.C6 LINK	0	.61900	.97500	.75073	.95320 -1	12.697
.C7 LINK	7	.70500	.87567	.77762	.67368 -1	8.663
.TOTLENG	7	4.9120	5.5350	5.2521	.22327	4.251

TABLE B.22 ANTHROPOMETRY BY SEX, AGE ANO STATURE MALES 35-44 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STO OEV	COEF VAR
.WT(KG)	10	61.364	110.45	84.841	15.532	18.303
.WT(LB)	10	135.00	243.00	186.65	34.171	18.303
.STATURE	10	153.00	170.00	165.51	6.2214	3.759
.PONOINOX	10	10.689	12.269	11.466	.55332	4.826
.C7HT	10	129.30	147.20	140.95	5.3149	4.480
.CHNKINT	10	129.60	146.50	141.66	5.5247	3.900
.ERSITHT	10	83.100	91.700	86.770	2.7142	3.128
.SITC7HT	10	59.100	67.500	62.980	2.7684	4.396
.RTACR	10	54.100	62.200	56.930	2.4363	4.280
.LTACR	10	54.300	62.300	57.590	2.2388	3.887
.LTTRAG	10	70.100	77.300	73.420	2.5032	3.409
.RTTRAG	10	70.600	77.300	73.090	2.4113	3.299
.NASRTDEP	10	71.400	80.500	75.250	2.9406	3.908
.LTEYE	10	70.100	79.400	74.290	2.8738	3.868
.SUPSTREN	10	52.800	60.800	55.850	2.4596	4.404
.BIACRBR	10	35.600	42.400	38.810	2.0567	5.299
.BIOELT	10	45.700	53.700	49.370	3.1648	6.410
.LATNKBR	10	10.700	12.800	11.980	.65963	5.506
.APNKBR	10	10.600	13.700	12.420	1.0433	8.400
.ANTNKLG	10	5.1000	8.3000	6.4400	1.1227	17.433
.POSTNKLG	10	8.0000	13.200	9.7800	1.8831	19.255
.SLMPSIT	10	80.900	89.400	84.610	2.7994	3.309
.SLLTEYE	10	69.500	78.600	72.800	2.8760	3.950
.SUPNKCIR	10	37.000	48.000	42.730	3.3869	7.926
.INFNKCIR	10	40.500	47.000	43.390	2.1579	4.973
.HEADCIR	10	55.200	60.000	57.920	1.6818	2.904
.HEADELPS	10	64.000	71.500	67.580	2.1699	3.211
.HEADBR	10	15.500	16.800	15.990	.52589	3.289

.HEADLG	10	17.000	19.600	18.730	.78464	4.139
.HEADHT	10	11.300	14.100	12.740	.96747	7.594
.SAGARC	10	32.600	36.800	34.950	1.5834	4.531
.CORARC	10	33.500	38.400	35.420	1.6505	4.660
.BITRGDI	10	13.800	15.300	14.630	.40838	2.791
.MINFRTDI	10	10.200	11.700	11.060	.45019	4.070
.MINFRTAR	10	11.300	14.400	13.140	.80166	6.101
.BITRGMFA	10	29.000	34.000	30.960	1.5834	5.114
.BITRGINA	10	26.600	29.600	28.050	1.0157	3.621
.POSTARC	10	25.400	30.000	27.810	1.4903	5.359
.SITKNEE	10	46.500	53.100	50.640	2.3590	4.653
.KNEEMAX	10	49.800	55.300	53.250	2.1814	4.336
.RTILACSP	10	20.500	23.900	22.290	1.3486	6.050
.HIPBP	10	33.300	43.700	38.070	3.4596	9.098
.BICFLCIR	10	30.700	41.500	35.760	3.5485	9.923
.CALFCIR	10	34.600	44.700	39.930	3.4403	8.616
.FEMDIA	10	9.2000	11.500	10.380	.67132	[illegible]
.HUMDIA	10	6.2000	7.8000	7.0600	.57194	8.101
.TRICEPSF	10	.60000	2.2000	1.2000	.52068	43.390
.SUBSCPSF	10	1.5000	4.3000	2.6100	.86339	33.080
.SUPILSF	10	1.5000	3.3000	2.4300	.58128	23.921
.CALFSF	10	.20000	1.2000	.62000	.34897	56.235
.C2 LINK	10	1.3307	1.5447	1.4201	.73902 -1	5.204
.C3 LINK	10	.50233	.71700	.64563	.62512 -1	9.682
.C4 LINK	10	.56133	.70767	.63417	.41371 -1	6.524
.C5 LINK	10	.54933	.68933	.63490	.45774 -1	7.210
.C6 LINK	10	.55067	.67433	.62723	.36489 -1	.817
.C7 LINK	9	.64967	.76367	.70656	.37794 -1	5.349
.TOTLENG	6	4.4973	4.7377	4.6133	.12543	2.716

TABLE B.23 ANTHROPOMETRY BY SEX, AGE AND STATURE MALES 35-44 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	10	69.318	89.545	76.568	6.8931	9.003
.WT(LB)	10	152.50	197.00	168.45	15.165	9.003
.STATURE	10	171.00	176.00	173.85	1.5932	.916
.PONDINDX	10	11.870	12.972	12.415	39910	3.215
.C7HT	10	144.80	151.30	148.20	2.2216	1.499
.CHNKINT	10	147.60	151.90	149.74	1.4120	.943
.ERSITHT	10	85.200	95.000	89.950	2.6647	2.962
.SITC7HT	10	60.200	69.300	65.030	2.9273	4.501
.RTACR	10	52.100	61.200	58.410	2.7070	4.634
.LTACR	10	54.600	63.500	59.340	2.6395	4.443
.LTTRAG	10	71.600	80.800	76.320	2.4957	3.270
.RTTRAG	10	71.400	82.000	76.470	2.8445	3.720
.NASRTDEP	10	73.800	82.900	78.180	2.6591	3.401
.LTEYE	10	73.000	82.000	77.340	2.4604	3.181
.SUPSTREN	10	52.900	61.800	57.270	2.5042	4.373
.BIACRBR	10	35.800	44.000	39.990	.4287	6.073
.BIDELT	10	44.300	51.800	47.650	2.5088	5.265
.LATNKBR	10	9.5000	12.700	11.450	.85016	7.425
.APNKBR	10	10.500	13.100	11.770	.78323	6.654
.ANTNKLG	10	7.3000	9.9000	8.6200	1.0304	11.954
.POSTNKLG	10	7.1000	13.700	10.470	1.8542	17.709
.SLMPSIT	10	84.400	93.100	87.850	2.6057	2.965
.SLLTEYE	10	70.800	80.300	75.080	2.5143	3.349
.SUPNKCIR	10	38.300	46.000	40.090	2.3067	5.754
.INFNKCIR	10	38.700	47.000	42.490	2.6210	6.169
.HEADCIR	10	55.800	59.800	58.010	1.2170	2.099
.HEADELPS	10	63.500	69.600	67.620	1.8665	2.760
HEADBR	10	14.800	18.000	15.750	.92646	5.882

HEADLG	10	18.200	19.400	18.920	.41042	2.169
HEADHT	10	12.000	13.200	12.770	.34010	2.663
SAGARC	10	34.000	38.700	36.680	1.4987	4.086
CORARC	10	33.100	36.900	35.200	1.0446	2.963
BITRGDI	10	13.200	15.100	14.040	.59666	[illegible].250
MINFRTDI	10	9.7000	11.500	10.710	.51951	4.851
MINFRTAR	10	11.800	14.300	13.080	.86127	6.585
BITRGMFA	10	29.500	32.000	30.560	.86564	2.833
BITRGINA	10	26.000	31.000	28.370	1.4930	5.263
POSTARC	10	25.500	30.600	27.900	1.3695	4.909
SITKNEE	10	49.600	56.400	52.540	2.1665	4.124
KNEEMAX	10	52.300	56.700	54.690	1.5257	2.790
RTILACSP	10	20.600	25.100	23.010	1.3892	[illegible]
HIPBR	10	35.500	37.600	36.520	.87534	2.397
BICFLCIR	10	27.300	37.100	32.730	2.8480	8.702
CALFCIP	10	33.500	41.500	36.210	2.6219	7.241
FEMDIA	10	9.1000	11.000	9.9000	.54975	5.553
HUMDIA	10	6.5000	7.5000	6.8900	.34140	4.955
TRICEPSF	10	.50000	2.4000	1.1700	.60378	51.635
SUBSCPSF	10	.90000	3.4000	1.8600	.78060	41.968
SUPILSF	10	.80000	4.8000	2.1500	1.0876	50.584
CALFSF	10	.40000	1.9000	.79000	.43830	55.482
C2 LINK	10	1.4210	1.7457	1.5214	.10658	7.006
C3 LINK	10	.63933	.77967	.71260	.39887 -	5.597
C4 LINK	10	.65133	.73200	.68777	.31175 -1	4.533
C5 LINK	10	.60367	.75533	.67233	.45501 -1	6.768
C6 LINK	10	.62633	.73033	.69167	.39583 -1	5.723
C7 LINK	7	.68333	.80000	.73886	.43640 -1	5.906
TOTLENG	7	4.8113	5.3123	5.0336	.19921	3.955

TABLE B.24 ANTHROPOMETRY BY SEX, AGE AND STATURE MALES 35-44 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	10	64.091	121.14	88.932	15.892	17.870
.WT(LB)	10	141.00	266.50	195.65	34.963	17.870
.STATURE	10	178.60	195.00	182.40	5.0142	2.749
.PONDINDX	10	11.667	13.512	12.438	.57077	4.589
.C7HT	10	151.10	169.70	156.62	5.2291	3.339
.CHNKINT	10	153.20	168.30	157.21	4.6479	2.957
.ERSITHT	10	92.100	97.100	94.700	1.5839	1.673
.SITC7HT	10	65.400	72.700	69.300	2.1669	3.127
.RTACR	10	58.200	64.900	62.620	2.2856	3.650
.LTACR	10	60.500	65.700	63.250	1.6588	2.623
.LTTRAG	10	77.500	84.400	81.060	1.9873	2.452
.RTTRAG	10	77.400	83.600	80.820	1.8689	2.312
.NASRTOEP	10	79.500	85.700	82.800	1.8821	2.273
.LTEYE	10	78.900	84.500	81.510	1.8297	2.245
.SUPSTREN	10	57.400	63.500	60.620	2.0154	3.325
.BIACRBR	10	38.400	42.900	40.350	1.6834	4.172
.BIDELT	10	45.700	56.000	49.420	3.5383	7.160
.LATNKBR	10	10.500	12.800	11.630	.77035	6.624
.APNKBR	10	11.100	13.900	12.360	.89716	7.259
.ANTNKLG	10	5.0000	10.800	8.4200	1.6745	19.887
.POSTNKLG	10	9.6000	11.500	10.720	.59404	5.541
.SLMPSIT	10	85.700	92.600	90.080	2.4948	2.770
.SLLTEYE	10	71.700	81.700	77.360	3.2908	4.254
.SUPNKCIR	10	36.100	46.200	40.730	3.1948	7.844
.INFNKCIR	10	39.500	51.500	43.740	3.8561	8.816
.HEADCIR	10	55.400	64.600	58.800	2.8394	4.829
.HEADELPS	10	65.300	72.300	68.480	2.2215	3.244
.HEADBR	10	14.700	16.800	15.660	.53790	3.435

.HEADLG	10	18.000	22.900	19.500	1.3597	6.973
.HEADHT	10	12.300	13.700	12.920	.54528	4.220
.SAGARC	10	34.900	41.500	36.660	2.0684	5.642
.CORARC	10	33.800	37.800	35.670	1.4652	4.108
.BITRGOI	10	13.700	15.500	14.450	.60599	4.194
.MINFRTDI	10	10.100	11.800	10.860	.57581	5.302
.MINFRTAR	10	11.800	14.200	12.880	.78853	6.122
.BITRGMFA	10	29.700	34.500	31.090	1.5103	4.858
.BITRGINA	10	27.300	31.400	28.790	1.3940	4.842
.POSTARC	10	27.400	31.200	28.360	1.3624	4.804
.SITKNEE	10	52.900	61.300	55.940	2.3623	4.223
.KNEEMAX	10	55.400	64.100	58.160	2.4780	4.261
.RTILACSP	10	21.000	26.700	24.080	1.7637	7.324
.HIPBR	10	34.200	43.200	39.100	2.9071	7.435
.BICFLCIR	10	29.500	38.300	34.410	3.1723	9.219
.CALFCIR	10	33.500	44.500	39.380	3.4595	8.785
.FEMDIA	10	9.5000	12.000	10.510	.77953	7.417
.HUMDIA	10	6.1000	8.2000	7.2700	.64644	8.892
.TRICEPSF	10	.50000	2.3000	1.0100	53635	53.104
.SUBSCPSF	10	.90000	3.8000	1.9200	1.0717	55.815
.SUPILSF	10	.80000	4.3000	2.0000	1.1215	56.075
.CALFSF	10	.30000	2.2000	1.1100	.61001	54.956
.C2 LINK	10	1.3673	1.8670	1.5529	.14896	9.592
.C3 LINK	10	.70000	.81767	.75203	.36998 -1	4.920
.C4 LINK	10	.65867	.79600	.71347	.45928 -1	6.437
.C5 LINK	10	.60300	.77800	.69160	.57592 -1	8.327
.C6 LINK	10	.66267	.76067	.70487	.28831 -1	4.090
.C7 LINK	8	.64867	.81867	.74512	.57784 -1	7.755
.TOTLENG	9	4.7510	5.7013	5.1809	.28340	5.470

TABLE B.25 ANTHROPOMETRY BY SEX, AGE AND STATURE MALES 62-74 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	6	50.682	77.955	64.318	9.0248	14.031
.WT(LB)	6	111.50	171.50	141.50	19.854	14.031
.STATURE	6	152.00	166.40	162.20	5.2444	3.233
.PONDINDX	6	11.793	12.544	12.288	.28368	2.309
.C7HT	6	129.70	142.20	138.40	4.5042	3.254
.CHNKINT	6	130.10	142.20	138.77	4.4657	3.218
.ERSITHT	6	78.900	87.200	83.717	2.7838	3.325
.SITC7HT	6	57.900	65.600	61.067	2.5610	4.194
.RTACR	6	50.300	56.800	53.650	2.0983	3.911
.LTACR	6	48.500	57.000	53.567	3.0071	5.614
LTTRAG	6	66.800	72.500	69.633	1.9065	2.733
.RTTRAG	6	65.700	72.300	69.917	2.4227	3.465
.NASRTOEP	6	66.900	75.100	71.733	2.9015	4.045
.LTEYE	6	65.700	73.700	70.567	2.8898	4.095
.SUPSTREN	6	48.600	55.600	52.250	2.2528	4.312
BIACRBR	6	36.000	39.300	37.683	1.2734	3.379
.BIDELT	6	40.300	46.300	43.583	1.9914	4.569
.LATNKBR	6	9.7000	11.100	10.533	.53166	5.047
.APNKBR	6	10.600	14.000	12.083	1.2057	9.978
.ANTNKLG	6	6.8000	10.000	8.5833	1.1125	12.961
POSTNKLG	6	7.8000	11.600	9.0000	1.4014	15.571
.SLMPSIT	6	77.600	82.000	80.517	1.5905	1.975
SLLTEYE	6	63.500	70.800	67.250	2.5898	3.851
.SUPNKCIR	6	36.900	42.500	40.083	2.3464	5.854
.INFNKCIR	6	37.200	42.600	39.283	2.1967	5.592
.HEADCIR	6	54.500	58.200	56.967	1.4137	2.482
.HEADELPS	6	63.500	69.000	66.367	2.3880	3.598
HEADBR	6	15.000	15.900	15.450	.37283	2.413

.HEADLG	6	17.700	19.600	18.750	.64109	3.419
.HEADHT	6	12.100	13.300	12.650	.45056	3.562
.SAGARC	6	31.600	39.100	34.967	2.5657	7.337
.COPARC	6	32.400	35.700	34.233	1.2972	3.789
.BITRGDI	6	13.300	14.100	13.717	.33714	2.458
.MINFRTDI	6	9.7000	10.800	10.417	.38687	3.714
.MINFRTAR	6	11.600	12.600	12.300	.35777	2.909
.BITRGMFA	6	29.200	31.000	30.200	.67231	2.226
.BITRGINA	6	26.100	30.400	27.550	1.5540	5.641
.POSTARC	6	26.000	29.100	27.350	1.2128	4.435
.SITKNEE	6	44.400	51.800	49.083	2.5087	5.111
.KNEEMAX	6	46.700	53.500	51.117	2.4161	4.727
.RTILACSP	6	20.400	23.500	21.750	1.0932	5.026
.HIPBR	6	30.800	38.000	35.267	2.6920	7.633
.BICFLCIR	6	28.000	33.400	30.850	1.9326	6.265
.CALFCIR	6	29.800	37.200	33.517	2.5373	7.570
.FEMDIA	6	8.6000	10.500	9.4833	.75211	7.931
.HUMDIA	6	6.2000	7.0000	6.6000	.28983	4.391
.TRICEPSF	6	.20000	1.3000	.66667	.39328	58.992
.SUBSCPSF	6	.90000	1.9000	1.3167	.39200	29.772
.SUPILSF	6	.90000	1.9000	1.2167	.35449	29.137
.CALFSF	6	.20000	.60000	.43333	.16330	37.685
.C2 LINK	6	1.2947	1.5680	1.4227	.11277	7.926
.C3 LINK	6	.57133	.72267	.67689	.55620 -1	8.217
.C4 LINK	6	.60133	.70633	.66589	.37324 -1	5.605
.C5 LINK	6	.55367	.69667	.63167	.54954 -1	8.700
.C6 LINK	6	.59067	.72033	.62328	.48953 -1	7.854
.C7 LINK	6	.60300	.76167	.68317	.67977 -1	9.950
.TOTLENG	6	4.3917	5.1237	4.7036	.30124	6.405

TABLE B.26 ANTHROPOMETRY BY SEX, AGE AND STATU MALES 62-74 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	11	65.682	89.545	76.219	8.6413	11.337
.WT(LB)	11	144.50	197.00	167.66	19.011	11.337
.STATURE	11	167.10	173.20	169.75	1.7952	1.058
.PONDINDX	11	11.450	12.748	12.152	.44775	3.685
.C7HT	11	142.90	150.30	145.95	1.9582	1.342
.CHNKINT	11	144.00	147.30	145.63	1.1118	.763
.ERSITHT	11	86.000	91.700	88.418	1.7308	1.958
.SITC7HT	11	63.200	69.200	65.355	2.1224	3.248
.RTACR	11	56.100	65.400	58.873	2.7441	4.661
.LTACR	11	56.300	62.900	59.182	1.9508	3.296
.LTTRAG	11	73.600	78.900	75.591	1.7178	2.273
.RTTRAG	11	73.200	77.400	75.009	1.5391	2.052
.NASRTDEP	11	74.800	79.000	76.855	1.6591	2.159
.LTEYE	11	73.800	78.000	75.809	1.5896	2.097
.SUPSTREN	11	55.100	60.400	57.300	1.7776	3.102
.BIACRBR	11	35.500	41.700	38.882	1.7566	4.518
.BIDELT	11	41.400	47.900	45.527	2.1086	4.632
.LATNKBR	11	9.7000	12.800	11.327	.81497	7.195
.APNKBR	11	11.700	14.300	12.864	.79909	6.212
.ANTNKLG	11	6.7000	9.1000	8.2364	.73113	8.877
.POSTNKLG	11	7.9000	10.500	9.5818	.85067	8.878
.SLMPSIT	11	83.500	89.100	86.245	1.8817	2.182
.SLLTEYE	11	69.000	77.700	73.755	2.7387	3.713
.SUPNKCIR	11	38.800	48.500	42.873	2.8468	6.640
.INFNKCIR	11	38.200	46.20	42.336	2.3725	5.604
.HEADCIR	11	54.900	59.500	57.818	1.1839	2.048
.HEADELPS	11	63.700	69.300	67.100	1.6739	2.495
.HEADBR	11	14.900	16.600	15.618	.52119	3.337

.HEADLG	11	18.400	19.500	19.109	.42061	2.[illegible]01
.HEADHT	11	11.000	14.000	12.418	.76527	6.162
.SAGARC	11	31.900	36.800	35.345	1.3589	3.845
.CORARC	11	32.500	36.000	33.991	1.0435	3.070
.BITRGDI	11	13.400	15.400	14.513	.56713	3.906
.MINERTDI	11	10.300	11.200	10.718	.34298	3.200
.MINERTAR	11	12.200	14.100	12.973	.56937	4.389
.BITRGMEA	11	29.200	31.700	30.282	.88974	2.938
.BITRGINA	11	26.200	30.000	28.200	1.0658	3.780
.POSTARC	11	25.900	29.500	28.191	1.1131	3.948
.SITKNEE	11	48.600	53.100	51.355	1.2226	2.381
.KNEEMAX	11	50.000	55.000	53.245	1.2848	2.413
.RTILACSP	11	21.100	24.400	22.918	.92824	4.050
.HIPBR	11	34.200	40.400	37.055	2.0878	5.634
.BICFLCIR	11	27.000	35.900	32.191	2.8222	8.767
.CALFCIR	11	33.500	38.000	35.700	1.5427	4.321
.FEMDIA	11	9.2000	10.800	9.9545	.46337	4.655
.HUMDIA	11	6.1000	7.3000	6.7636	.40564	5.997
.TRICEPSF	11	.30000	2.3000	.92727	.65892	71.061
.SUBSCPSF	11	1.2000	2.5000	1.6545	.50272	30.384
.SUPILSF	11	1.1000	2.6000	1.5545	.51452	33.098
.CALFSF	11	.40000	.90000	.49091	.17003	34.635
.C2 LINK	9	1.3417	1.6110	1.5091	.86058 -1	5.703
.C3 LINK	9	.59667	.72533	.66270	.43531 -1	6.569
.C4 LINK	9	.53667	.72967	.65389	.54854 -1	8.389
.C5 LINK	9	.53167	.72000	.62781	.63871 -1	10.173
.C6 LINK	9	.55900	.67233	.62078	.32533 -1	5.241
.C7 LINK	5	.54300	.72067	.65013	.65733 -1	10.111
.TOTLENG	5	4.1393	4.9163	4.6679	.32103	6.878

TABLE B.27 ANTHROPOMETRY BY SEX, AGE AND STATURE MALES 62-74 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.WT(KG)	10	61.591	87.045	74.409	8.0397	10.805
.WT(LB)	10	135.50	191.50	163.70	17.687	10.805
.STATURE	10	174.30	184.20	178.55	2.9553	1.655
.PONDINDX	10	12.465	13.692	12.878	.36002	2.796
.C7HT	10	149.70	159.50	152.80	2.9174	1.909
.CHNKINT	10	149.60	160.50	154.43	3.3635	2.178
.ERSITHT	10	87.200	96.500	92.220	3.1675	3.435
.SITC7HT	10	63.200	72.400	67.500	3.0565	4.528
.RTACR	10	55.700	65.700	60.160	3.0171	5.015
.LTACR	10	54.400	63.700	60.250	3.2888	5.459
.LTTRAG	10	73.800	83.000	79.130	3.2448	4.101
.RTTRAG	10	73.500	83.300	78.710	3.3857	4.302
.NASRTDEP	10	76.600	87.200	81.300	3.3353	4.103
.LTEYE	10	75.400	86.000	80.220	3.4624	4.316
.SUPSTREN	10	55.000	63.500	59.400	2.8425	4.785
.BIACRBR	10	36.700	42.700	39.840	2.0012	5.023
.BIDELT	10	41.500	47.600	45.140	2.0271	4.491
.LATNKBR	10	10.000	12.500	11.080	.75248	6.791
.APNKBR	10	11.700	13.600	12.620	.70679	5.601
.ANTNKLG	10	6.9000	12.100	9.6900	1.6052	16.565
.POSTNKLG	10	8.7000	15.200	11.350	2.2609	19.920
.SLMPSIT	10	85.500	96.000	90.640	3.7414	4.123
.SLLTEYE	10	72.300	85.300	78.510	4.2265	5.333
.SUPNKCIR	10	38.700	44.700	40.590	1.8526	4.564
.INFNKCIR	10	38.700	42.200	40.820	1.3223	3.239
HEADCIR	10	54.800	60.800	58.350	1.9946	3.418
.HEADELPS	10	65.800	70.500	67.470	1.3937	2.066
HEADBR	10	14.800	16.800	15.900	.66833	4.203

HEADLG	10	17.300	21.000	19.490	.99605	5.111
HEADHT	10	10.900	14.200	12.570	.96959	7.714
SAGARC	10	33.800	37.800	35.110	1.3412	3.820
CORARC	10	33.000	36.700	34.890	1.1445	3.280
BITRGDI	10	13.600	15.400	14.420	.59591	4.133
MINFRTD	10	9.5000	11.700	10.820	.60882	5.627
MINFRTAR	10	11.000	15.600	13.320	1.1793	8.853
BITRGMFA	10	28.400	33.000	31.020	1.3863	4.469
BITRGINA	10	27.000	30.500	28.640	1.1177	3.903
POSTARC	10	25.200	29.500	27.630	1.1431	4.137
SITKNEE	10	51.200	57.600	54.480	1.9640	3.605
KNEEMAX	10	53.600	59.300	56.520	1.7763	3.143
RTILACSP	10	21.600	26.000	23.970	1.4221	[illegible]
HIPBR	10	33.700	41.900	37.610	2.5488	6.777
BICFLCIR	10	28.900	32.500	30.710	1.4746	4.802
CALFCIR	10	31.000	38.500	34.640	2.5665	[illegible]
FEMDIA	10	9.7000	11.700	10.460	.77632	7.422
HUMDIA	10	6.8000	8.2000	7.3400	.46714	6.364
TRICEPSF	10	.50000	1.5000	.87000	.28694	[illegible]
SUBSCPSF	10	.80000	1.7000	1.1800	.34897	[illegible]
SUPILSF	10	.50000	1.8000	1.2300	.40014	[illegible]
CALFSF	10	.20000	1.0000	.54000	.24129	[illegible]
C2 LINK	10	1.5467	1.7917	1.6244	.77662 -1	[illegible]
C3 LINK	10	.67867	.80233	.74717	.36652 -1	[illegible]
C4 LINK	10	.69333	.77133	.74087	.31100 -1	[illegible]
C5 LINK	10	.62867	.78500	.69630	.57803 -1	8.301
C6 LINK	10	.57600	.77167	.65810	.55703 -1	8.464
C7 LINK	[illegible]	.71400	.85533	.76383	.50962 -1	6.672
TOTLENG	[illegible]	[illegible]	5.6153	5.1990	.21250	4.094

APPENDIX C

RANGE OF MOTION - DESCRIPTIVE STATISTICS

Summary descriptive statistics from the range of motion portion of the study are contained in this appendix. These data are reported in the following order:

TABLE	
C.1	All subjects Combined
C.2	Subjects grouped by Sex--Females
C.3	--Males
C.4	Subjects grouped by Sex and Age--Females, 18-24
C.5	--Females, 35-44
C.6	--Females, 62-74
C.7	--Males, 18-24
C.8	--Males, 35-44
C.9	--Males, 62-74
C.10	Subjects grouped by Sex, Age, and Stature --Females, 18-24, 1-20%ile
C.11	--Females, 18-24, 40-60%ile
C.12	--Females, 18-24, 80-99%ile
C.13	--Females, 35-44, 1-20%ile
C.14	--Females, 35-44, 40-60%ile
C.15	--Females, 35-44, 80-99%ile
C.16	--Females, 62-74, 1-20%ile
C.17	--Females, 62-74, 40-60%ile
C.18	--Females, 62-74, 80-99%ile
C.19	--Males, 18-24, 1-20%ile
C.20	--Males, 18-24, 40-60%ile
C.21	--Males, 18-24, 80-99%ile
C.22	--Males, 35-44, 1-20%ile
C.23	--Males, 35-44, 40-60%ile
C.24	--Males, 35-44, 80-99%ile
C.25	--Males, 62-74, 1-20%ile
C.26	--Males, 62-74, 40-60%ile
C.27	--Males, 62-74, 80-99%ile

The data tables are in the format produced by the University of Michigan Statistical Laboratory Michigan Interactive Data Analysis System (MIDAS). Each of the measurements is given a code name; the measurement name associated with the code names are identified on the following page. All dimensions are in degrees.

CODE	MEASUREMENT NAME
XNTANG	X RAY-NEUTRAL HEAD POSITION
XFLEX	X RAY-FLEXION
XEXT	X RAY-EXTENSION
XROM	X RAY-RANGE OF MOTION
PITANG	PHOTO 1-NEUTRAL HEAD POSITION
P1FLX	PHOTO 1-FLEXION
P1EXT	PHOTO 1-EXTENSION
P1ROM	PHOTO 1-RANGE OF MOTION
P2NTANGE	PHOTO 2-NEUTRAL HEAD POSITION
P2FLX	PHOTO 2-FLEXION
P2EXT	PHOTO 2-EXTENSION
P2ROM	PHOTO 2-RANGE OF MOTION
P3NTANGE	PHOTO 3-NEUTRAL HEAD POSITION
P3FLX	PHOTO 3-FLEXION
P3EXT	PHOTO 3-EXTENSION
P3ROM	PHOTO 3-RANGE OF MOTION
XPAVGNT	AVERAGE NEUTRAL HEAD POSITION FROM X-RAYS AND 3 PHOTOS
XPAVGFLX	AVERAGE FLEXION FROM X-RAYS AND 3 PHOTOS
XPAVGEXT	AVERAGE EXTENSION FROM X-RAYS AND 3 PHOTOS
XPAVGROM	AVERAGE RANGE OF MOTION FROM X-RAYS AND 3 PHOTOS
PAVGNT	AVERAGE NEUTRAL HEAD POSITION FROM 3 PHOTOS ONLY
PAVGFLX	AVERAGE FLEXION FROM 3 PHOTOS ONLY
PAVGEXT	AVERAGE EXTENSION FROM 3 PHOTOS ONLY
PAVGROM	AVERAGE RANGE OF MOTION FROM 3 PHOTOS ONLY

The following summary statistics are reported for each measurement:

Column Heading	Statistic
N	Number of Subjects in the Group
MINIMUM	Smallest Observation
MAXIMUM	Largest Observation
MEAN	Numerical Average
STD DEV	Standard Deviation
COEF VAR	Coefficient of Variation (Mean/Std Dev)
5TH %ILE	Fifth Percentile (Calculated)
50TH %ILE	Fiftieth Percentile (Calculated)
95TH %ILE	Ninety-fifth Percentile (Calculated)

Note: MIDAS specifies, as the percentile, the indiviual measurement which is closest to the requested percentile. For example: in a data set of 178 observations, the 9th smallest is called the 5th percentile, the 89th in rank is the 50th percentile and the 169th is the 95th percentile. This approach can cause misleading errors when small subsets of the data are analyzed; therefore, only the 50th percentile is included in Tables C.4 through C.9 and no percentiles are included for Tables C.10 through C.27.

TABLE C.1 RANGE OF MOTION ALL SUBJECTS COMBINED

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	5TH %ILE	50TH %ILE	95TH %ILE
.XNTANG	176	55.000	89.500	75.119	6.4970	8.649	64.500	75.000	86.000
.XFLEX	177	18.000	79.000	54.514	12.118	22.229	33.000	55.500	73.000
.XEXT	177	25.500	112.50	62.915	18.024	28.648	37.500	60.500	100.500
.XROM	177	59.500	174.00	117.36	24.391	20.783	78.000	118.000	162.000
.P1TANG	170	55.500	89.000	73.465	6.1741	8.404	65.000	73.000	84.000
.P1FLX	170	22.000	89.000	54.574	11.696	21.432	36.000	54.000	72.000
.P1EXT	170	20.000	117.50	60.471	15.592	25.784	36.500	60.500	86.000
.P1ROM	175	57.000	168.50	115.21	22.436	19.474	81.000	116.000	149.500
.P2NTANG	178	50.000	88.000	72.393	6.4315	8.884	62.000	72.000	84.000
.P2FLX	177	25.000	90.500	56.720	12.216	21.538	33.000	58.500	77.000
.P2EXT	176	5.0000	109.50	60.057	16.317	27.169	34.000	60.000	87.000
.P2ROM	176	38.000	170.00	116.76	23.522	20.146	75.500	119.000	152.500
.P3NTANG	176	53.000	88.500	72.278	6.9048	9.553	60.000	72.500	85.000
.P3FLX	176	21.500	86.500	57.412	12.624	21.988	35.000	58.000	78.500
.P3EXT	176	14.000	108.00	61.006	16.085	26.366	33.000	60.500	85.500
.P3ROM	176	40.000	163.50	118.41	23.359	19.727	80.500	120.500	156.500
.XPAVGNT	178	55.375	88.125	73.318	5.7941	7.903	63.875	73.125	82.750
.XPAVGFLX	178	24.000	82.875	55.757	10.895	19.541	36.625	55.250	73.875
.XPAVGEXT	178	20.750	111.25	61.165	15.605	25.513	37.125	60.500	89.500
.XPAVGROM	178	53.625	166.50	116.89	22.404	19.167	80.375	117.125	150.625
.PAVGNT	178	55.000	88.500	72.683	6.0284	8.294	62.333	72.500	83.000
.PAVGFLX	178	25.500	85.500	56.210	11.620	20.672	36.833	56.333	76.250
.PAVGEXT	173	15.667	111.67	60.597	15.491	25.563	35.167	60.167	86.000
.PAVGROM	178	45.000	165.50	116.76	22.777	19.508	76.000	118.167	151.000

TABLE C.2 RANGE OF MOTION BY SEX FEMALES

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	5TH %ILE	50TH %ILE	95TH %ILE
.XNTANG	91	55.000	88.000	74.077	6.3635	8.590	64.000	74.500	84.500
.XFLEX	91	13.000	79.000	54.984	12.153	22.103	35.000	56.500	71.000
.XEXT	91	25.500	112.50	63.264	17.991	28.438	40.500	60.500	100.500
.XROM	91	71.000	173.50	118.12	23.206	19.646	80.500	118.500	163.000
.P1NTANG	83	56.000	89.000	72.693	6.4825	8.918	65.000	71.500	85.500
.P1FLX	83	22.000	79.500	54.392	11.134	20.469	34.000	55.000	70.500
.P1EXT	83	21.500	117.50	62.593	16.339	26.061	35.000	62.000	90.500
.P1ROM	83	70.000	168.50	117.31	21.516	18.342	83.500	120.000	148.500
.P2NTANG	91	56.000	88.000	71.533	6.3608	8.892	62.000	71.500	83.000
.P2FLX	91	29.500	90.500	57.621	11.540	20.028	34.000	60.000	74.000
.P2EXT	91	5.0000	109.50	62.709	16.500	26.312	40.000	62.500	88.000
.P2ROM	91	67.000	170.00	120.33	22.722	18.883	74.000	124.000	155.000
.P3NTANG	90	55.500	88.500	71.717	6.8294	9.523	60.000	72.000	84.500
.P3FLX	90	24.000	86.500	57.800	12.478	21.589	38.500	58.000	78.500
.P3EXT	90	22.500	108.00	63.606	15.123	23.777	38.000	62.000	86.000
.P3ROM	90	62.000	163.50	121.41	21.630	17.817	84.500	122.000	158.500
.XPAVGNT	91	55.875	88.125	72.500	5.8080	8.011	63.875	72.125	81.875
.XPAVGFLX	91	26.125	82.875	56.147	10.496	18.694	36.625	55.875	72.250
.XPAVGEXT	91	23.250	111.25	63.082	15.356	24.343	40.375	63.375	89.750
.XPAVGROM	91	73.250	166.50	119.17	21.119	17.722	82.875	119.250	153.125
.PAVGNT	91	55.000	88.500	71.951	6.0973	8.474	62.167	71.333	82.833
.PAVGFLX	91	27.833	85.500	56.588	11.195	19.783	36.833	57.167	76.250
.PAVGEXT	91	22.500	111.67	62.996	15.232	24.179	38.000	62.333	87.333
.PAVGROM	91	71.333	166.50	119.49	21.521	18.011	82.333	119.333	148.833

TABLE C.3 RANGE OF MOTION BY SEX MALES

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	5TH %ILE	50TH %ILE	95TH %ILE
XNTANG	85	60.000	89.500	76.235	6.4897	8.513	66.500	76.000	86.500
XFLEX	86	27.500	76.000	54.017	12.132	22.459	31.000	54.500	73.000
.XEXT	86	23.500	112.50	62.547	18.157	29.030	37.500	60.000	98.500
XROM	86	59.500	174.00	116.56	25.699	22.047	78.000	116.000	160.500
.P1TANG	87	55.500	88.000	74.201	5.8067	7.826	65.000	74.000	84.000
.P1FLX	87	23.500	89.000	54.747	12.271	22.414	37.000	53.000	72.000
.P1EXT	87	20.000	100.00	58.351	14.625	25.064	36.500	58.000	78.500
.P1ROM	87	57.000	165.00	113.10	23.263	20.569	78.000	110.500	149.500
.P2NTANG	87	57.000	88.000	73.293	6.4179	8.756	62.500	74.000	84.500
.P2FLX	86	25.000	84.500	55.767	12.892	23.118	32.500	56.500	77.000
.P2EXT	85	13.000	90.000	57.218	15.723	27.479	31.500	58.500	84.500
.P2ROM	85	38.000	166.50	112.94	23.893	21.156	77.500	110.500	149.000
.P3NTANG	86	53.000	88.000	72.866	6.9741	9.571	61.000	73.000	85.000
.P3FLX	86	21.500	84.000	57.006	12.835	22.515	32.500	57.500	75.500
.P3EXT	86	14.000	97.500	58.285	16.689	28.634	32.000	59.000	84.000
.P3ROM	86	40.000	162.00	115.28	24.781	21.497	74.500	114.000	153.000
.XPAVGNT	87	61.500	87.875	74.173	5.6873	7.668	65.250	74.500	84.250
.XPAVGFLX	87	26.000	80.250	55.350	11.345	20.496	37.875	54.375	73.875
.XPAVGEXT	87	20.750	103.33	59.161	15.699	26.536	35.250	58.875	82.750
.XPAVGROM	87	53.625	164.83	114.5[illegible]	23.561	20.575	80.375	115.250	148.625
.PAVGNT	87	59.6[illegible]	87.833	73.447	5.8935	8.024	63.500	73.667	83.833
.PAVGFLX	87	25.500	84.333	55.814	12.101	21.681	37.333	55.333	75.167
.PAVGEXT	87	15.667	98.750	58.087	15.44[illegible]	26.592	35.000	58.500	81.000
.PAVGROM	87	45.000	164.50	113.90	23.810	20.904	76.000	114.333	151.000

TABLE C.4 RANGE OF MOTION BY SEX AND AGE FEMALES 18-24

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.XNTANG	30	68.000	68.000	78.167	5.1333	6.567	78.000
.XFLEX	30	38.500	75.000	60.883	8.4728	13.916	59.000
.XFXT	30	51.000	112.50	77.100	18.512	24.010	68.000
.XROM	30	98.000	173.50	137.62	19.017	13.819	134.000
.P1TANG	28	66.000	89.000	75.036	6.5531	8.733	74.500
.P1FLX	28	34.000	79.500	58.018	10.807	18.627	57.500
.P1EXT	28	51.500	117.50	74.268	15.276	20.569	73.500
.P1ROM	29	96.500	168.50	132.84	16.061	12.090	128.500
.P2NTANG	30	62.500	88.000	74.517	6.6131	8.875	75.000
.P2FLX	30	39.500	90.500	62.033	10.362	16.703	61.500
.P2EXT	30	55.000	109.50	75.200	13.435	17.866	74.500
.P2ROM	30	102.00	170.00	137.23	15.904	11.589	137.500
.P3NTANG	30	62.500	88.500	74.750	6.7027	8.967	73.000
.P3FLX	30	38.500	36.500	61.717	12.749	20.658	59.000
.P3EXT	30	51.500	108.00	75.533	12.570	16.642	73.500
.P3ROM	30	101.00	163.50	137.25	16.271	11.855	138.000
.XPAVGNT	30	65.625	88.125	75.637	5.5614	7.353	75.125
.XPAVGFLX	30	40.875	82.875	60.785	9.4696	15.579	60.667
.XPAVGEXT	30	54.625	111.25	75.682	14.012	18.514	72.750
.XPAVGROM	30	100.75	166.50	136.35	14.988	10.992	133.750
.PAVGNT	30	64.333	88.500	74.781	6.2313	8.333	74.250
.PAVGFLX	30	37.333	85.500	60.850	10.770	17.699	61.333
.PAVGEXT	30	52.667	111.67	75.161	13.116	17.451	74.333
.PAVGROM	30	101.67	166.50	135.90	14.966	11.012	135.667

TABLE C.5 RANGE OF MOTION BY SEX AND AGE FEMALES 35-44

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.XNTANG	30	63.000	84.500	74.033	5.2423	7.081	72.500
.XFLEX	30	33.000	79.000	59.133	10.687	18.072	59.000
.XEXT	30	42.500	93.000	61.450	12.571	20.458	59.500
.XROM	30	95.000	143.00	120.58	13.527	11.218	123.500
.P1TANG	27	65.000	85.500	72.630	4.8369	6.660	72.000
.P1FLX	27	34.000	74.000	56.630	10.958	19.350	59.500
.P1EXT	27	39.500	81.000	64.222	10.664	16.605	67.500
.P1ROM	29	84.000	144.00	121.16	17.607	14.532	126.000
.P2NTANG	30	60.500	79.500	70.800	4.5686	6.453	69.000
.P2FLX	30	33.000	81.000	60.533	9.9905	16.504	60.500
.P2EXT	30	36.500	88.000	62.883	12.572	19.992	63.000
.P2ROM	30	90.000	155.00	123.42	17.412	14.108	124.500
.P3NTANG	30	59.500	83.000	71.167	5.8048	8.157	71.500
.P3FLX	30	41.000	80.500	60.783	10.610	17.456	61.000
.P3EXT	30	35.500	85.500	62.667	11.391	18.177	61.500
.P3ROM	30	92.500	156.50	123.45	17.150	13.892	122.000
.XPAVGNT	30	63.625	81.375	72.151	4.4647	6.188	72.125
.XPAVGFLX	30	44.250	74.750	59.315	8.4453	14.238	58.625
.XPAVGEXT	30	40.375	79.125	62.657	10.303	16.444	64.000
.XPAVGROM	30	94.000	145.50	121.97	15.081	12.364	124.750
.PAVGNT	30	61.667	81.500	71.511	4.5744	6.397	71.333
.PAVGFLX	30	36.833	76.333	59.342	9.8500	16.649	60.667
.PAVGEXT	30	37.167	82.000	63.075	10.829	17.168	61.833
.PAVGROM	30	89.667	148.83	122.42	17.057	13.933	123.667

TABLE C.6 RANGE OF MOTION BY SEX AND AGE FEMALES 62-74

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.XNTANG	31	55.000	80.000	70.161	6.0723	8.655	69.500
.XFLEX	31	18.000	67.000	45.258	10.655	23.543	46.000
.XEXT	31	25.500	83.000	51.629	12.342	23.906	52.500
.XROM	31	71.000	136.50	96.871	15.370	15.867	95.500
.P1TANG	28	56.000	86.500	70.411	7.1454	10.148	69.500
.P1FLX	28	22.000	68.000	48.607	9.5242	19.594	49.500
.P1EXT	28	21.500	78.500	49.643	12.247	24.669	50.000
.P1ROM	30	70.000	131.50	98.567	14.863	15.079	98.500
.P2NTANG	31	50.000	80.500	69.355	6.6773	9.628	70.000
.P2FLX	31	29.500	65.500	50.532	10.926	21.622	53.000
.P2EXT	31	5.0000	72.000	50.452	13.349	26.459	49.500
.P2ROM	31	67.000	130.00	100.98	18.146	17.970	105.500
.P3NTANG	30	55.500	84.500	69.233	6.9502	10.039	69.500
.P3FLX	30	24.000	68.000	50.900	11.332	22.264	51.000
.P3EXT	30	32.500	81.500	52.617	11.380	22.578	51.500
.P3ROM	30	62.000	132.00	103.52	16.791	16.220	106.000
.XPAVGNT	31	55.375	80.250	69.801	5.8769	8.419	69.500
.XPAVGFLX	31	26.125	65.625	48.593	9.1839	18.900	49.875
.XPAVGEXT	31	23.250	76.375	51.298	10.611	20.685	51.125
.XPAVGROM	31	73.250	131.38	99.821	14.530	14.556	100.875
.PAVGNT	31	55.000	81.000	69.640	6.3284	9.087	69.500
.PAVGFLX	31	27.833	65.167	49.758	9.8029	19.685	50.167
.PAVGEXT	31	22.500	74.833	51.148	11.105	21.712	50.167
.PAVGROM	31	71.333	129.67	100.77	15.864	15.743	104.750

TABLE C.7 RANGE OF MOTION BY SEX AND AGE MALES 18-24

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
XNTANG	28	62.500	88.000	77.107	6.6588	8.636	77.000
.XFLEX	30	39.000	75.500	62.450	7.8007	12.491	61.000
.XEXT	30	54.500	112.50	79.617	15.172	19.057	78.000
.XROM	30	102.50	174.00	142.07	15.901	11.193	141.500
.P1TANG	30	62.500	88.000	74.867	6.2325	8.325	74.500
P1FLX	30	44.000	80.000	62.950	10.214	16.225	63.000
.P1EXT	30	56.000	100.00	71.067	9.6541	13.585	70.500
.P1ROM	30	104.50	165.00	134.02	13.927	10.392	133.000
.P2NTANG	30	60.000	88.000	74.617	7.0181	9.405	74.000
.P2FLX	29	37.500	84.500	63.569	10.231	16.094	63.500
.P2EXT	28	59.000	90.000	70.982	8.7533	12.332	68.500
.P2ROM	28	104.50	166.50	134.68	12.427	9.227	132.500
.P3NTANG	30	60.000	87.500	74.300	7.1155	9.577	74.500
.P3FLX	30	42.500	84.000	65.183	9.2097	14.129	65.000
.P3EXT	30	50.500	97.500	72.467	11.024	15.213	70.000
.P3ROM	30	103.00	162.00	137.62	13.130	9.541	135.500
.XPAVGNT	30	61.500	87.875	75.289	6.2468	8.297	75.500
.XPAVGFLX	30	47.375	80.250	63.543	7.6880	12.099	64.167
.XPAVGEXT	30	60.500	103.33	73.822	10.305	13.959	70.250
.XPAVGROM	30	114.63	164.83	137.37	11.790	8.583	135.125
.PAVGNT	30	61.167	87.833	74.594	6.5011	8.715	74.167
.PAVGFLX	30	41.500	84.333	63.925	9.3012	14.550	64.500
.PAVGEXT	30	59.333	98.750	71.836	9.3793	13.056	69.500
.PAVGROM	30	105.17	164.50	135.76	12.628	9.302	133.833

TABLE C.8 RANGE OF MOTION BY SEX AND AGE MALES 35-44

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.XNTANG	30	60.000	[illegible]8.000	76.850	6.6555	8.660	76.500
.XFLEX	30	27.500	76.000	51.183	13.157	25.705	52.500
.XEXT	30	34.000	81.000	56.783	11.798	20.777	56.500
.XROM	30	74.500	144.00	107.97	18.516	17.149	109.500
.P1TANG	30	55.500	83.000	73.933	6.0767	8.219	74.000
.P1FLX	30	36.500	79.500	53.467	10.504	19.645	52.000
.P1EXT	30	34.500	78.500	55.267	12.366	22.376	53.000
.P1ROM	30	76.500	152.00	108.73	18.648	17.150	105.500
.P2NTANG	30	62.500	82.000	73.600	4.8181	6.546	74.000
.P2FLX	30	31.000	77.500	54.650	12.427	22.739	56.500
.P2EXT	30	35.000	83.500	54.633	12.515	22.907	51.000
P2ROM	30	65.000	149.00	109.28	20.464	18.726	109.000
P3NTANG	30	61.000	82.500	73.033	5.5661	7.621	74.000
P3FLX	30	32.500	78.500	56.017	10.912	19.480	53.000
P3EXT	30	23.500	81.000	54.633	13.570	24.839	55.000
P3ROM	30	65.500	148.00	110.65	19.311	17.453	107.000
XPAVGNT	30	62.000	81.000	74.354	4.9372	6.640	74.625
XPAVGFLX	30	36.375	75.625	53.829	10.359	20.174	52.500
XPAVGEXT	30	34.250	76.500	55.329	11.680	21.110	54.750
XPAVGROM	30	70.625	148.25	109.16	18.476	16.926	107.000
PAVGNT	30	59.667	81.667	73.522	5.0326	6.845	73.667
.PAVGFLX	30	33.833	78.333	54.711	10.741	19.632	53.667
.PAVGEXT	30	22.000	78.000	54.844	12.364	22.543	54.667
PAVGROM	30	69.333	149.67	109.56	19.098	17.433	106.000

TABLE C.9 RANGE OF MOTION BY SEX AND AGE MALES 62-74

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
XNTANG	27	64.000	89.500	74.648	6.0619	8.121	74.500
XFLFX	26	27.500	72.000	47.558	9.5229	20.024	47.000
XEXT	26	28.500	82.500	49.500	11.221	22.670	50.000
XROM	26	59.500	127.00	97.058	17.020	17.536	99.000
.P1TANG	27	65.000	85.500	73.759	5.1204	6.942	73.000
.P1FLX	27	23.500	77.500	47.056	10.848	23.054	47.500
.P1EXT	27	20.000	68.000	47.648	10.792	22.648	48.000
.P1ROM	27	57.000	127.00	94.704	17.536	18.517	95.500
.P2NTANG	27	57.000	85.000	71.481	7.0622	9.880	71.000
.P2FLX	27	25.000	75.500	48.630	11.669	23.996	47.500
.P2EXT	27	13.000	74.500	45.815	14.058	30.684	48.000
.P2ROM	27	38.000	123.50	94.444	18.366	19.446	96.000
.P3NTANG	26	53.000	88.000	71.019	8.0405	11.322	71.500
.P3FLX	26	21.500	70.500	48.712	13.062	26.814	50.000
.P3EXT	26	14.000	76.500	46.135	13.474	29.206	45.500
.P3ROM	26	40.000	126.50	94.846	19.916	20.998	99.000
.XPAVGNT	27	62.750	86.375	72.731	5.7132	7.855	71.750
.XPAVGFLX	27	26.000	73.875	47.937	9.5421	19.906	47.250
.XPAVGEXT	27	20.750	75.375	47.130	11.373	24.131	47.500
.XPAVGROM	27	53.625	124.38	95.066	16.487	17.343	93.875
.PAVGNT	27	61.500	85.333	72.090	6.0048	8.330	71.250
.PAVGFLX	27	25.500	74.500	48.028	10.905	22.705	47.167
.PAVGEXT	27	15.667	73.000	46.414	12.199	26.284	48.167
.PAVGROM	27	45.000	124.50	94.441	18.004	19.064	95.000

TABLE C.10 RANGE OF MOTION BY SEX,AGE AND STATURE FEMALES 18-24 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	68.000	86.000	76.550	5.4029	7.058
.XFLEX	10	38.500	71.000	60.200	10.277	17.072
.XEXT	10	51.000	96.000	66.300	14.336	21.622
.XROM	10	98.000	152.00	126.40	17.715	14.015
.P1TANG	9	66.500	78.000	70.389	3.3799	4.802
.P1FLX	9	47.000	74.500	61.389	8.5175	13.875
.P1EXT	9	51.500	77.000	62.611	8.9749	14.334
.P1ROM	9	98.500	140.50	124.00	13.105	10.569
.P2NTANG	10	64.000	77.000	70.700	4.1513	5.872
.P2FLX	10	50.500	78.000	62.250	7.4096	11.903
.P2EXT	10	55.000	80.500	66.950	8.7542	13.076
.P2ROM	10	105.50	143.50	129.20	11.889	9.202
.P3NTANG	10	62.500	77.000	70.750	4.3028	6.082
.P3FLX	10	49.000	84.000	63.300	10.398	16.427
.P3EXT	10	51.500	81.500	68.200	9.2051	13.497
.P3ROM	10	101.00	145.00	131.50	14.636	11.130
.XPAVGNT	10	68.625	77.750	72.271	3.3475	4.632
.XPAVGFLX	10	46.375	76.750	61.767	8.1668	13.222
.XPAVGEXT	10	54.625	86.000	66.600	9.4312	14.161
.XPAVGROM	10	100.75	146.67	128.34	13.187	10.275
.PAVGNT	10	64.333	77.000	70.833	3.7400	5.280
.PAVGFLX	10	49.000	78.833	62.375	8.0918	12.973
.PAVGEXT	10	52.667	81.000	66.533	8.4059	12.634
.PAVGROM	10	101.67	144.25	128.91	12.369	9.595

TABLE C.11 RANGE OF MOTION BY SEX,AGE AND STATURE FEMALES 18-24 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	68.000	88.000	77.350	5.5280	7.147
.XFLEX	10	46.500	75.000	61.300	8.5186	13.897
.XEXT	10	53.500	112.50	77.150	18.096	23.455
.XROM	10	114.50	173.50	138.45	16.940	12.236
.P1TANG	9	66.000	86.000	75.833	6.3443	8.366
.P1FLX	9	34.000	79.500	55.222	15.429	27.941
.P1EXT	9	56.000	91.500	74.389	13.019	17.501
.P1ROM	10	96.500	150.50	131.50	16.240	12.349
.P2NTANG	10	62.500	85.000	75.250	7.4731	9.931
.P2FLX	10	39.500	90.500	61.650	14.735	23.901
.P2EXT	10	56.000	87.500	73.150	12.120	16.569
.P2ROM	10	102.00	155.50	134.80	16.684	12.377
.P3NTANG	10	64.000	87.000	73.900	6.8629	9.287
.P3FLX	10	38.500	86.500	61.150	15.669	25.623
.P3EXT	10	57.000	87.000	72.450	10.715	14.789
.P3ROM	10	106.50	161.00	133.60	16.728	12.521
.XPAVGNT	10	65.625	86.500	75.567	5.8164	7.697
.XPAVGFLX	10	40.875	82.875	60.200	12.470	20.714
.XPAVGEXT	10	55.625	94.375	74.458	12.687	17.039
.XPAVGROM	10	109.25	154.88	134.59	13.862	10.300
.PAVGNT	10	64.833	86.000	74.942	6.3891	8.525
.PAVGFLX	10	37.333	35.500	60.042	14.937	24.878
.PAVGEXT	10	56.333	88.333	73.583	11.348	15.421
.PAVGROM	10	103.17	155.00	133.30	15.494	11.624

TABLE C.12 RANGE OF MOTION BY SEX,AGE AND STATURE FEMALES 18-24 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	74.000	87.000	80.600	3.8644	4.795
.XFLEX	10	49.500	75.000	61.150	7.2344	11.831
.XEXT	10	66.000	110.00	87.850	17.700	20.148
.XROM	10	121.50	166.50	148.00	17.440	11.784
.P1TANG	10	68.500	89.000	78.500	6.8799	8.764
.P1FLX	10	48.500	71.000	57.500	7.4012	12.872
.P1EXT	10	67.500	117.50	84.650	14.905	17.608
.P1ROM	10	125.00	168.50	142.15	14.480	10.186
.P2NTANG	10	68.500	88.000	77.600	6.3631	8.200
.P2FLX	10	46.000	80.000	62.200	8.5836	13.800
.P2EXT	10	69.000	109.50	85.500	12.647	14.792
.P2ROM	10	125.50	170.00	147.70	13.977	9.463
.P3NTANG	10	71.500	88.500	79.600	5.8680	7.372
.P3FLX	10	39.500	81.500	60.700	12.878	21.216
.P3EXT	10	72.000	108.00	85.950	10.897	12.678
.P3ROM	10	126.50	163.50	146.65	14.468	9.866
.XPAVGNT	10	70.625	88.125	79.075	5.3755	6.798
.XPAVGFLX	10	48.000	75.250	60.387	8.0701	13.364
.XPAVGEXT	10	71.625	111.25	85.987	13.091	15.225
.XPAVGROM	10	124.75	166.50	146.13	13.303	9.104
.PAVGNT	10	69.500	88.500	78.567	6.0859	7.746
.PAVGFLX	10	44.667	77.500	60.133	9.0140	14.990
.PAVGEXT	10	71.500	111.67	85.367	12.399	14.524
.PAVGROM	10	125.83	166.50	145.50	12.823	8.813

TABLE C.13 RANGE OF MOTION BY SEX,AGE AND STATURE FEMALES 35-44 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	68.000	81.000	72.900	3.8210	5.241
.XFLEX	10	52.000	70.500	62.250	6.3037	10.126
.XEXT	10	44.500	73.500	56.200	8.5512	15.216
.XROM	10	96.500	134.50	118.45	12.205	10.304
.P1TANG	10	66.500	77.000	71.550	3.4030	4.756
.P1FLX	10	38.000	74.000	57.500	11.951	20.785
.P1EXT	10	39.500	72.500	59.400	10.690	17.996
.P1ROM	10	[illegible]4.000	141.00	116.90	18.704	16.000
.P2NTANG	10	64.500	78.500	69.650	3.7197	5.341
.P2FLX	10	44.500	81.000	61.250	11.149	18.202
.P2EXT	10	36.500	72.000	58.250	11.984	20.574
.P2ROM	10	90.000	146.00	119.50	16.367	13.696
.P3NTANG	10	64.000	79.500	70.350	4.7612	6.768
.P3FLX	10	45.000	75.500	60.000	10.677	17.795
.P3EXT	10	35.500	69.500	57.150	11.652	20.389
.P3ROM	10	96.500	145.00	117.15	15.228	12.999
.XPAVGNT	10	67.000	79.000	71.112	3.4169	4.805
.XPAVGFLX	10	50.250	74.750	60.250	8.0305	13.329
.XPAVGEXT	10	40.375	71.875	57.750	10.015	17.343
.XPAVGROM	10	94.000	141.63	118.00	14.250	12.077
.PAVGNT	10	66.333	78.333	70.517	3.5957	5.099
.PAVGFLX	10	44.667	76.333	59.583	10.665	17.899
.PAVGEXT	10	37.167	71.333	58.267	11.005	18.887
.PAVGROM	10	90.167	144.00	117.85	16.507	14.007

TABLE C.14 RANGE OF MOTION BY SEX,AGE AND STATURE FEMALES 35-44 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	9	63.000	30.000	73.333	5.7554	7.848
.XFLEX	9	45.500	74.500	57.889	10.380	17.930
.XEXT	9	46.500	85.000	64.667	14.246	22.029
.XROM	9	103.50	136.50	122.56	10.777	8.794
.P1TANG	6	65.000	73.500	69.333	2.9777	4.295
.P1FLX	6	36.500	69.000	56.917	11.736	20.620
.P1EXT	6	49.000	77.000	64.917	12.761	19.657
.P1ROM	8	85.500	144.00	122.69	18.902	15.407
.P2NTANG	9	60.500	77.500	70.111	5.3489	7.629
.P2FLX	9	33.000	73.500	57.556	12.606	21.902
.P2EXT	9	46.500	81.000	63.111	12.374	19.606
.P2ROM	9	91.000	146.00	120.67	19.237	15.942
.P3NTANG	9	59.500	83.000	70.111	7.5572	10.779
.P3FLX	9	41.000	80.500	59.333	14.186	23.909
.P3EXT	9	48.000	81.000	64.389	11.837	18.383
.P3ROM	9	92.500	156.50	123.72	20.762	16.781
.XPAVGNT	9	63.625	80.167	70.977	5.2790	7.438
.XPAVGFLX	9	44.250	72.000	58.051	10.190	17.554
.XPAVGEXT	9	50.500	79.125	63.718	11.817	18.545
.XPAVGROM	9	95.750	145.50	121.78	17.084	14.029
.PAVGNT	9	61.667	80.250	70.148	5.5341	7.889
.PAVGFLX	9	36.833	71.500	57.991	12.288	21.189
.PAVGEXT	9	49.833	77.333	63.454	11.509	18.137
.PAVGROM	9	89.667	148.83	121.45	19.618	16.153

TABLE C.15 RANGE OF MOTION BY SEX,AGE AND STATURE FEMALES 35-44 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
XNTANG	11	67.000	84.500	75.636	5.9586	7.878
XFLEX	11	33.000	79.000	57.318	13.947	24.332
XEXT	11	42.500	93.000	63.591	13.720	21.576
XROM	11	95.000	143.00	120.91	17.190	14.217
P1TANG	11	66.500	85.500	75.409	5.4581	7.238
P1FLX	11	34.000	68.000	55.682	10.628	19.088
P1EXT	11	54.500	91.000	68.227	8.3796	12.282
P1ROM	11	96.500	141.00	123.91	16.575	13.377
P2NTANG	11	64.500	79.500	72.409	4.5377	6.267
P2FLX	11	54.000	72.500	62.318	6.2019	9.952
P2EXT	11	43.000	88.000	66.909	12.932	19.328
P2ROM	11	98.500	155.00	129.23	16.816	13.013
P3NTANG	11	61.000	79.500	72.773	5.2075	7.156
P3FLX	11	50.000	73.000	62.682	7.5109	11.983
P3EXT	11	53.000	85.500	66.273	9.7246	14.674
P3ROM	11	106.00	148.50	128.95	15.044	11.666
XPAVGNT	11	67.250	81.375	74.057	4.3234	5.838
XPAVGFLX	11	44.875	72.250	59.500	7.9606	3.379
XPAVGEXT	11	52.375	78.625	66.250	8.1603	12.317
XPAVGROM	11	101.38	145.00	125.75	14.555	11.574
PAVGNT	11	66.167	81.500	73.530	4.1712	5.673
PAVGFLX	11	48.667	70.000	60.227	7.5734	12.575
PAVGEXT	11	53.500	82.000	67.136	9.1490	13.628
PAVGROM	11	102.33	147.83	127.36	15.557	12.215

TABLE C.16 RANGE OF MOTION BY SEX, AGE AND STATURE FEMALES 62-74 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
XNTANG	10	55.000	78.000	68.750	6.0656	8.823
XFLEX	10	39.500	67.000	48.650	9.7726	20.087
XEXT	10	33.000	60.500	46.450	9.0874	19.564
XROM	10	72.500	127.50	95.100	14.554	15.304
P1TANG	10	57.000	84.000	70.200	7.1266	10.152
P1FLX	10	23.500	68.000	48.850	10.588	21.675
P1EXT	10	21.500	63.000	47.250	13.651	28.891
P1ROM	10	81.500	122.00	96.100	13.339	13.881
P2NTANG	10	59.500	80.500	69.100	6.9234	10.019
P2FLX	10	34.000	65.500	52.600	11.506	21.874
P2EXT	10	30.000	62.500	50.650	9.9862	19.716
P2ROM	10	82.000	127.50	103.25	16.725	16.199
P3NTANG	9	55.500	79.000	68.444	7.4391	10.869
P3FLX	10	42.000	66.000	54.950	9.4940	17.278
P3EXT	10	33.000	68.500	51.000	10.384	20.361
P3ROM	10	83.500	124.00	105.95	14.538	13.722
XPAVGNT	10	56.750	80.250	69.129	6.4312	9.303
XPAVGFLX	10	39.875	65.625	51.262	9.0476	17.650
XPAVGEXT	10	32.500	61.375	48.837	8.0243	16.431
XPAVGROM	10	82.875	117.13	100.10	12.449	12.436
PAVGNT	10	57.333	81.000	69.267	6.6797	9.643
PAVGFLX	10	39.333	65.167	52.133	9.6883	18.584
PAVGEXT	10	22.333	64.000	49.633	9.4152	18.970
PAVGROM	10	63.000	119.33	101.77	13.807	13.567

TABLE C.17 RANGE OF MOTION BY SEX,AGE AND STATURE FEMALES 62-74 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	58.500	78.000	69.350	6.6251	9.553
.XFLEX	10	38.000	57.000	47.850	6.4033	13.382
.XEXT	10	25.500	83.000	49.200	16.071	32.665
.XROM	10	71.000	136.50	97.050	18.263	18.818
.P1TANG	9	56.000	80.500	70.222	7.1024	10.114
.P1FLX	9	46.000	57.000	51.556	3.9564	7.674
.P1EXT	9	26.500	78.500	50.444	14.176	28.103
.P1ROM	9	72.500	131.50	102.00	15.805	15.496
.P2NTANG	10	56.000	77.000	69.800	8.7152	12.486
.P2FLX	10	31.000	65.500	54.050	10.051	18.596
.P2EXT	10	5.0000	72.000	47.000	18.504	39.370
.P2ROM	10	67.000	130.00	101.05	20.328	20.117
.P3NTANG	10	59.000	84.500	70.250	7.8324	11.149
.P3FLX	9	31.500	68.000	51.444	11.772	22.884
.P3EXT	9	22.500	81.500	52.556	16.499	31.393
.P3ROM	9	76.000	127.50	104.00	17.375	16.706
.XPAVGNT	10	55.875	77.875	70.046	6.8667	9.803
.XPAVGFLX	10	36.167	58.250	50.687	6.3393	12.507
.XPAVGEXT	10	23.250	76.875	49.733	14.838	29.835
.XPAVGROM	10	73.250	121.38	100.42	16.602	16.533
.PAVGNT	10	55.000	78.000	70.242	7.3818	10.509
.PAVGFLX	10	31.250	60.167	51.592	8.4744	16.426
.PAVGEXT	10	22.500	74.833	49.850	14.993	30.077
.PAVGROM	10	71.333	129.67	101.44	17.748	17.496

TABLE C.18 RANGE OF MOTION BY SEX,AGE AND STATURE FEMALES 62-74 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	11	60.000	30.000	72.182	5.5555	7.697
.XFLEX	11	18.000	59.500	39.818	12.921	32.451
.XFEXT	11	45.500	71.500	58.545	8.0544	13.757
.XROM	11	76.500	125.50	98.318	14.576	14.825
.P1TANG	9	58.000	86.500	70.833	8.0273	11.333
.P1FLX	9	22.000	58.500	45.389	11.952	26.333
.P1EXT	9	35.000	64.500	51.500	9.1549	17.777
.P1ROM	11	70.000	120.50	98.000	16.236	16.567
.P2NTANG	11	62.000	76.000	69.182	4.6865	6.774
.P2FLX	11	29.500	59.000	45.455	10.152	22.335
.P2EXT	11	40.000	70.500	53.409	10.728	20.087
.P2ROM	11	72.000	126.50	98.864	18.818	19.034
.P3NTANG	11	60.000	77.500	68.955	6.2388	9.048
.P3FLX	11	24.000	59.500	46.773	12.042	25.747
.P3EXT	11	38.000	72.500	54.136	9.4501	17.456
.P3ROM	11	62.000	132.00	100.91	19.294	19.120
.XPAVGNT	11	63.000	77.625	70.169	4.8244	6.873
.XPAVGFLX	11	26.125	58.250	44.261	10.537	23.807
.XPAVGEXT	11	43.875	66.000	54.958	7.6457	13.912
.XPAVGROM	11	75.125	120.25	99.023	15.643	15.798
.PAVGNT	11	60.333	77.500	69.432	5.5135	7.941
.PAVGFLX	11	27.833	57.833	46.045	10.725	23.291
.PAVGEXT	11	43.333	69.167	53.705	8.7583	16.308
.PAVGROM	11	73.333	126.17	99.258	17.205	17.334

TABLE C.19 RANGE OF MOTION BY SEX,AGE AND STATURE MALES 18-24 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	9	62.500	85.500	76.389	7.3305	9.596
.XFLEX	10	39.000	75.500	60.050	9.5756	15.946
.XEXT	10	55.500	98.500	75.100	12.765	16.997
.XROM	10	102.50	160.50	135.15	15.983	11.826
.P1TANG	10	62.500	84.000	72.650	6.2940	8.663
.P1FLX	10	44.500	89.000	62.750	13.050	20.796
.P1EXT	10	56.500	79.000	67.450	8.2780	12.273
.P1ROM	10	104.50	165.00	130.20	18.582	14.272
.P2NTANG	10	60.000	86.000	72.150	7.5168	10.418
.P2FLX	10	37.500	82.000	62.450	12.831	20.546
.P2EXT	10	59.000	84.500	68.700	7.3907	10.758
.P2ROM	10	104.50	166.50	131.15	16.667	12.708
.P3NTANG	10	61.000	81.500	71.050	6.5211	9.178
.P3FLX	10	42.500	82.000	64.100	11.709	18.267
.P3EXT	10	59.500	82.500	69.150	6.8761	9.944
.P3ROM	10	103.00	152.00	133.25	15.465	11.606
.XPAVGNT	10	61.500	84.250	73.079	6.4224	8.788
.XPAVGFLX	10	47.375	78.125	62.337	9.8363	15.779
.XPAVGEXT	10	60.500	85.375	70.100	7.7034	10.989
.XPAVGROM	10	114.63	153.50	132.44	14.261	10.768
.PAVGNT	10	61.167	83.833	71.950	6.4755	9.000
.PAVGFLX	10	41.500	83.500	63.100	12.211	19.352
.PAVGEXT	10	60.000	81.000	68.433	6.4765	9.464
.PAVGROM	10	105.17	164.50	131.53	16.407	12.474

TABLE C.20 RANGE OF MOTION BY SEX,AGE AND STATURE MALES 18-24 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	68.500	88.000	77.100	6.1860	8.023
.XFLEX	10	53.500	75.000	63.200	6.6089	10.457
.XEXT	10	54.500	110.50	82.800	16.528	19.961
.XROM	10	122.50	171.50	146.00	15.774	10.804
.P1TANG	10	70.000	83.000	76.200	5.8793	7.716
.P1FLX	10	44.000	72.000	61.500	9.2346	15.016
.P1EXT	10	56.000	84.000	71.100	7.6768	10.797
.P1ROM	10	115.50	145.50	132.60	9.1251	6.882
.P2NTANG	10	65.000	88.000	75.650	6.7167	8.879
.P2FLX	10	51.500	74.500	63.200	7.2426	11.460
.P2EXT	10	59.500	90.000	71.600	10.135	14.155
.P2ROM	10	120.50	153.00	134.80	9.4110	6.981
.P3NTANG	10	60.000	87.500	74.500	7.4722	10.030
.P3FLX	10	53.500	71.500	66.450	6.0526	9.109
.P3EXT	10	60.000	94.500	72.750	11.016	15.142
.P3ROM	10	129.50	155.00	139.20	9.0253	6.484
.XPAVGNT	10	65.875	87.875	75.862	6.1561	8.115
.XPAVGFLX	10	52.375	73.750	63.587	5.9264	9.320
.XPAVGEXT	10	61.500	92.125	74.563	9.1900	12.325
.XPAVGROM	10	131.00	148.88	138.15	7.2693	5.262
.PAVGNT	10	65.000	87.933	75.450	6.5206	8.642
.PAVGFLX	10	50.000	72.000	63.717	6.8611	10.768
.PAVGEXT	10	59.333	86.000	71.817	8.6286	12.015
.PAVGROM	10	127.33	151.00	135.53	7.7443	5.714

TABLE C.21 RANGE OF MOTION BY SEX,AGE AND STATURE MALES 18-24 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	9	68.500	88.000	77.833	7.1894	9.237
.XFLEX	10	55.000	75.500	64.100	7.1173	11.103
.XEXT	10	61.000	112.50	80.950	16.424	20.289
.XROM	10	123.50	174.00	145.05	15.174	10.461
P1TANG	10	63.000	84.000	75.750	6.5330	8.624
.P1FLX	10	57.000	84.500	64.600	8.6692	13.420
.P1EXT	10	60.000	100.00	74.650	12.002	16.078
.P1ROM	10	120.50	159.00	139.25	12.148	8.724
.P2NTANG	10	62.500	85.500	76.050	6.8453	9.001
.P2FLX	9	53.500	84.500	65.222	10.831	16.607
.P2EXT	8	63.500	88.500	73.063	8.9620	12.266
.P2ROM	8	128.50	152.50	138.94	9.2792	6.679
.P3NTANG	10	65.000	85.500	77.350	6.5322	8.445
.P3FLX	10	53.000	64.000	65.000	9.8206	15.109
.P3EXT	10	50.500	97.500	75.500	14.158	18.752
.P3ROM	10	115.00	161.50	140.40	14.224	10.131
.XPAVGNT	10	65.375	85.000	76.925	6.1507	7.996
.XPAVGFLX	10	55.125	80.250	64.704	7.4472	11.510
.XPAVGEXT	10	60.375	103.33	76.804	13.133	17.100
.XPAVGROM	10	124.50	164.83	141.51	12.039	8.507
.PAVGNT	10	63.500	85.000	76.383	6.2923	8.238
.PAVGFLX	10	54.500	84.333	64.958	8.9768	13.819
.PAVGEXT	10	60.333	98.750	75.258	11.882	15.788
.PAVGROM	10	121.33	160.25	140.22	11.946	8.520

TABLE C.22 RANGE OF MOTION BY SEX,AGE AND STATURE MALES 35-44 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	60.000	79.000	71.400	5.4610	7.648
.XFLEX	10	27.500	69.000	50.300	14.240	28.311
.XEXT	10	34.000	67.000	51.550	9.7138	18.843
.XROM	10	83.000	122.50	101.85	14.633	14.367
.P1TANG	10	55.500	78.500	69.200	6.6173	9.563
.P1FLX	10	39.500	66.000	53.150	8.8225	16.599
.P1EXT	10	34.500	78.500	50.350	12.320	24.469
.P1ROM	10	86.000	130.00	103.50	15.429	14.907
.P2NTANG	10	62.500	77.500	70.300	4.6975	6.682
.P2FLX	10	39.500	70.000	51.950	10.412	20.043
.P2EXT	10	39.000	76.000	51.300	10.691	20.839
.P2ROM	10	81.500	120.00	103.25	12.986	12.577
.P3NTANG	10	61.000	82.000	68.100	5.8822	8.638
.P3FLX	10	45.500	70.000	55.550	8.5844	15.453
.P3EXT	10	36.500	72.500	49.550	10.434	21.057
.P3ROM	10	83.000	123.50	105.10	12.767	12.147
.XPAVGNT	10	62.000	78.375	69.750	5.0607	7.256
.XPAVGFLX	10	40.750	68.125	52.737	9.7139	18.419
.XPAVGEXT	10	39.500	73.500	50.688	9.9835	19.696
.XPAVGROM	10	83.500	119.50	103.42	12.785	12.362
.PAVGNT	10	59.667	78.167	69.200	5.2978	7.656
.PAVGFLX	10	44.000	67.833	53.550	8.6553	16.163
.PAVGEXT	10	29.333	75.667	50.400	10.738	21.305
.PAVGROM	10	83.667	124.17	103.95	13.267	12.762

TABLE C.23 RANGE OF MOTION BY SEX.AGE AND STATURE MALES 35-44 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	73.000	88.000	80.900	4.2216	5.218
.XFLEX	10	37.000	70.000	51.250	10.133	19.772
.XEXT	10	39.000	67.000	55.100	10.110	18.348
.XROM	10	76.000	133.00	106.35	17.923	16.853
.P1TANG	10	68.500	83.000	75.850	5.0445	6.651
.P1FLX	10	36.500	71.000	52.550	10.029	19.085
.P1EXT	10	36.500	69.500	54.350	10.752	19.784
.P1ROM	10	82.000	140.50	106.90	17.288	16.172
.P2NTANG	10	69.000	81.000	75.800	3.6071	4.759
.P2FLX	10	32.500	77.500	53.150	13.151	24.743
.P2EXT	10	35.500	33.500	54.750	12.566	22.951
.P2ROM	10	81.500	148.00	107.90	20.041	18.574
.P3NTANG	10	73.000	79.500	76.350	2.3100	3.026
.P3FLX	0	32.500	75.500	52.550	11.807	22.469
.P3EXT	10	33.000	81.000	56.400	13.691	24.274
.P3ROM	10	86.000	144.50	108.95	17.999	16.521
.XPAVGNT	10	73.250	81.000	77.225	3.3176	4.296
.XPAVGFLX	10	37.875	71.500	52.375	10.604	20.247
.XPAVGEXT	10	36.125	75.250	55.150	11.206	20.322
.XPAVGROM	10	82.250	141.50	107.52	17.695	16.457
.PAVGNT	10	71.333	79.667	76.000	3.2565	4.285
.PAVGFLX	10	33.833	72.000	52.750	11.338	21.494
.PAVGEXT	10	35.000	78.000	55.167	11.924	21.615
.PAVGROM	10	84.333	144.33	107.92	18.145	16.813

TABLE C.24 RANGE OF MOTION BY SEX,AGE AND STATURE MALES 35-44 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	67.000	86.000	78.250	6.4560	8.251
.XFLEX	10	30.000	76.000	52.000	15.832	30.447
.XEXT	10	41.000	81.000	63.700	12.852	20.176
.XROM	10	74.500	144.00	115.70	21.410	18.505
.P1TANG	10	72.500	81.500	76.750	3.4581	4.506
.P1FLX	10	37.000	79.500	54.700	13.204	24.139
.P1EXT	10	37.500	73.500	61.100	12.640	20.687
.P1ROM	10	76.500	152.00	115.80	22.224	19.192
.P2NTANG	10	66.500	82.000	74.700	4.5717	6.120
.P2FLX	10	31.000	77.000	58.850	13.640	23.178
.P2EXT	10	35.000	74.000	57.850	14.443	24.967
.P2ROM	10	66.000	149.00	116.70	25.988	22.269
.P3NTANG	10	70.000	82.500	74.650	4.2101	5.640
.P3FLX	10	42.000	78.500	59.950	11.824	19.723
.P3EXT	10	23.500	77.500	57.950	15.896	27.431
.P3ROM	10	65.500	143.00	117.90	24.877	21.100
.XPAVGNT	10	72.125	79.500	76.087	2.4246	3.187
.XPAVGFLX	10	36.375	75.625	56.375	12.740	22.599
.XPAVGEXT	10	34.250	76.500	60.150	12.827	21.324
.XPAVGROM	10	70.625	148.25	116.52	22.883	19.638
.PAVGNT	10	70.167	81.667	75.367	3.4028	4.515
.PAVGFLX	10	37.333	78.333	57.833	12.315	21.294
.PAVGEXT	10	32.000	75.000	58.967	13.933	23.628
.PAVGROM	10	69.333	149.67	116.80	23.956	20.510

TABLE C.25 RANGE OF MOTION BY SEX.AGE AND STATURE MALES 62-74 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	6	68.500	76.000	72.167	2.7689	3.837
.XFLEX	6	41.000	66.000	51.333	9.7091	18.914
.XEXT	6	38.000	57.500	48.583	7.0811	14.575
.XROM	6	79.000	120.50	99.917	14.709	14.721
.P1NTANG	6	69.000	78.000	72.583	3.1530	4.344
.P1FLX	6	33.500	53.500	45.917	8.1512	17.752
.P1EXT	6	36.500	54.500	46.583	7.2830	15.634
.P1ROM	6	78.000	107.50	92.500	11.773	12.727
.P2NTANG	6	57.000	77.000	67.500	6.6933	9.916
.P2FLX	6	27.000	64.000	48.833	12.778	26.166
.P2EXT	6	33.500	52.000	43.250	6.5173	15.069
.P2ROM	6	75.500	104.50	92.083	12.039	13.074
.P3NTANG	5	53.000	74.500	65.800	8.9903	13.663
.P3FLX	5	26.000	68.000	54.300	16.498	30.384
.P3EXT	5	33.000	58.000	46.300	9.2100	19.892
.P3ROM	5	84.000	106.50	100.60	9.5355	9.479
.XPAVGNT	6	65.750	76.000	69.750	3.6563	5.242
.XPAVGFLX	6	38.125	56.125	49.646	7.1512	14.404
.XPAVGEXT	6	37.125	53.000	45.958	5.9784	13.008
.XPAVGROM	6	84.500	104.38	95.604	7.8396	8.200
.PAVGNT	6	62.333	76.500	68.931	4.8139	6.984
.PAVGFLX	6	28.833	58.167	48.903	11.753	24.033
.PAVGEXT	6	36.500	52.500	44.833	6.7594	15.077
.PAVGROM	6	76.750	105.00	93.736	12.020	12.823

TABLE C.26 RANGE OF MOTION BY SEX,AGE AND STATURE MALES 62-74 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
XNTANG	11	66.000	84.000	75.136	5.2254	6.955
.XFLEX	10	27.500	59.000	44.250	9.9729	22.538
.XEXT	10	28.500	58.000	43.650	9.0063	20.633
XROM	10	59.500	117.00	87.900	17.572	19.991
.P1TANG	11	68.000	85.500	74.455	4.8860	6.562
.P1FLX	11	23.500	65.000	44.182	11.572	26.192
.P1EXT	11	20.000	57.000	41.773	10.539	25.229
.P1ROM	11	57.000	122.00	85.955	19.233	22.376
.P2NTANG	11	66.500	76.500	71.682	3.1406	4.381
.P2FLX	11	25.000	65.000	46.864	12.576	26.835
.P2EXT	11	13.000	55.000	36.955	12.770	34.556
.P2ROM	11	38.000	107.50	83.818	19.967	23.821
.P3NTANG	11	63.000	82.000	71.591	5.4946	7.675
.P3FLX	11	21.500	62.000	44.227	14.397	32.552
.P3EXT	11	14.000	53.500	38.409	11.296	29.409
.P3ROM	11	40.000	114.50	82.636	21.456	25.964
.XPAVGNT	11	68.625	80.500	73.216	3.6461	4.980
.XPAVGFLX	11	26.000	60.375	44.947	11.001	24.477
.XPAVGEXT	11	20.750	54.875	40.091	9.5576	23.840
.XPAVGROM	11	53.625	115.25	85.038	17.625	20.726
.PAVGNT	11	68.000	79.667	72.576	3.6707	5.058
.PAVGFLX	11	25.500	60.833	45.091	12.045	26.712
.PAVGEXT	11	15.667	53.333	39.045	10.789	27.633
.PAVGROM	11	45.000	114.67	84.136	19.461	23.131

TABLE C.27 RANGE OF MOTION BY SEX,AGE AND STATURE MALES 62-74 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.XNTANG	10	64.000	89.500	75.600	3.1336	10.759
.XFLEX	10	41.500	72.000	48.600	8.7870	18.080
.XEXT	10	35.500	82.500	55.900	12.518	22.394
.XROM	10	78.000	127.00	104.50	14.680	14.048
.P1TANG	10	55.000	84.000	73.700	6.4944	8.812
.P1FLX	10	38.000	77.500	50.900	11.264	22.130
.P1EXT	10	41.000	68.000	54.750	9.1962	16.797
.P1ROM	10	88.000	127.00	105.65	13.056	12.357
.P2NTANG	10	59.000	85.000	73.650	9.6121	13.051
.P2FLX	10	38.500	75.500	50.450	10.928	21.660
.P2EXT	10	34.000	74.500	57.100	11.147	19.523
.P2ROM	10	91.500	123.50	107.55	10.879	10.116
.P3NTANG	10	59.000	88.000	73.000	9.4985	13.012
.P3FLX	10	41.000	70.500	50.850	8.6956	17.101
.P3EXT	10	30.500	76.500	54.550	13.160	24.125
.P3ROM	10	74.500	126.50	105.40	15.018	14.249
.XPAVGNT	10	62.750	86.375	73.987	8.0081	10.824
.XPAVGFLX	10	40.375	73.375	50.200	9.0324	17.993
.XPAVGEXT	10	39.000	75.375	55.575	10.563	19.008
.XPAVGROM	10	83.125	124.38	105.77	12.468	11.788
.PAVGNT	10	61.500	85.333	73.450	8.2050	11.171
.PAVGFLX	10	40.000	74.500	50.733	9.2960	18.323
.PAVGEXT	10	35.167	73.000	55.467	10.775	19.427
.PAVGROM	10	85.333	124.50	106.20	12.311	11.592

APPENDIX D

X-RAY RANGE OF MOTION - DESCRIPTIVE STATISTICS

Summary descriptive statistics from the X-ray range of motion portion of the study are contained in this appendix. These data are angular relationships between anatomical coordinate systems and between individual vertebrae and were all obtained from analysis of the X-rays. The order of reporting is as follows:

TABLE	
D.1	All Subjects Combined
D.2	Subjects grouped by Sex--Females
D.3	--Males
D.4	Subjects grouped by Sex and Age--Females, 18-24
D.5	--Females, 35-44
D.6	--Females, 62-74
D.7	--Males, 18-24
D.8	--Males, 35-44
D.9	--Males, 62-74

The data tables are in the format produced by the University of Michigan Statistical Laboratory Michigan Interactive Data Analysis System (MIDAS). Each of the measurements is given a code name; the measurement name associated with the code names are identified on the following page. All dimensions are in degrees.

CODE	MEASUREMENT NAME
FPVERTN	Angle from vertical to Frankfort Plane, head in neutral position
FPC7FL	Relative flexion between Frankfort Plane and the ventral surface of the C7 vertebra
FPC7EXT	Relative extension between Frankfort Plane and the ventral surface of the C7 vertebra
EWGVERTN	Angle from vertical to + X-axis of Ewing's spine anatomical coordinate system,* head in neutral position
FPEWG	Angle between Frankfort Plane and + X-axis of Ewing's spine anatomical coordinate system, head in neutral position
FPC2FLEX	Relative flexion between Frankfort Plane and C2 link. This measurement accounts for relative motion both between the skull and C1 and between C1 and C2.
FPC2EXT	Relative extension between Frankfort Plane and C2 link. This measurement accounts for relative motion both between the skull and C1 and between C1 and C2.
FPC2ROM	Total range of motion of skull relative to the C2 link
C2C3FL	Relative flexion between C2 and C3 links
C2C3EXT	Relative extension between C2 and C3 links
C2C3ROM	Total range of motion of C2 link relative to C3 link
C3C4FL	Relative flexion between C3 and C4 links
C3C4EXT	Relative extension between C3 and C4 links
C3C4ROM	Total range of motion of C3 link relative to C4 link

*The positive X-axis of this coordinate system is established by projecting a vector, from the midpoint of a line connecting the superior and inferior corners of the spinous process of T1 through the mid-sagittal anterior superior corner of the T1 vertebral body. See Ewing and Thomas (1972), p. 22.

CODE	MEASUREMENT NAME
C4C5FL	Relative flexion between C4 and C5 links
C4C5EXT	Relative extension between C4 and C5 links
C4C5ROM	Total range of motion of C4 link relative to C5 link
C5C6FL	Relative flexion between C5 and C6 links
C5C6EXT	Relative extension between C5 and C6 links
C5C6ROM	Total range of motion of C5 link relative to C6 link
C6C7FL	Relative flexion between C6 and C7 links
C6C7EXT	Relative extension between C6 and C7 links
C6C7ROM	Total range of motion of C6 link relative to C7 link

The following summary statistics are reported:

Column Heading	Statistic
N	Number of Observations
MINIMUM	Smallest Observation
MAXIMUM	Largest Observation
MEAN	Numerical Average
STD DEV	Standard Deviation

Note: Minimum and maximum values for the range of motion of individual links have been omitted. This was done because the combination of large sample size and precision of the X-ray coding device resulted in unusual extremes. The X-ray coding device does produce randomly-distributed errors, however, so the estimate of the mean may be considered reliable for the numbers of observations reported.

TABLE D.1 X RAY RANGE OF MOTION-ALL SUBJECTS COMBINED

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV
.FPVERTN	150	63.100	98.100	82.875	6.9179
.FPC7FL	175	5.5000	69.000	40.191	10.816
.FPC7EXT	172	15.500	98.500	56.401	17.918
.FPC7ROM	172	46.500	141.50	96.640	20.961
.EWGVERTN	130	74.900	118.10	94.458	8.0154
.FPEWG	116	-16.300	45.300	12.027	10.311
.FPC2FLEX	175			3.1051	7.3822
.FPC2EXT	176			17.649	8.3972
.FPC2ROM	175			20.817	9.8314
.C2C3FL	175			2.4880	6.8927
.C2C3EXT	176			1.9994	6.5688
.C2C3ROM	175			4.4983	6.9056
.C3C4FL	176			7.2977	9.7135
.C3C4EXT	176			5.9136	9.5635
.C3C4ROM	176			13.211	9.4339
.C4C5FL	176			12.516	8.4229
.C4C5EXT	176			10.484	10.199
.C4C5ROM	176			22.999	7.1202
.C5C6FL	176			8.9534	9.9478
.C5C6EXT	176			12.315	10.983
.C5C6ROM	176			21.269	9.8764
.C6C7FL	154			9.8526	9.9727
.C6C7EXT	153			8.9922	10.037
.C6C7ROM	152			18.692	10.616

TABLE D.2 X RAY RANGE OF MOTION BY SEX FEMALES

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV
.FPVERTN	34	63.100	96.300	82.088	6.5304
.FPC7FL	91	9.5000	67.000	40.615	10.402
.FPC7EXT	90	18.000	98.500	58.733	17.792
.FPC7ROM	90	56.500	141.50	99.667	19.724
.EWGVERTN	80	76.400	110.60	94.097	8.0387
.FPEWG	76	-16.300	45.300	12.220	10.577
.FPC2FLEX	90			4.4200	7.0943
.FPC2EXT	91			16.833	7.6950
.FPC2ROM	90			21.364	8.7937
.C2C3FL	90			3.0156	7.1194
.C2C3EXT	91			2.3495	6.9246
.C2C3ROM	90			5.3900	7.4120
.C3C4FL	91			6.7769	9.9069
.C3C4EXT	91			5.7571	9.5000
.C3C4ROM	91			12.534	8.7228
.C4C5FL	91			12.189	8.8568
.C4C5EXT	91			11.441	11.280
.C4C5ROM	91			23.630	7.2270
.C5C6FL	91			7.1989	10.866
.C5C6EXT	91			13.670	11.383
.C5C6ROM	91			20.869	9.8720
.C6C7FL	39			10.029	10.563
.C6C7EXT	88			10.236	9.6396
.C6C7ROM	88			20.252	11.301

TABLE D.3 X RAY RANGE OF MOTION BY SEX MALES

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV
.FPVERTN	66	66.300	98.100	83.876	7.3096
.FPC7FL	84	15.500	69.000	39.732	11.292
.FPC7EXT	82	15.500	92.000	53.841	17.313
.FPC7ROM	62	46.500	139.50	93.317	21.881
.EWGVERT	50	74.900	118.10	95.036	8.0250
.FPEWG	40	-9.7000	31.800	11.660	9.9058
.FPC2FLEX	85			1.7129	7.4665
.FPC2EXT	85			18.524	9.0534
.FPC2ROM	85			20.236	10.845
.C2C3FL	85			1.9294	6.6405
.C2C3EXT	85			1.6247	6.1842
.C2C3ROM	85			3.5541	6.2304
.C3C4FL	85			7.8553	9.5290
.C3C4EXT	85			6.0812	9.6846
.C3C4ROM	85			13.936	10.142
.C4C5FL	85			12.866	7.9699
.C4C5EXT	85			9.4588	8.8489
.C4C5ROM	85			22.325	6.9835
.C5C6FL	85			10.832	8.5299
.C5C6EXT	85			10.865	10.411
.C5C6ROM	85			21.696	9.9217
.C6C7FL	65			9.6108	9.1777
.C6C7EXT	65			7.3077	10.390
.C6C7ROM	64			16.547	9.7973

TABLE D.4 X RAY RANGE OF MOTION BY SEX AND AGE FEMALES 18-24

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV
.FPVERTN	25	67.400	96.300	85.488	6.3608
.FPC7FL	30	18.500	67.000	41.417	10.697
.FPC7EXT	29	52.000	98.500	76.414	11.196
.FPC7ROM	29	86.000	141.50	118.84	12.355
.EWGVERTN	25	76.400	105.30	91.668	8.3803
.FPEWG	23	-16.300	24.100	6.2913	10.070
.FPC2FLEX	30			5.9800	6.7512
.FPC2EXT	30			17.380	6.3237
.FPC2ROM	30			23.360	7.0989
.C2C3FL	30			3.7733	7.4775
.C2C3EXT	30			3.0700	8.1293
.C2C3ROM	30			6.8433	7.8276
.C3C4FL	30			4.4867	9.8509
.C3C4EXT	30			8.2233	9.5247
.C3C4ROM	30			12.710	8.1999
.C4C5FL	30			10.190	7.6958
.C4C5EXT	30			14.140	9.8628
.C4C5ROM	30			24.330	6.4955
.C5C6FL	30			1.9267	6.7063
.C5C6EXT	30			20.770	10.377
.C5C6ROM	30			22.697	9.8870
.C6C7FL	30			13.480	9.5231
.C6C7EXT	29			10.714	10.664
.C6C7ROM	29			24.272	10.922

TABLE D.5 X RAY RANGE OF MOTION BY SEX AND AGE FEMALES 35-44

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV
.FPVERTN	29	70.700	95.300	82.214	5.8155
.FPC7FL	30	22.000	65.000	44.600	8.6467
.FPC7EXT	30	24.500	81.500	56.033	14.242
.FPC7ROM	30	67.000	121.50	100.63	12.614
.EWGVERTN	29	80.700	108.10	95.748	7.0274
.FPEWG	28	-7.7000	28.700	13.400	8.7973
.FPC2FLEX	30			3.3933	6.3553
.FPC2EXT	30			17.747	8.4428
.FPC2ROM	30			21.143	11.294
.C2C3FL	30			2.8300	7.3452
.C2C3EXT	30			1.8300	6.5429
.C2C3ROM	30			4.6600	5.7989
.C3C4FL	30			8.7700	11.114
.C3C4EXT	30			5.6767	9.5525
.C3C4ROM	30			14.447	7.1136
.C4C5FL	30			11.157	8.7102
.C4C5EXT	30			14.070	12.389
.C4C5ROM	30			25.227	7.5977
.C5C6FL	30			9.8900	10.138
.C5C6EXT	30			10.807	10.716
.C5C6ROM	30			20.697	8.3222
.C6C7FL	30			9.6933	9.1986
.C6C7EXT	30			11.140	8.0042
.C6C7ROM	30			20.833	10.699

TABLE D.6 X RAY RANGE OF MOTION BY SEX AND AGE FEMALES 62-74

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV
.FPVERTN	30	63.100	94.100	79.133	6.0748
.FPC7FL	31	9.5000	57.500	35.984	10.151
.FPC7EXT	31	18.000	64.000	44.806	10.777
.FPC7ROM	31	56.500	102.50	80.790	11.541
EWGVERTN	26	79.700	110.60	94.592	8.4943
FPEWG	25	-1.1000	45.300	16.352	0.794
FPC2FLEX	30			3.8867	3.0367
FPC2EXT	31			15.419	8.1780
FPC2ROM	30			19.593	7.2078
C2C3FL	30			2.4433	6.6873
C2C3EXT	31			2.1548	6.1447
C2C3ROM	30			4.6667	8.3921
C3C4FL	31			7.0645	8.4805
C3C4EXT	31			3.4484	9.1240
C3C4ROM	31			10.513	10.317
C4C5FL	31			15.123	9.5280
C4C5EXT	31			6.2839	9.8820
.C4C5ROM	31			21.406	7.2078
.C5C6FL	31			9.6968	13.035
.C5C6EXT	1			9.5710	9.8809
.C5C6ROM	31			19.268	11.176
.C6C7FL	29			6.8069	12.062
.C6C7EXT	29			8.8241	10.270
.C6C7ROM	29			15.631	10.943

TABLE D.7 X RAY RANGE OF MOTION BY SEX AND AGE MALES 18-24

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV
.FPVERTN	23	66.300	98.000	84.052	7.6036
.FPC7FL	30	23.000	69.000	43.517	9.1317
.FPC7EXT	29	43.500	92.000	71.121	10.032
.FPC7ROM	29	83.000	139.50	114.53	13.422
.EWGVERTN	19	74.900	104.00	92.811	7.0837
.FPEWG	15	-4.0000	23.900	9.1800	9.0290
.FPC2FLEX	30			.34667	4.4653
.FPC2EXT	30			20.797	8.1417
.FPC2ROM	30			21.143	8.1091
.C2C3FL	30			3.4800	6.0664
.C2C3EXT	30			.90333	6.5594
.C2C3ROM	30			4.3833	5.5498
C3C4FL	30			10.317	7.6847
C3C4EXT	30			7.7633	9.0997
C3C4ROM	30			18.080	8.4575
C4C5FL	30			9.8033	7.8138
C4C5EXT	30			12.957	8.7868
C4C5ROM	30			22.760	7.4902
C5C6FL	30			11.397	6.9986
C5C6EXT	30			15.367	10.764
C5C6ROM	30			26.763	9.4534
C6C7FL	25			10.136	8.9005
C6C7EXT	24			12.092	9.8282
C6C7ROM	24			21.804	8.7059

TABLE D.8

X RAY RANGE OF MOTION BY SEX AND AGE   MALES 35-44

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV
.FPVERTN	26	67.100	98.100	84.827	7.5268
.FPC7FL	29	15.500	68.500	38.293	13.291
.FPC7EXT	28	15.500	73.500	47.500	14.458
.FPC7ROM	28	46.500	121.00	35.268	16.948
.FWGVERTN	14	82.000	118.10	97.929	10.129
.FPEWG	13	-9.7000	31.800	13.292	11.791
.FPC2FLEX	30			-.12333	10.079
.FPC2EXT	30			16.100	10.286
.FPC2ROM	30			15.977	13.435
.C2C3FL	30			3.0367	6.7844
.C2C3EXT	30			1.5300	6.4639
.C2C3ROM	30			4.5667	6.7160
.C3C4FL	30			4.6867	10.504
.C3C4EXT	30			7.1367	10.581
.C3C4ROM	30			11.823	11.581
.C4C5FL	30			12.383	7.2309
.C4C5EXT	30			8.7067	9.8847
.C4C5ROM	30			21.090	7.0767
.C5C6FL	30			11.147	8.7817
.C5C6EXT	30			11.017	9.5487
.C5C6ROM	30			22.163	6.3665
.C6C7FL	21			10.648	8.4936
.C6C7EXT	22			5.3955	9.8587
.C6C7ROM	21			15.329	7.4774

TABLE D.9 X RAY RANGE OF MOTION BY SEX AND AGE MALES 62-74

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV
.FPVERTN	17	70.100	97.900	82.182	6.6694
.FPC7FL	25	15.500	59.500	36.860	10.253
.FPC7EXT	25	18.500	66.000	40.900	11.667
.FPC7ROM	25	51.000	106.00	77.720	14.477
.EWGVERTN	17	82.200	107.60	95.141	6.6486
.FPEWG	12	-2.3000	26.100	12.992	8.8877
.FPC2FLEX	25			5.5560	5.1321
.FPC2EXT	25			18.704	8.0687
.FPC2ROM	25			24.260	8.5754
.C2C3FL	25			-1.2600	6.2545
.C2C3EXT	25			2.6040	5.4515
.C2C3ROM	25			1.3440	6.0759
.C3C4FL	25			8.7040	9.6052
.C3C4EXT	25			2.7960	8.7615
.C3C4ROM	25			11.500	8.8484
.C4C5FL	25			17.120	7.3821
.C4C5EXT	25			6.1640	5.9496
.C4C5ROM	25			23.284	5.2678
.C5C6FL	25			9.7760	10.030
.C5C6EXT	25			5.2800	8.4457
.C5C6ROM	25			15.056	10.45[illegible]
.C6C7FL	19			7.7737	10.417
.C6C7EXT	19			3.4789	9.8269
.C6C7ROM	19			11.253	10.431

APPENDIX E

STRENGTH AND REFLEX TIME - DESCRIPTIVE STATISTICS

Summary descriptive statistics from the anthropometry portion of the study are contained in this appendix. These data are reported in the following order:

TABLE	
E.1	All Subjects Combined
E.2	Subjects grouped by Sex--Females
E.3	--Males
E.4	Subjects Grouped by Sex and Age--Females, 18-24
E.5	--Females, 35-44
E.6	--Females, 62-74
E.7	--Males, 18-24
E.8	--Males, 35-44
E.9	--Males, 62-74
E.10	Subjects Grouped by Sex, Age, and Stature --Females, 18-24, 1-20%ile
E.11	--Females, 18-24, 40-60%ile
E.12	--Females, 18-24, 80-99%ile
E.13	--Females, 35-44, 1-20%ile
E.14	--Females, 35-44, 40-60%ile
E.15	--Females, 35-44, 80-99%ile
E.16	--Females, 62-74, 1-20%ile
E.17	--Females, 62-74, 40-60%ile
E.18	--Females, 62-74, 80-99%ile
E.19	--Males, 18-24, 1-20%ile
E.20	--Males, 18-24, 40-60%ile
E.21	--Males, 18-24, 80-99%ile
E.22	--Males, 35-44, 1-20%ile
E.23	--Males, 35-44, 40-60%ile
E.24	--Males, 35-44, 80-99%ile
E.25	--Males, 62-74, 1-20%ile
E.26	--Males, 62-74, 40-60%ile
E.27	--Males, 62-74, 80-99%ile

The data tables are in the format produced by the University of Michigan Statistical Laboratory Michigan Interactive Data Analysis System (MIDAS). Each of the measurements is given a code name; the measurement names associated with the code names are identified on the following page. Units of measurement are indicated in the third column.

Code	Measurement Name	Units of Measurement
FLXRAVG	Strength of flexor muscles, average of three trials per subject	lbs. Force
EXTAVG	Strength of extensor muscles, average of three trials per subject	"
FLEM1RT	Flexor muscle reflex time	Milliseconds
FLMAXGTM	Time to peak deceleration (response time)	"
FLCONTM	Flexor muscle contraction time	"
EXEMG2RT	Extensor muscle reflex time	"
EXMAXGTM	Time to peak deceleration (response time)	"
EXCONTM	Extensor muscle contraction time	"
FLMAXG	Peak deceleration of head as measured at the top of the head-piece during flexor muscle test	g's
EXMAXG	Peak deceleration of head as measured at the top of the head-piece, during extensor muscle test	g's

The following summary statistics are reported for each measurement:

Column Heading	Statistic
N	Number of Subjects in the Group
MINIMUM	Smallest Observation
MAXIMUM	Largest Observation
MEAN	Numerical Average
STD DEV	Standard Deviation
COEF VAR	Coefficient of Variation (Mean/Std Dev)
5TH %ILE	Fifth Percentile (Calculated)
50TH %ILE	Fiftieth Percentile (Calculated)
95TH %ILE	Ninety-fifth Percentile (Calculated)

Note: MIDAS specifies, as the percentile, the individual measurement which is closest to the requested percentile. For example: in a data set of 178 percentile, the 89th in rank is the 50th percentile and the 169th is the 95th percentile. This approach can cause misleading errors when small subsets of the data are analyzed; therefore, only the 50th percentile is included in Tables E.4 through E.9 and no percentiles are included for Tables E.10 through E.27.

TABLE E.1 STRENGTH, REFLEX, AND ACCELERATION ALL SUBJECTS COMBINED

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	5TH %ILE	50TH %ILE	95TH %ILE
.FLXRAVG	178	4.8000	56.800	23.789	10.575	44.453	10.000	21.900	46.400
.EXTAVG	178	8.2000	61.100	32.133	11.179	34.791	16.200	31.700	53.900
.FLEM1RT	177	34.700	140.00	71.754	16.427	22.894	46.000	72.000	100.000
.FLMAXGTM	175	96.000	221.00	132.37	17.783	13.438	107.000	130.000	163.000
.FLCONTM	174	16.300	95.700	60.683	14.609	24.075	40.000	59.700	87.000
.EXEMG2RT	174	37.300	120.00	64.645	12.683	19.619	48.000	64.000	86.700
.EXMAXGTM	170	101.00	175.00	134.02	13.032	9.724	115.000	133.000	156.000
.EXCONTM	170	35.700	103.00	69.139	13.112	18.964	51.000	68.000	94.700
.FLMAXG	173	.50000	1.4700	.96468	.19352	20.061	.660	.960	1.310
.EXMAXG	173	.44000	1.6000	.95422	.20824	21.823	.610	.950	1.320

TABLE E.2 STRENGTH, REFLEX, AND ACCELERATION BY SEX **FEMALES**

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	5TH %ILE	50TH %ILE	95TH % ILE
.FLXRAVG	91	4.8000	30.300	16.573	5.3727	32.420	8.800	16.400	26.000
.EXTAVG	91	8.2000	42.700	25.495	7.6490	30.002	13.700	25.000	38.800
.FLEM1RT	91	34.700	100.70	66.379	14.882	22.419	42.700	63.300	91.300
.FLMAXGTM	88	98.000	175.00	125.08	15.376	12.005	106.000	125.000	151.000
.FLCONTM	88	10.300	95.700	61.657	15.274	24.773	39.000	59.000	93.000
.EXEMG2RT	91	37.300	92.700	63.201	12.072	19.101	44.700	62.000	85.300
.EXMAXGTM	88	104.00	150.00	133.50	11.515	8.626	115.000	132.000	153.000
.EXCONTM	88	50.300	106.00	70.032	12.236	17.472	52.300	69.000	92.000
.FLMAXG	88	.65000	1.4700	.98318	.19936	20.277	.710	.960	1.390
.EXMAXG	89	.54000	1.6000	1.0054	.21786	21.669	.650	.980	1.360

TABLE E.3 STRENGTH, REFLEX, AND ACCELERATION BY SEX MALES

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	5TH %ILE	50TH %ILE	95TH %ILE
.FLXRAVG	87	12.700	56.300	31.337	9.3387	29.801	17.500	30.900	48.500
.EXTAVG	87	16.200	61.100	39.077	10.029	25.665	24.200	38.800	54.300
.FLXM1ST	86	46.000	140.00	77.442	16.143	20.846	56.000	76.700	103.300
.FLMAXGTM	87	96.000	221.00	136.70	19.058	13.941	109.000	135.000	169.000
.FLCONTM	66	31.300	93.000	59.686	13.914	23.313	40.000	60.000	85.000
.EXTMG2ST	63	44.700	120.00	66.228	13.212	19.949	50.700	65.300	87.300
.EXMAXGTM	82	101.00	175.00	134.57	14.537	10.803	113.000	135.000	160.000
.EXCONTM	62	35.700	103.00	68.180	14.003	20.538	49.000	67.000	95.000
.FLMAXG	85	.50000	1.4600	.94553	.18653	19.727	.610	.950	1.250
.EXMAXG	84	.54000	1.3200	.90000	.18373	20.414	.610	.890	1.190

TABLE E.4 STRENGTH, REFLEX, AND ACCELERATION BY SEX AND AGE FEMALES 18-24

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.FLXTAVG	30	10.500	30.300	19.427	5.1773	26.651	19.100
.EXTAVG	30	16.700	42.700	27.043	7.5229	27.818	25.300
.FLXM1GT	30	42.700	82.700	62.250	9.5762	15.383	61.300
.FLMAXGTZ	28	102.00	143.00	119.36	9.9451	8.332	121.000
.FLCONTM	26	38.300	89.300	57.279	11.410	19.920	54.700
.EXTMG2GT	30	44.000	75.300	56.963	8.0801	14.185	56.000
.EXMAXGTZ	28	111.00	157.00	130.46	11.761	9.015	127.000
.EXCONTM	28	54.000	106.00	73.482	13.197	17.959	71.000
.FLMAXG	28	.63000	1.4700	.97786	.24745	25.305	.940
.EXMAXG	30	.44000	1.6000	.92400	.24725	26.759	.890

TABLE E.5 STRENGTH, REFLEX, AND ACCELERATION BY SEX AND AGE FEMALES 35-44

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
FLXMAVG	30	4.2000	26.000	16.597	4.3959	26.487	16.400
.EXTAVG	30	12.200	39.600	26.727	6.4697	24.207	26.400
FLEX1RM	30	34.700	82.700	61.883	13.576	21.938	61.000
.FLMAXGTM	29	98.000	147.00	122.86	11.057	9.000	122.000
.FLCONTM	29	35.000	95.000	61.121	14.494	23.714	58.000
.EXEMG2FT	30	37.300	85.300	58.830	10.159	17.268	58.700
.EXMAXGTM	29	10[illegible].00	145.00	127.97	9.6232	7.520	129.000
.EXCONTM	29	51.700	96.000	68.924	10.917	15.839	69.000
.FLMAXG	30	.6[illegible]000	1.4500	.95867	.17350	18.098	.930
.EXMAXG	29	.75000	1.4900	1.0855	.18450	16.996	1.030

TABLE E.6 STRENGTH, REFLEX, AND ACCELERATION BY SEX AND AGE **FEMALES 62-74**

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.FLXRAVG	31	4.8000	26.900	13.787	5.0837	36.873	12.600
.EXTAVG	31	8.2000	38.800	22.803	8.3036	36.414	22.200
.FLEM1RT	31	40.700	100.70	74.726	16.980	22.723	80.000
.FLMAXGTM	31	110.00	175.00	140.84	14.729	10.458	145.000
.FLCONTM	31	16.300	95.700	66.113	18.018	27.254	69.300
.EXEMG2RT	31	53.300	92.700	73.468	10.362	14.104	75.000
.EXMAXGTM	31	127.00	160.00	141.42	8.4015	5.941	140.000
.EXCONTM	31	50.300	94.700	67.952	12.225	17.991	68.000
.FLMAXG	30	.75000	1.3700	1.0127	.17487	17.268	.990
.EXMAXG	30	.60000	1.3800	1.0093	.19167	18.990	1.020

TABLE E.7 STRENGTH, REFLEX, AND ACCELERATION BY SEX AND AGE MALES 18-24

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.FLXRAVG	30	13.100	55.800	32.377	9.9926	30.864	31.700
.EXTAVG	30	19.500	54.200	37.723	9.2509	24.523	35.200
.FLEM1RT	30	46.000	98.000	68.180	11.856	17.389	67.300
.FLMAXGTM	30	96.000	177.00	129.93	19.104	14.703	125.000
.FLCONTM	30	40.000	87.000	61.753	14.184	22.969	60.700
.EXEMG2RT	27	44.700	92.000	58.981	10.054	17.045	56.000
.EXMAXGTM	26	101.00	160.00	129.77	15.534	11.970	131.000
.EXCONTM	26	35.700	104.00	70.546	16.828	23.854	68.000
.FLMAXG	30	.50000	1.4600	.92300	.23928	25.924	.990
.EXMAXG	28	.56000	1.1700	.87143	.18660	21.413	.870

TABLE E.8 STRENGTH, REFLEX, AND ACCELERATION BY SEX AND AGE MALES 35-44

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.FLXFAVG	30	22.600	54.100	34.847	8.5934	24.661	32.600
.EXFAVG	30	24.300	61.100	45.123	9.5019	21.058	45.800
.FLEX1PT	29	50.000	106.00	77.134	13.634	17.675	77.000
.FLMXGTH	30	100.00	173.00	136.07	16.524	12.144	135.000
.FLCONTR	29	37.000	93.000	60.176	14.481	24.064	60.300
.EXLMG2PT	29	50.700	76.000	62.224	7.5173	12.081	63.300
.EXMXGTH	29	115.00	167.00	131.93	12.095	9.167	132.000
.EXCONTR	29	52.300	109.00	69.707	13.203	18.941	68.300
.FLMAXG	28	.73000	1.3100	.97786	.16070	16.434	.940
.EXMAXG	29	.61000	1.4200	.94138	.18351	19.494	.940

TABLE E.9 STRENGTH, REFLEX, AND ACCELERATION BY SEX AND AGE MALES 62-74

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR	50TH %ILE
.FLXRAVG	27	12.700	50.200	26.231	7.2613	27.629	25.800
.EXTAVG	27	16.200	52.600	33.863	8.0014	23.629	35.000
.FLRS1RT	27	56.700	140.00	88.063	16.698	18.961	85.300
.FLMAXGTM	27	125.00	221.00	144.93	19.135	13.203	140.000
.FLCONTM	27	31.300	81.000	56.863	13.010	22.880	57.000
.EXTMG2PT	27	59.300	120.00	77.774	13.331	17.141	74.700
.EXMAXGTM	27	115.00	175.00	142.04	13.421	9.445	142.000
.EXCONTM	27	39.700	88.700	64.263	11.257	17.517	65.400
.FLMAXG	27	.64000	1.1500	.93704	.14120	15.067	.950
.EXMAXG	27	.60000	1.3400	.88519	.17977	20.309	.860

TABLE E.10 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE FEMALES 18-24 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	10	10.800	21.100	17.490	2.8734	16.429
.EXTAVG	10	17.500	39.900	24.070	7.5338	31.299
.FLEM1RT	10	42.700	70.000	58.870	8.2480	14.010
.FLMAXGTM	10	105.00	125.00	114.70	8.3140	7.248
.FLCONTM	10	38.300	80.300	55.830	12.811	22.947
.EXEMG2RT	10	44.000	68.000	54.270	7.4382	13.706
.EXMAXGTM	10	119.00	130.00	125.40	2.9889	2.383
.EXCONTM	10	62.000	84.000	71.130	7.0498	9.911
.FLMAXG	10	.78000	1.4700	1.1030	.24581	22.286
.EXMAXG	10	.70000	1.6000	1.0460	.25255	24.144

TABLE E.11 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE FEMALES 18-24 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	10	10.500	25.200	20.510	4.8574	23.683
.EXTAVG	10	19.900	39.700	28.720	6.2163	21.646
.FLRM1RT	10	48.000	78.000	60.550	8.3892	13.855
.FLMAXGTM	9	112.00	133.00	122.11	7.6884	6.296
.FLCONTM	9	50.700	76.000	62.389	8.8167	14.132
.EXRMG2RT	10	48.000	66.700	57.140	6.7079	11.739
.EXMAXGTM	10	115.00	157.00	133.50	15.035	11.262
.EXCONTM	10	57.000	106.00	76.360	16.469	21.568
.FLMAXG	9	.65000	1.4500	.97111	.25541	26.301
.EXMAXG	10	.44000	1.2600	.91900	.27286	29.691

TABLE E.12 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE FEMALES 18-24 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	10	11.800	30.300	20.280	6.9455	34.248
.EXTAVG	10	16.700	42.700	28.340	8.4933	29.969
.FLXM1RT	10	47.300	82.700	67.330	10.607	15.753
.FLMAXGTM	9	102.00	143.00	121.78	12.438	10.213
.FLXCONTM	9	39.000	71.700	53.778	11.455	21.300
.EXTMG2RT	10	44.700	75.300	59.460	9.7424	16.379
.EXMAXGTM	8	111.00	149.00	133.00	13.202	9.926
.EXCONTM	8	52.000	92.000	72.825	15.456	21.223
.FLMAXG	9	.65000	1.2600	.84556	.18474	21.848
.EXMAXG	10	.40000	1.1400	.60700	.16425	20.353

TABLE E.13 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE FEMALES 35-44 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXTAVG	10	9.2000	21.600	15.560	4.0214	25.844
.EXTAVG	10	12.200	34.100	23.510	6.6221	28.167
.ELBFLEX	10	35.000	72.700	55.630	12.376	22.247
.FLMAXGTH	10	106.00	147.00	124.90	11.318	9.062
.FLCONTR	10	51.700	95.000	69.270	13.966	20.162
.EXTNG2ET	10	37.300	66.700	55.130	10.350	18.774
.EXMAXGTH	10	114.00	145.00	126.00	9.3690	7.436
.EXCONTR	10	59.000	80.700	70.870	9.9481	14.037
.TIMEAVG	10	.71000	1.1000	.90500	.13591	15.018
.ACCAVG	10	.75000	1.3600	1.0690	.19925	18.639

TABLE E.14 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE FEMALES 35-44 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	9	10.000	26.000	18.322	5.6051	30.592
.EXTAVG	9	20.300	39.600	28.500	5.7382	20.134
.FLEM1RT	9	34.700	82.700	66.300	16.145	24.351
.FLMAXGTM	9	109.00	139.00	122.33	9.8615	8.061
.FLCONTM	9	35.000	87.300	56.033	15.292	27.291
.EXEMG2RT	9	40.000	85.300	60.733	12.742	20.981
.EXMAXGTM	9	125.00	145.00	134.67	7.2111	5.355
.EXCONTM	9	59.000	96.000	73.933	12.119	16.392
.FLMAXG	9	.79000	1.1700	.97444	.13173	13.518
.EXMAXG	9	.86000	1.4900	1.1333	.20988	18.519

TABLE E.15 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE FEMALES 35-44 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	11	10.100	21.500	16.127	3.5149	21.794
.EXTAVG	11	17.000	35.100	28.200	6.3253	22.430
.FLEM1RT	11	42.700	82.700	63.955	11.258	17.603
.FLMAXGTM	10	98.000	144.00	121.30	12.579	10.370
.FLCONTM	10	41.300	76.300	57.550	11.696	20.324
.EXEMG2RT	11	50.700	73.300	60.636	7.2420	11.943
.EXMAXGTM	10	104.00	135.00	123.90	9.3029	7.508
.EXCONTM	10	51.700	73.700	62.470	8.1036	12.972
.FLMAXG	11	.69000	1.4500	.99455	.22862	22.987
.EXMAXG	10	.88000	1.3700	1.0590	.15387	14.530

TABLE E.16 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE FEMALES 62-74 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	10	7.9000	16.000	11.710	2.8846	24.634
.EXTAVG	10	11.500	29.700	17.900	5.2203	29.163
.FLEM1GT	10	45.300	100.70	74.190	19.504	26.289
.FLMAXGTM	10	110.00	170.00	142.50	17.024	11.947
.FLCONTM	10	16.300	95.700	68.310	22.833	33.425
.EXEM1G2T	10	53.300	84.000	72.290	9.5449	13.204
.EXMAXGTM	10	127.00	160.00	142.00	10.477	7.379
.EXCONTM	10	50.300	94.700	69.710	14.838	21.286
.FLMAXG	10	.87000	1.3000	1.1070	.13425	12.127
.EXMAXG	9	.75000	1.3800	1.1356	.19844	17.475

TABLE E.17 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE FEMALES 62-74 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	10	8.9000	19.700	13.840	3.6473	26.353
.EXTAVG	10	15.900	33.000	23.450	6.3008	26.869
.FLEMG2FT	10	40.700	100.00	78.460	17.660	22.508
.FLMAXGTM	10	115.00	153.00	139.60	13.624	9.759
.FLCONTM	10	37.000	82.700	61.140	14.103	23.066
.EXEMG2FT	10	55.300	92.700	73.220	11.257	15.374
.EXMAXGTM	10	135.00	153.00	142.00	5.7927	4.079
.EXCONTM	10	53.700	84.700	68.780	9.3763	13.632
.FLMAXG	9	.75000	1.2900	.93667	.17699	18.896
.EXMAXG	10	.77000	1.2000	.98200	.16040	16.334

TABLE E.18 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE FEMALES 62-74 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	11	4.8000	26.900	15.627	7.0731	45.261
.EXTAVG	11	8.2000	38.800	26.673	10.279	38.538
.FLEM1RT	11	44.000	88.000	71.818	14.778	20.576
.FLMAXGTM	11	124.00	175.00	140.45	14.781	10.524
.FLCONTM	11	44.700	95.000	68.636	17.006	24.777
.EXEMG2RT	11	56.700	90.700	74.764	11.081	14.821
.EXMAXGTM	11	127.00	158.00	140.36	8.9919	6.406
.EXCONTM	11	50.300	84.700	65.600	12.697	19.355
.FLMAXG	11	.60000	1.3700	.98909	.18080	18.280
EXMAXG	11	.60000	1.1600	.93091	.17329	18.615

TABLE E.19

STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE MALES 18-24 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXPAVG	10	16.900	43.100	27.450	9.2164	33.575
.EXPAVG	10	25.800	39.400	33.590	4.3672	13.001
.FLEX1RT	10	47.300	81.300	65.410	11.506	17.591
.FLMAXGTY	10	96.000	157.00	122.00	20.205	16.561
.FLCONTM	10	40.000	75.700	56.590	11.610	20.516
.EXPMG2RT	9	44.700	66.000	53.933	5.7131	10.593
.EXMAXGTM	8	113.00	152.00	128.13	14.486	11.306
.EXCONTM	9	49.000	100.00	74.037	18.299	24.715
.FLMAXG	10	.67000	1.1300	.98300	.12641	12.859
.EXMAXG	8	.96000	1.1700	1.0175	.94529 -1	9.290

TABLE E.20 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE MALES 18-24 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXBAVG	10	23.400	46.400	33.360	7.4621	22.368
.EXBAVG	10	19.500	54.200	36.630	11.598	31.663
.FLEM1BT	10	46.000	81.000	64.870	9.6695	14.906
.FLMAXGTM	10	111.00	144.00	127.40	10.298	8.083
.FLCONTM	10	40.000	87.000	62.530	13.858	22.163
.EXEMG2BT	9	45.000	92.000	64.933	14.089	21.697
.EXMAXGTM	9	101.00	156.00	127.73	17.290	13.531
.EXCONTM	9	35.700	81.300	62.844	15.574	24.781
.FLMAXG	10	.54000	1.3900	.97200	.23011	23.674
.EXMAXG	10	.57000	1.1200	.82500	.15357	18.614

TABLE E.21 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE MALES 18-24 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXBAVG	10	13.100	56.800	36.320	11.653	32.085
.EXTAVG	10	36.100	53.200	42.950	8.4558	19.688
.FLEM1RT	10	57.000	93.000	74.260	12.854	17.310
.FLMAXGTM	10	114.00	177.00	140.40	21.516	15.325
.FLCONTM	10	42.000	85.000	66.140	16.425	24.833
.EXEMG2RT	9	52.700	59.000	58.078	5.2846	9.039
.EXMAXGTM	9	110.00	160.00	133.22	15.841	11.891
.EXCONTM	9	56.000	104.00	75.144	15.708	20.903
.FLMAXG	10	.50000	1.4600	.81400	.30934	38.003
.EXMAXG	10	.56000	1.1200	.80100	.21692	27.081

TABLE E.22 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE MALES 35-44 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
FLXRAVG	10	22.600	54.100	33.140	10.564	31.877
EXTAVG	10	29.200	61.100	43.520	8.7547	20.116
FLEX1RT	9	70.000	106.00	82.444	11.606	14.077
FLMAXGTM	10	100.00	167.00	136.40	19.923	14.606
FLCONTM	9	40.700	93.000	58.000	15.930	27.466
EXRNG2RT	9	50.700	68.700	61.278	6.3437	10.352
EXMAXGTM	9	117.00	167.00	129.56	15.150	11.694
EXCONTM	9	52.300	109.00	68.278	17.010	24.913
FLMAXG	9	.76000	1.2500	.99111	.15398	15.537
EXMAXG	9	.66000	1.1900	.91667	.19944	21.757

TABLE E.23 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE MALES 35-44 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
FLXRAVG	10	28.200	47.500	35.900	6.8607	19.111
EXTAVG	10	24.600	58.200	46.260	10.502	22.701
FLEM1RT	10	50.000	92.700	75.450	14.792	19.605
FLMAXGTM	10	115.00	153.00	136.10	13.780	10.125
FLCONTM	10	43.700	73.000	60.650	10.891	17.958
EXEMG2RT	10	53.300	68.700	60.770	6.3290	10.415
EXMAXGTM	10	122.00	149.00	137.30	9.9448	7.243
EXCONTM	10	58.700	95.000	76.530	11.634	15.202
FLMAXG	9	.87000	1.3100	1.0667	.17364	16.279
EXMAXG	10	.61000	1.2000	.98500	.16467	16.718

TABLE E.24 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE MALES 35-44 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	10	22.800	49.000	35.500	8.6222	24.288
.EXTAVG	10	27.800	59.500	45.590	9.9730	21.875
.FLEX1RT	10	52.000	90.000	74.040	14.063	18.994
.FLMAXGIM	10	111.00	173.00	135.70	17.108	12.607
.FLCONTM	10	37.000	88.000	61.660	17.342	28.125
.EXTNG2RT	10	52.000	76.000	64.530	9.5304	14.769
.EXMAXGIM	10	115.00	143.00	128.70	10.144	7.882
.EXCONTM	10	53.000	80.000	64.170	7.8725	12.268
.FLMAXG	10	.73000	1.0900	.88600	.11027	12.446
.EXMAXG	10	.71000	1.4200	.92000	.19765	21.484

TABLE E.25 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE MALES 62-74 1-20%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	6	12.700	28.700	23.250	5.8930	25.346
.EXTRAVG	6	16.200	39.700	32.150	9.1356	28.416
.FLEX1RT	6	56.700	97.000	79.383	15.188	19.132
.FLMAXGTH	6	132.00	162.00	141.83	10.944	7.716
.FLCONTM	6	42.000	78.300	62.450	14.811	23.716
.EXTNG2AT	6	59.300	70.000	66.667	4.1879	6.282
.EXMAXGTM	6	122.00	144.00	136.83	8.6120	6.294
.EXCONTM	6	58.000	74.700	70.167	6.2063	8.845
.FLMAXG	6	.64000	1.1400	.94333	.17512	18.564
.EXMAXG	6	.69000	1.0200	.65833	.14414	16.793

TABLE E.26 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE MALES 62-74 40-60%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
FLXRAVG	11	16.300	50.200	28.809	9.4504	32.804
EXTAVG	11	17.200	52.600	35.145	10.020	28.509
FLEM1ST	11	80.000	112.00	91.627	10.544	11.507
FLMAXGTM	11	125.00	169.00	141.45	14.060	9.939
FLCONTM	11	36.700	64.700	49.827	8.2941	16.646
EXEMG2ST	11	60.000	87.300	75.691	8.5584	11.307
EXMAXGTM	11	115.00	168.00	140.73	15.434	10.968
EXCONTM	11	39.700	88.700	65.036	13.521	20.791
FLMAXG	11	.74000	1.1300	.95000	.12806	13.480
EXMAXG	11	.76000	1.3400	.94273	.19499	20.684

TABLE E.27 STRENGTH, REFLEX, AND ACCELERATION BY SEX AGE AND STATURE MALES 62-74 80-99%ile

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	COEF VAR
.FLXRAVG	10	17.900	31.600	25.320	4.3397	17.139
.EXTAVG	10	25.600	40.600	33.480	4.7865	14.297
.FLEM1RT	10	71.300	140.00	89.350	22.049	24.678
.FLMAXGTM	10	132.00	221.00	150.60	26.734	17.752
.FLCONTM	10	31.300	81.000	61.250	13.711	22.385
.EXEMG2RT	10	68.700	120.00	86.730	15.673	18.071
.EXMAXGTM	10	131.00	175.00	146.60	13.083	8.924
.EXCONTM	10	42.700	77.300	59.870	9.8039	16.375
.FLMAXG	10	.70000	1.1500	.91900	.14746	16.045
.EXMAXG	10	.60000	1.1300	.83800	.18048	21.537