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A BIBLIOGRAPHY OF WHIPLASH  
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## FOREWORD

The cervical hyperextension - hyperflexion syndrome, commonly referred to as "whiplash", has been well-documented in the clinical and experimental literature. However, it has become so prolific, that review and retrieval have become major research tasks. With the scientific, medical and technical literature expanding at an exponential growth rate, the deluged scientific researcher or physician cannot even begin to adequately keep abreast of, let alone review, the literature. Time limitations created by this problem force the researcher into reviewing only the popular, well known journals. Multi-discipline system approaches are virtually impossible under such conditions, and misconceptions caused by information "inbreeding" are often the end result. Medical doctors not specifically trained in complex engineering principles and engineers not specifically trained in complex medical principles create misconceptions which, when inbred with even less informed colleagues, produce aberrant mutations of fact. The whiplash literature of today still contains reference to several of these misconceptions generated in the 1950's. Realizing the inherent danger of such an approach, this literature search was undertaken to provide a broad base of information for use of diverse disciplines such as engineer, physician, and anthropologist. The objective of this report, therefore, is to bring together for the first time in a single compilation an up-to-date and comprehensive multidisciplinary literature search related to the cervical hyperextension-hyperflexion syndrome. This comprehensive bibliography produced 2,326 references in surveying four major areas of the cervical hyperextension-hyperflexion syndrome.

The references have been arbitrarily organized into four major areas of emphasis. The first major area contains references which have evaluated

motion and/or mobility of the cervical spine. A total of 222 references are included which have analyzed the motion and kinematics of the normal and pathological spine. A second major area involves the biomechanics and/or experimental characteristics of the cervical region. A total of 376 references investigate how external and internal forces affect the individual cervical structures, as well as the entire cervical spine. A third major area provides references which have examined the role of anatomy and/or radiology in diagnosis and treatment of injury. A total of 360 references describe the anatomical composition of the cervical tissues and structures and analyze the various methods and problems of radiographic visualization. The preponderance of cervical syndrome references can be found in the final section, which includes 1,368 references relating to the clinical aspects, diagnosis and treatment of cervical injuries.

Prefacing each of the four major sections is an introduction which defines in detail the nature of the subject matter in that section. Within each section the references are alphabetized by author. It is important to note that this bibliography includes numerous foreign references in over 23 languages, reflecting the increasing international interest in the cervical hyperextension-hyperflexion syndrome.

Although this bibliography represents the first major comprehensive multidisciplinary literature search relating to the cervical whiplash syndrome, it must be stressed that work of this nature can never claim total completeness and represents only an initial compendium. It would be greatly appreciated therefore, if any excluded references or errors would be brought to the attention of the authors.

The bibliography and data presented herein were collected under contract titled "Bioengineering Study of Basic Physical Measurements Related to Susceptibility to Cervical Hyperextension-Hyperflexion Injury" sponsored by the Insurance Institute for Highway Safety, Washington, D.C.

SECTION I  
MOTION/MOBILITY



## MOTION/MOBILITY

The high incidence of reported injuries to the neck emphasizes the need for more accurate measurement of range of motion. Accurate measurements are required to assess the extent of injuries and to monitor progress during recovery, as well as to assist in improved design of occupant impact protection when such limits may be exceeded. Evaluation of motion and/or mobility in the cervical region is a difficult process. The complexity of vertebral articulations, differences in ligamentous strength or atrophy, and variances in disc degeneration allow a wide range of motion. Lack of adequate landmark standards, varying measurement techniques, and reproducibility are additional difficulties encountered.

Included in this section are references evaluating motion and/or mobility in the normal and pathological spine. Flexion, extension, right rotation, left rotation, right lateral flexion and left lateral flexion are measurements listed. In addition, numerous references are included that evaluate cervical motion and kinematics from an engineering approach. This approach is important in the analysis of the mechanics of cervical injury, as well as in the fabrication of anthropomorphic dummies used in experimental tests of whiplash and human impact tolerance.

The references for this section totaled 222.



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SECTION II  
BIOMECHANICS/EXPERIMENTAL



## BIOMECHANICS/EXPERIMENTAL

The cervical region consists of numerous structures and supporting tissues which have a mechanical function. Lesions and injuries occur when forces exceed the strength of these structures and tissues. Biomechanical and experimental investigations, therefore, determine how forces affect not only the individual structures, but the entire cervical region as a whole and, in addition, analyze the physical nature and properties of these structures.

Included in this section are articles describing tests of strength, tension, torsion, electrical activity, stress, crush, strain, pressure, and compression of the individual discs, muscles, vertebrae, spinal cord and nerves. Pre- and post-impact kinematics of the cervical spine have been analyzed using cadaver, dummy, animal and human subjects in a variety of accelerator-decelerator sled and barrier tests. Mechanisms of injury were determined from these experimental tests and from automobile and ejection seat accidents. Numerous additional articles are referenced in this section representing various mathematical, physiological, two-dimensional, three-dimensional and computerized models of the cervical spine.

Due to the intricate interrelationships of the cervical structures, no attempt was made to break down or cross index any sub-categories within the Biomechanics/Experimental grouping. References concerning the lumbar and thoracic spines were occasionally included in this cervical bibliography if the results or methods of the research were applicable to the cervical spine. The references for this section totaled 376.



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SECTION III  
ANATOMY/RADIOLOGY



## ANATOMY/RADIOLOGY

Anatomy and the techniques of radiographic visualization play an extremely important role in the evaluation of whiplash injury and cervical kinematics. Included in this section are references pertaining to the anatomy, radiology, physiology, and pathology of the cervical region. Since so many of the references within these subcategories could be cross indexed, no further breakdown of subject areas occurred within the anatomy and/or radiology grouping.

Before any thorough diagnosis of whiplash injury can be made, the potential sites of injury must be recognized. The nerves, arteries, veins, spinal cord, ligaments, disks and the numerous complex elements of the vertebrae can be considered as the potentially injured structures. References in this section describe the anatomy, physiology, growth and development of these tissues and structures in humans as well as in experimental animals.

The diagnosis of the site of whiplash injury may frequently require extended painstaking radiologic examination of the cervical region. The radiologic examination is complicated by the composition of the cervical tissues (ie. bone, muscle, vascular, disk, etc.), each requiring different methods of visualization, exposure levels and viewing angles. Articles referenced in this section analyze these various methods of visualization and techniques that are required for effective evaluation of the injury.

The references for this section totaled 360.



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SECTION IV

INJURIES



## INJURIES

The cervical hyperextension-hyperflexion injury, commonly referred to as "whiplash", is most frequently the result of rear-end automobile collisions. The high incidence of neck injury related to rear-end impact has been well documented by numerous references included in this section on cervical injuries.

The unique position of the head and the neck in relation to the rest of the body presents a situation in which the cervical elements are particularly vulnerable to injury or fracture. Simplistically stated, the head and the neck are often modelled as a pendulum with the body as a base and may accumulate considerable momentum. When the normal limits of the range of motion are reached abruptly, the forces generated by this momentum may produce various types of structural damage in the cervical region.

The cervical hyperextension-hyperflexion syndrome may be characterized by a number of symptoms and injuries. Cervical pain, tenderness, muscle spasm, blurring of vision, loss of balance, unconsciousness, ill-defined mental changes, suboccipital headaches, subdural hemorrhage, ligamentous damage, nerve root compression, extrusion of disk material, hemorrhage, hematoma, occluded arteries, spinal cord damage, paralysis and cervical vertebral fractures or subluxation are among the many potential lesions. Acute or chronic symptoms of these lesions may persist for years, while in other cases injuries or symptoms may not be evident for a considerable time.

Included in this section are 1368 references which describe the clinical aspects, diagnosis, and treatment of the symptoms and injuries of the cervical syndrome.



## INJURIES

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