

	SURFACE VEHICLE INFORMATION REPORT	SAE J1460-2 FEB2011
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		Superseding J1460-2 JUN2008
Human Mechanical Impact Response Characteristics - Response of the Human Neck to Inertial Loading by the Head for Automotive Seated Postures		

RATIONALE

The members of the SAE Human Biomechanics and Simulations Standards Steering Committee have reviewed J1460-2 and made a conscientious decision to stabilize this Information Report. Additional research into the inertial loading response of the human neck has been conducted since this Information Report was last revised. The neck design of the Hybrid III family of dummies was developed based on the data included in J1460-2. This Information Report has historical value.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE Human Biomechanics and Simulations Standards Steering Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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Foreword—Human mechanical impact response is defined as the reaction of a body segment in terms of measurable engineering parameters such as forces, accelerations, and deflections due to direct or indirect impact loading. The impact response of a body region can depend upon the test conditions used to generate the data (such as impactor shape, stiffness, mass, and body region boundary conditions) and thus, in most cases, can only be defined in terms of those conditions. Accordingly, the impact response of a test dummy component must be evaluated under test conditions similar to those used to obtain the defined response data.

A number of problems need to be addressed in defining human impact response characteristics, since most impact response studies use cadaver or animal surrogates to obtain data at severe impact levels. The impact response of surrogates can differ from that of living humans due to lack of physiological effects, such as muscle tone in the cadaver subject, and lack of geometric similitude with animal subjects. In cases where sub-injury tests are conducted with volunteers, there are also problems with extrapolation of the response data to represent the response at higher impact severities. Some studies only include response of the body region up to the injurious level while others include response well beyond the initiation of tissue structural failure associated with injury.

In addition, the human form is not of unique size, shape, and proportion. There are significant geometric differences between and among adults and children, and males and females. The available response data in the literature dictates that treatment of this topic be constrained essentially to guidelines for average adult male responses, with scaling used to define equivalent responses for the small adult female and the large adult male.

Finally, there may be response variability introduced by age, physical conditioning, and other factors not discussed here. This variability is discussed for those body regions where such information is available.

1. **Scope**—This series of reports provides response characteristics of the head, face, neck, shoulder, thorax, lumbar spine, abdomen, pelvis, and lower extremities. In each report, the descriptions of human impact response are based on data judged by the subcommittee to provide the most appropriate information for the development of human surrogates.

1.1 Purpose—This is one of a series of reports which define human mechanical impact response characteristics for specific body regions. These reports update SAE J1460 which is intended for use by anthropomorphic test dummy designers and analytical modelers who need quantitative definitions of human mechanical impact behavior. These reports do not discuss criteria for assessing human impact injury potential, which are the subject of SAE J885. Each document in the series covers material specific to a body region and will be independently updated when new response data become available. The goal of this report is to characterize the response of human neck due to head inertial loading when the occupant is sitting in an automotive posture.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J211-1 MAR95—Instrumentation for Impact Test—Part 1—Electronic Instrumentation
SAE J211-2 MAR95—Instrumentation for Impact Test—Part 2—Photographic Instrumentation
SAE J885—Human Tolerance to Impact Conditions as Related to Motor Vehicle Design
SAE J1460 MAR85—Human Mechanical Response Characteristics
SAE J1733—Sign Convention for Vehicle Crash Testing

2.1.2 ISO/TR PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, N.Y. 10036-8002

ISO/TR 9790-2—Road vehicles — Anthropomorphic side impact dummy — Part 2: Lateral neck impact response requirements to assess biofidelity of dummy

2.1.3 OTHER PUBLICATIONS

1. Mertz, H. J., "The Kinematics and Kinetics of Whiplash," Ph.D. Dissertation, Wayne State University, 1967.
2. Mertz, H. J. and Patrick, L. M., "Investigation of the Kinematic and Kinetics of Whiplash," SAE 670919, Eleventh Stapp Car Crash Conference, October 1967.
3. Mertz, H. J. and Patrick, L. M., "The Effect of Added Weight on the Dynamics of the Human Head," Final Report on Contract No. DAAG-17-67-C-0202, U.S. Army Natick Laboratories, Natick, Massachusetts, 1971.
4. Mertz, H. J. and Patrick, L. M., "Strength and Response of the Human Neck," SAE 710855, Fifteenth Stapp Car Crash Conference, November 1971.
5. Patrick, L. M. and Chou, C.C., "Response of the Human Neck in Flexion, Extension and Lateral Flexion," Vehicle Research Institute Report VRI 7.3, SAE, 1976.
6. Ewing, C. L., Thomas, D. J., Beeler, G. W., Patrick, L. M. and Gillis, D. B., "Dynamic Response of the Head and Neck of the Living Human to -Gx Impact Acceleration," SAE 680792, Twelfth Stapp Car Crash Conference, October 1968.
7. Ewing, C. L., Thomas, D. J., Patrick, L. M., Beeler, G. W. and Smith, M. J., "Living Human Dynamic Response to -Gx Impact Acceleration, Part II - Accelerations Measured on the Head and Neck," Thirteenth Stapp Car Crash Conference, December 1969.
8. Ewing, C. L. and Thomas, D. J., "Torque Versus Angular Displacement Response of the Human Head to -Gx Impact Acceleration," SAE 730976, Seventeenth Stapp Car Crash Conference, November 1973.
9. Ewing, C. L., Thomas, D. J., Lustick, L., Becker, E., Willems, G. and Muzzy, W. H., "The Effect of the Initial Position of the Head and Neck on the Dynamic Response of the Human Head and Neck to -Gx Impact Acceleration," SAE 751157, Nineteenth Stapp Car Crash Conference, November 197.
10. Ewing, C. L., Thomas, D. J., Lustick, L., Muzzy, W. H., Willems, G. and Majewski, P. L., "The Effect of Duration, Rate of Onset and Peak Sled Acceleration on the Dynamic Response of the Human Head and Neck," SAE 760800, Twentieth Stapp Car Crash Conference, October 1976.

11. Ewing, C. L., Thomas, D. J., Majewski, P. L., Black, R. and Lustick, L., "Measurement of Head, T1 and Pelvic Response to -Gx Impact Acceleration," SAE 770927, Twenty-First Stapp Car Crash Conference, October 1977.
12. Ewing, C. L., Thomas, D. J., Lustick, L., Muzzy, W. H., Willems, G. C. and Majewski, P., "Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration," SAE 770928, Twenty-First Stapp Car Crash Conference, October 1977.
13. Ewing, C. L., Thomas, D. J., Lustick, L., Muzzy, W. H., Willems, G. C. and Majewski, P., "Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration," SAE 780888, Twenty-Second Stapp Car Crash Conference, October 1978.
14. Zaborowski, A. V., "Lateral Impact Studies," Ninth Stapp Car Crash Conference, October 1965.
15. Hu, A. S., Bean, S. P. and Zimmerman, R. M., "Response of Belted Dummy and Cadaver to Rear Impact," SAE 770929, Twenty-First Stapp Car Crash Conference, October 1977.
16. Tarriere, C., "Proposal for Lateral Neck Response Requirements for Severe Impact Conditions," ISO/TC22/SC12/WG5 Document N166, 1986.
17. Ferlic, D., "The Range of Motion of the Normal Cervical Spine," Hopkins Hospital Bulletin 110, 1962.
18. Buck, C.A., Dameron, F. B., Dow, M. J. and Skowlund, H. V., "Study of Normal Range of Motion in the Neck Utilizing a Bubble Goniometer," Archives of Physical Medicine and Rehabilitation, Volume 40, September 1959.
19. Granville, A. D. and Kreezer, G., "The Maximum Amplitude and Velocity of Joint Movements in Normal Male Human Adults," Human Biology, Volume 9, 1937.
20. Foust, D. R., Chaffin, D. B., Snyder, R. G. and Baum, J. K., "Cervical Range of Motion and Dynamic Response and Strength of Cervical Muscles," SAE 730975, Seventeenth Stapp Car Crash Conference, November 1973.
21. Schneider, L. W., Foust, D. R., Bowman, B. M., Snyder, R. G., Chaffin, D. B., Abdelnour, T. A. and Baum, J. K., "Biomechanical Properties of the Human Neck in Lateral Flexion," SAE 751156, Nineteenth Stapp Car Crash Conference, November 1975.
22. Mertz, H. J., Neathery, R. F. and Culver, C. C., "Performance Requirements and Characteristics of Mechanical Necks," Human Impact Response - Measurement and Simulation, Plenum Press, NY, 1973.
23. Road Vehicles - Anthropomorphic Side Impact Dummy - Part 2 - Lateral Neck Impact Response Requirements to Assess Dummy Biofidelity, ISO Technical Report TR9790-2, 1989.
24. Mertz, H. J., Irwin, A. L., Melvin, J. W., Stalnaker, R. L. and Beebe, M. S., "Size, Weight and Biomechanical Impact Response Requirements for Adult Size Small Female and Large Male Dummies," SAE 890756, SP-782, March 1989.

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

Anatomy, Descriptive and Surgical, Gray, H., Bounty Books, N.Y., N.Y., 1977.

3. Introduction—In automotive collisions, the neck plays an important role in controlling the kinematics of the head. The primary neck characteristics affecting the resulting head kinematics are its length, range of articulation relative to the automotive seated posture and degree of bending resistance produced by active and passive muscle reactions and by ligament stretch. For a crash test dummy to have human-like head motion, its neck structure must be designed to mimic these important characteristics. In addition, the crash test dummy needs to be instrumented to measure internal neck loads to assess the potential for neck injury. This report will provide a summary of studies conducted to quantify neck response characteristics produced by fore, aft, and lateral head inertial loading. Performance requirements for judging neck biofidelity based on these data will be given. The SAE sign convention defined in SAE J211 and SAE J1733 is used in this report (see Appendix A). Response of the neck to pure tension, compression, torsion, shear, or direct impact will not be discussed.

4. **Neck Anatomy**—The primary load-carrying structures of the neck are the cervical spine, intervertebral disks, ligaments, and muscles. The cervical spine consists of seven bony vertebrae commonly referred to as C1 through C7 (see Figure 1). The top two vertebrae have unique shapes and functions. The top vertebra, C1, is called the atlas, and is shown in Figure 2. It supports the head at two bony articular surfaces called the occipital condyles which are symmetrically located on the base of the skull on each side of the foramen magnum, the hole through which the spinal cord passes, (see Figure 3). This joint allows the head to nod fore-aft relative to C1 without unduly stretching the spinal cord. The second cervical vertebra, C2, is called the axis and is shown in Figure 4. It is characterized by a bony protuberance, the odontoid process, which extends upwards into the atlas. The odontoid process forms an axis for head rotation as in the “no” gesture. The third through seventh cervical vertebrae, C3 through C7, are similar to the other vertebrae of the spine with their size increasing as one proceeds down the spine, (see Figure 5). These vertebrae have smooth superior and inferior bony surfaces called facets which form articular joints with adjacent vertebrae. The bodies of C2 through C7 are separated by fluid-filled fibrous pads called intervertebral disks. The amount of relative motion that can occur between adjacent vertebrae is limited by the articular joints and intervertebral disks as well as by fibrous tissue called ligaments which bind adjacent vertebrae together. Figure 6 is a lateral cross-sectional view of the base of the skull and of C1 and C2 which shows various ligaments, articular joints, intervertebral disks, and the spinal cord canal. Figure 7 is a posterior cross-sectional view of the base of the skull and of C1 and C2 showing the ligamentous connections.

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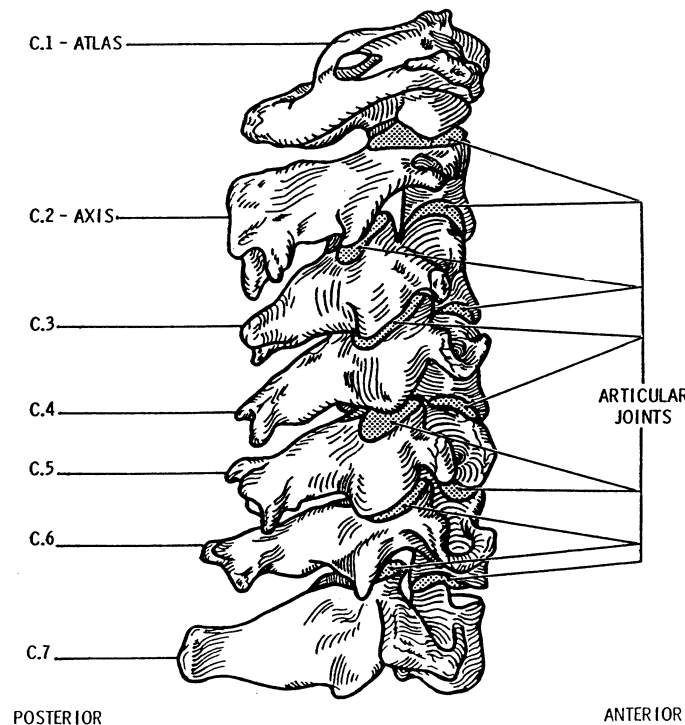


FIGURE 1—LATERAL VIEW OF THE CERVICAL VERTEBRAE SHOWING THE LOCATIONS OF THE ARTICULAR JOINTS

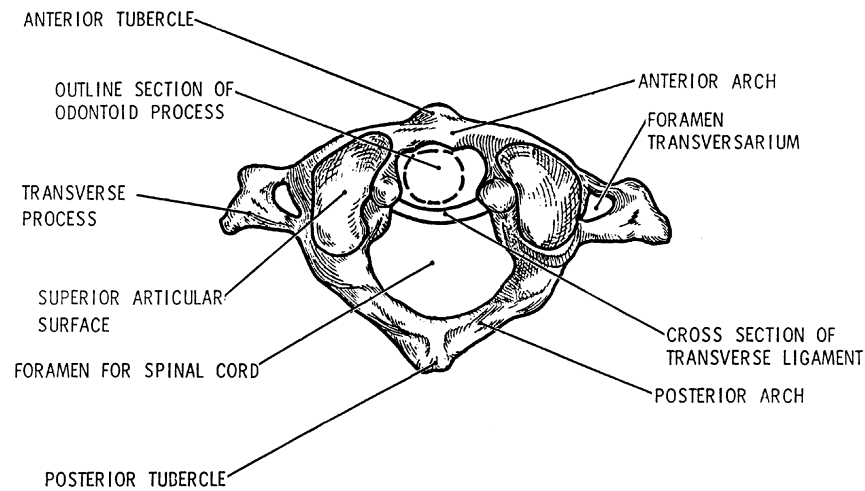


FIGURE 2—SUPERIOR VIEW OF THE FIRST CERVICAL VERTEBRAE, THE ATLAS

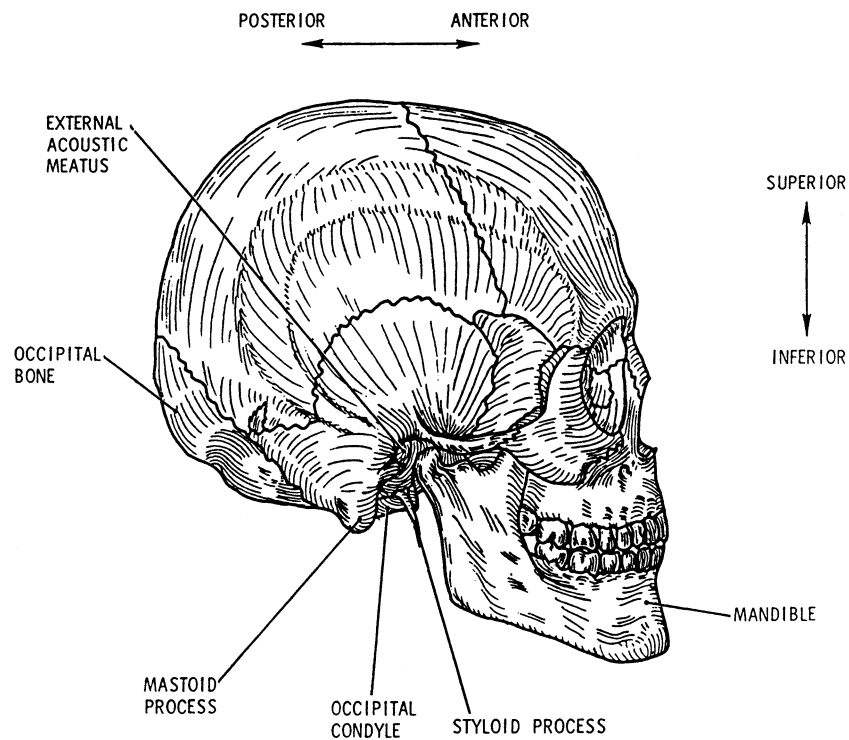


FIGURE 3—POSITION OF THE OCCIPITAL CONDYLES RELATIVE TO LANDMARKS OF THE SKULL

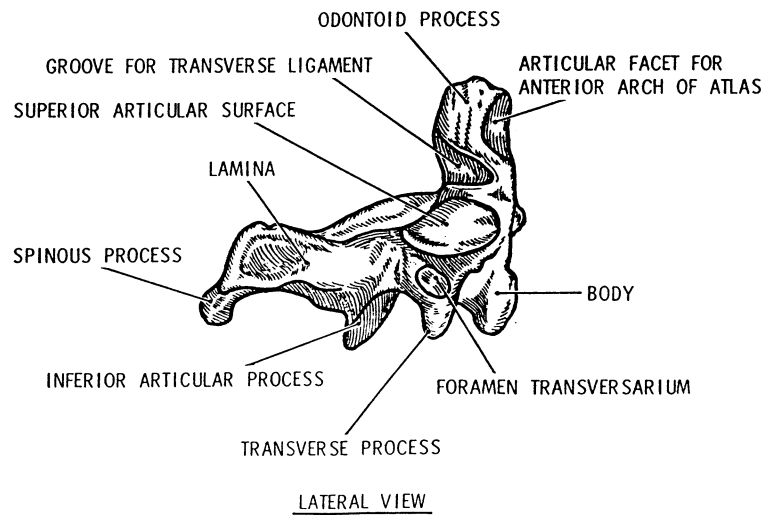


FIGURE 4—THE SECOND CERVICAL VERTEBRA, THE AXIS

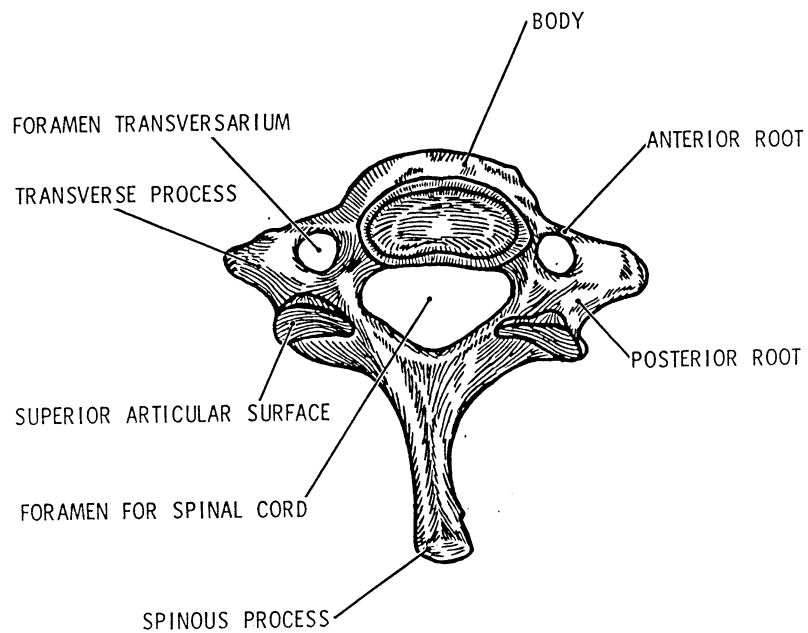


FIGURE 5—SUPERIOR VIEW OF THE SEVENTH CERVICAL VERTEBRA

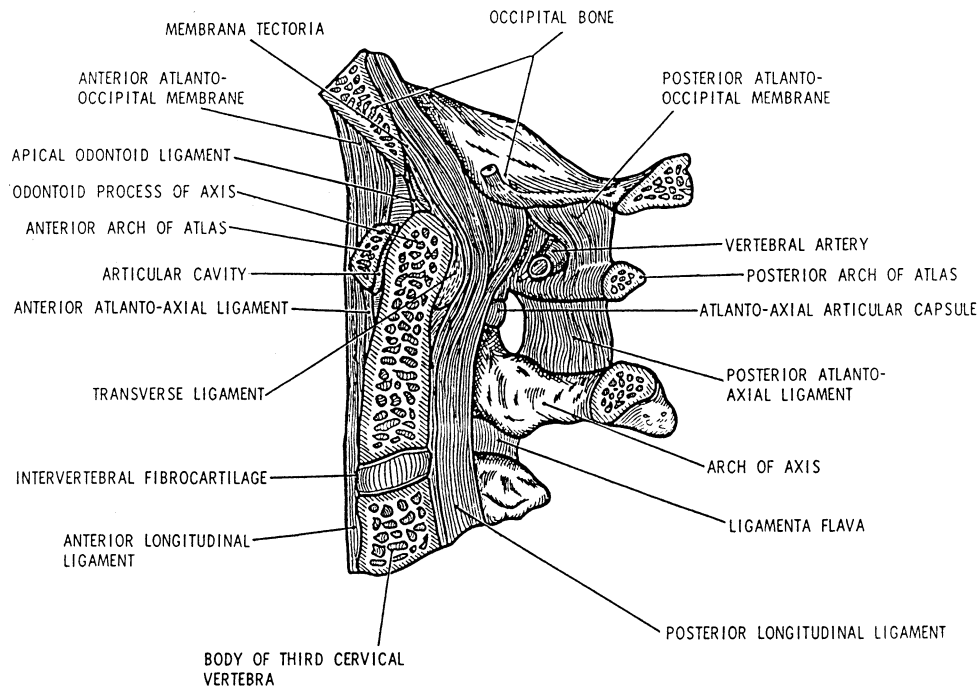


FIGURE 6—MIDSAGITTAL SECTION OF THE OCCIPUT, ATLAS, AND AXIS SHOWING THE LIGAMENTOUS CONNECTIONS

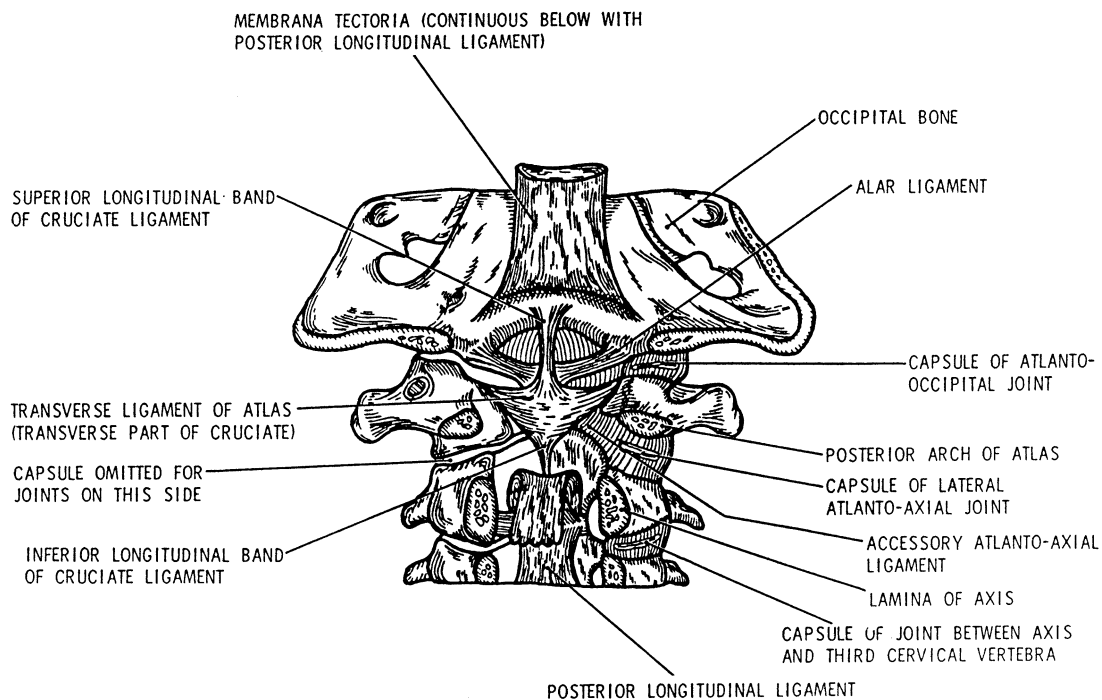


FIGURE 7—POSTERIOR VIEW OF THE OCCIPUT, ATLAS, AND AXIS SHOWING THE LIGAMENTOUS CONNECTIONS

Voluntary movements of the head and the cervical spine are produced by action of the neck muscles. Neck muscles occur in pairs which are symmetric with respect to the sagittal plane, the plane of symmetry of the body, and are attached to the head, individual cervical vertebrae, and/or the torso, (see Figures 8, 9, and 10). It is primarily the forces developed by the neck muscles, active and passive, that produce the bending stiffness of the neck within its voluntary range of motion. The neck ligaments contribute little to the bending resistance within this range. At the extremes of voluntary head-to-torso articulation, significant passive forces are developed in the ligaments which then add to the bending resistance produced by the muscles. Since the majority of the neck muscles are located posterior to the cervical spine (see Figure 11), the neck's bending stiffness is about three times greater in resisting forward bending than rearward bending. The neck's bending stiffness will vary with the degree of active muscle force and the rate of deformation of the muscle tissues which are viscoelastic. Without active or passive muscle force, the neck has very little bending resistance within the voluntary range of motion.

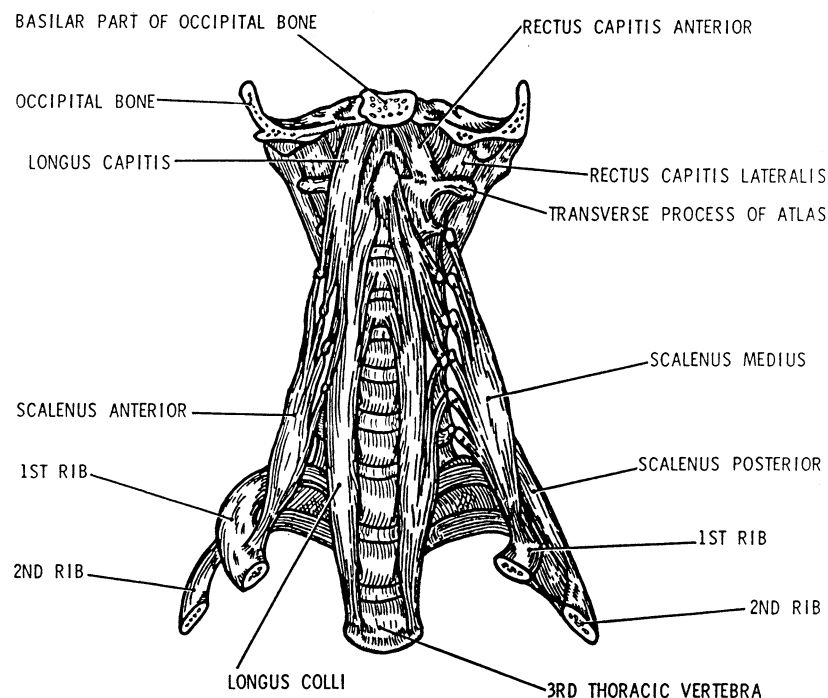


FIGURE 8—ANTERIOR VIEW OF THE PREVERTEBRAL CERVICAL MUSCLES

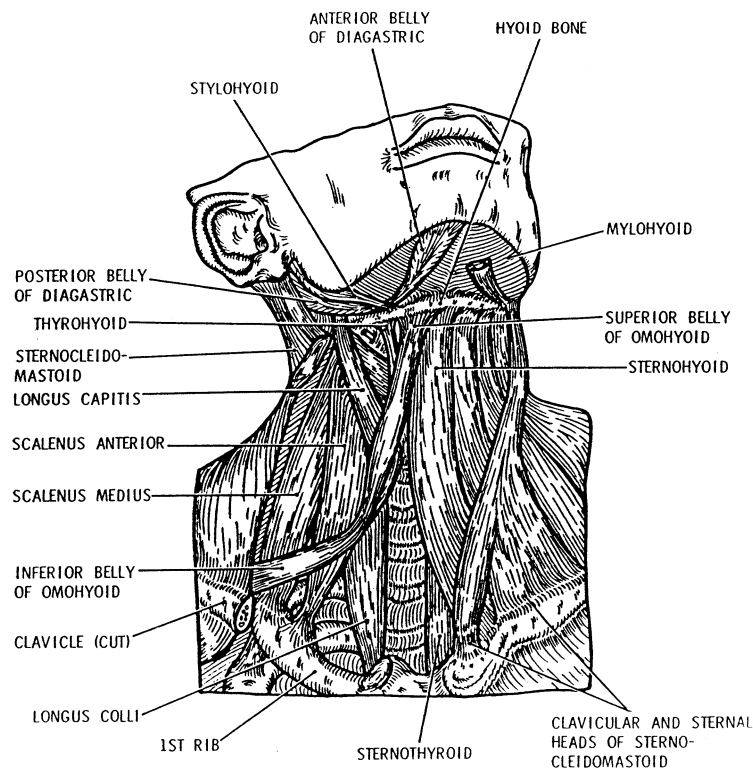


FIGURE 9—ANTEROLATERAL VIEW OF THE MUSCLES OF THE NECK

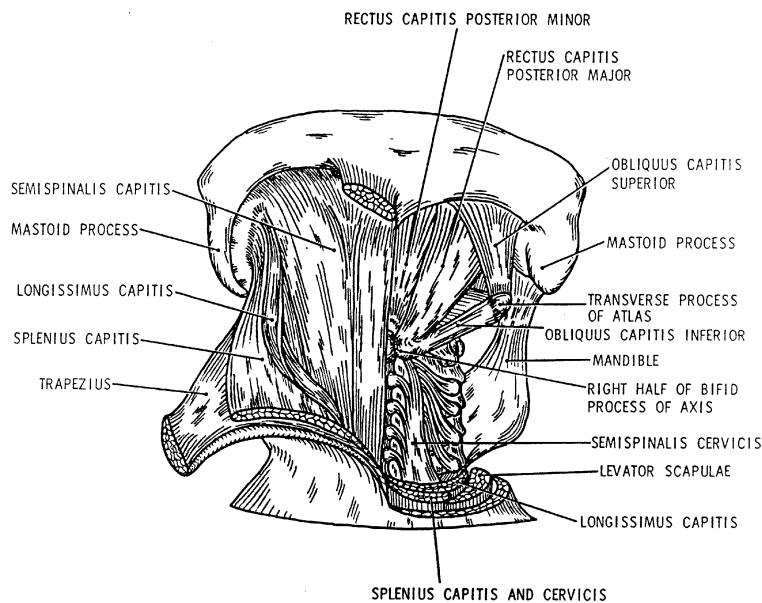


FIGURE 10—POSTERIOR MUSCLES OF THE NECK

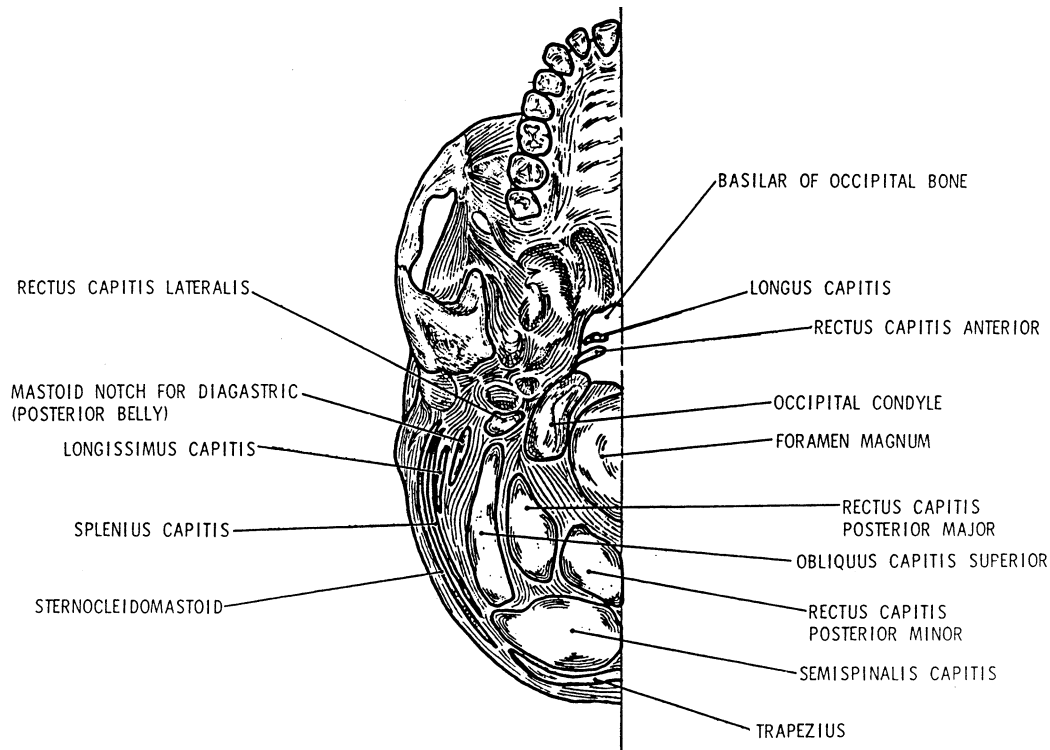


FIGURE 11—INFERIOR ASPECT OF THE SKULL BASE
SHOWING NECK MUSCLE ATTACHMENT AREAS

5. Studies of Inertial Loading of the Neck

5.1 Mertz and Patrick Results—Mertz and Patrick (see 2.1.3.(1), 2.1.3.(2), 2.1.3.(3), and 2.1.3.(4)) conducted a series of sled tests using a single human volunteer and six embalmed cadavers to characterize the responses of their necks to head inertial loads that produced either flexion or extension of the neck. The volunteer was 49 years old and was fairly representative in height (1.73 m = 5'8") and mass (72.7 kg = 160 pounds) of the 50th percentile adult male. Tests were conducted with the volunteer seated in a rigid chair that simulated a typical automotive seated posture. It had a 15-degree seat back angle and a 5-degree seat pan angle. He was restrained by a lap belt and two shoulder belts that crisscrossed his chest. The belts were 50 mm wide. This restraint system minimized the amount of torso motion relative to the seat during the test. Accelerometers were affixed to his head using a tightly-fitting, light-weight skull cap and bite plate. Outputs from these transducers along with estimates of the inertial characteristics of his head were used to calculate the resultant loading of the neck's reaction on the head. These resultant internal neck reactions acting on the head at the head-neck interface consisted of orthogonal fore-aft shear and axial forces and a bending moment about a lateral axis which is tangent to the inferior surfaces of the occipital condyles. A photographic target and biaxial accelerometers were mounted to a bracket that was tightly strapped to his back at the level of the first thoracic vertebra. A target was also attached to the skull cap. These targets were used to determine the change in head position and orientation relative to the torso.