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Effects of age and gender on functional rotation and lateral flexion of the back and the neck

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flexion of the back and the neck**

Netzer, Ofra, M.S.

San Jose State University, 1992

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Ann Arbor, MI 48106**

Effects of Age and Gender on Functional Rotation and Lateral
Flexion of the Back and the Neck

A Thesis

Presented to

The Department of Human Performance

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Ofra Netzer

May, 1992

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ABSTRACT

EFFECTS OF AGE AND GENDER ON FUNCTIONAL ROTATION AND LATERAL MOVEMENTS OF THE BACK AND THE NECK

by Ofra Netzer

Effects of age and gender on functional rotation and lateral movements of the back and the neck were examined. Subjects were 55 males and 55 females aged 6 through 80 years; they were divided into five age groups. Two spinal rotational movements and one lateral flexion movement were tested. The movements were measured and analyzed using the Peak Motion Measurement Analysis System. The results indicated non significant differences in spinal flexibility between genders. Statistical differences were observed between the oldest and youngest groups. These two groups differed significantly from the three middle groups. Middle adults showed a significant difference from adolescents and young adults in the neck and back test only.

On the basis of this study physical fitness programs and tests should be adding spinal rotation and lateral movements while evaluating flexibility. In addition, more emphasis should be placed on the cervical region when designing flexibility programs for the elderly.

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CHAPTER 1

INTRODUCTION

Individuals are considered "functionally fit" when they have the capacity to operate effectively in ordinary and unexpected demands of daily life. One of the parameters influencing one's capacity to be fit is flexibility (Clark, 1989). Body movements occur in the sagittal, coronal, and horizontal planes (White, 1971). For example, bending over to pick up an object or tying one's shoes requires spinal flexion of various parts of the body in the sagittal plane (Payne & Isaccs, 1991). On the other hand, getting out of bed or turning around, involves spinal rotation and lateral bending in the horizontal and coronal planes. Functional movements of the vertebral column usually occur in various combinations of planes (Hay & Reid, 1988).

Taylor and Twomey (1980) investigated the sagittal and horizontal movements of the lumbar vertebral column, concluding that the range of these motions tends to decrease with age. A decrease in the flexibility of the peripheral joints with age was also indicated by Munns (1981) and Blair (1983). Additionally, in their article, Rabb, Agre, Mcadam, and Smith (1988) described a decreased ability to perform simple daily tasks due to loss of flexibility with age.

The particular importance of trunk rotation in walking has been emphasized by Yekutieli (1990). M. Yekutieli (personal communication, January 10, 1991) has indicated that reduced spinal rotation resulted in smaller steps and in reduced arm movement. Having treated and observed elderly people for several years, the author of the present study confirms the general decrease in mobility indicated by previous research (Munns, 1981; Rabb et al., 1988; Taylor & Twomey, 1980), and specifically the limitation in back rotation.

In addition to limitations in rotational motion, elderly people also suffer a decline in sensory acuity, such as vision (especially side vision) and hearing (Payne & Isaacs, 1991), senses needed for gathering information from the surrounding environment. Thus, with increasing age one becomes more dependent upon other people (Rabb et al., 1988).

Many studies have been conducted on the relationship between flexibility and age; however, most consider the vertebral motion in the sagittal plane (flexion, extension), and neglect the movements of the horizontal plane (Adrichen & Krost, 1973; Balogun & Songonuga, 1990; Docherty & Bell, 1985; Hilton, Ball & Benn, 1979; Mellin, 1986). Few studies have investigated the horizontal and coronal movements of the spine (Frost, Stuckey & Smalley, 1982; Panjabi et al., 1988; Yamato, 1989).

Many physical fitness batteries include flexibility

measurements among their items (Clark, 1989; Jones, Splitler, Swan & Hawkins, 1989; Ross & Gilbert, 1985). However, these tests use the sit and reach test which examines the ability to bend forward from the waist, a motion in the sagittal plane (Althoff, Svoboda & Girdano, 1988). None of the fitness tests includes rotation and lateral bending movements as part of the flexibility evaluation, and none examines the cervical region. The need to extend the parameters of flexibility fitness tests has already been mentioned in the study of Brown, Cundiff and Thompson (1989). Discussing the implications of fitness programing and specifically the management of geriatric fitness, Brown et al. (1989) denoted the major areas in physical fitness in which fitness evaluation should be extended. They included flexibility measures among these areas emphasizing that the evaluation should not be limited to the lower back. Usually, fitness tests have been used in sport related situations. Recently, there are also plans to use them in industry and public service agencies (Jones et al., 1989). In their article about health and fitness assessment criteria for public service agencies, Jones et al. (1989) cited the police and fire departments as examples of public services which consider the health and fitness of their employees carefully. These agencies try to achieve goals like improved job effectiveness and reduced

job-related injuries.

Einkauf, Gohdes, Jensen, and Jewell (1987) have indicated the need for further research on spinal rotation because only limited data on this motion have been reported. Researchers have not measured the functional rotational motion of the spine, a motion which involves several spinal regions, but rather focused on small sections of the spine (Frost et al., 1982; Hilton et al., 1979; Pearcy & Tiberewal, 1984). In many studies, mostly those which used radiographic measurement techniques, the data were collected from cadavers (Hilton et al., 1979; Panjabi et al., 1988; Taylor & Twomey, 1980; Twomey, 1979; Yamato, 1989). Few studies have investigated rotation and lateral flexion through the life-span using living subjects. However, these studies included subjects of 20 to 80 years old neglecting the periods of childhood and adolescence (Frost et al., 1982; Taylor & Twomey, 1980).

Statement of the Problem

Previous studies conducted on the flexibility of the spine and fitness tests focused their examinations on movements occurring in small sections of the vertebral column (Hilton et al., 1979; Panjabi et al., 1988; Taylor & Twomey, 1980; Twomey, 1979; Yamato, 1989). Most movements were measured in the sagittal plane.

Although greatly involved in many functional motions in daily life, rotational and lateral movements were least investigated. The variability of these functional movements has not been examined through different stages of the life-span in living subjects.

Purpose of the Study

The purpose of this study was to examine the effects of age and gender on functional rotation and lateral flexion of the back and the neck.

Hypotheses

Based on the general decreased mobility found in spinal motions of the coronal and sagittal planes, the following hypotheses were established: a) older adults would perform with significantly less rotation and lateral movements than younger adults and children, and b) females would perform with significantly greater functional rotation and lateral flexion than males.

Delimitations

This study was delimited to females and males from five age groups: early childhood (6-8 years), adolescence (12-15 years), early adulthood (20-30 years), middle adulthood (40-50 years), and late adulthood (60 and up).

Although functional motions occur in various body positions, this study was delimited to measurements taken only in the sitting position. These measurements were taken only in the horizontal and coronal planes. The subjects were right handed and their weight did not exceed 25 percent over their recommended weight as determined by height and weight charts (Clayman, 1989; Mott, Fazekas & James, 1985; Wyngaarden & Smith, 1988).

Limitations

The generalization of the results may be limited because the subjects come from the same geographic location and from a homogeneous population in which sports play an important role in life. Various physical activity programs for all ages are offered to the population in this community.

Although clear instructions and encouragement were given to subjects, the performance of the movements depended on the subjects' motivation. Another limitation related to the procedure of choosing which movement to analyze out of the three movements performed during each test. Although this procedure was done by the researcher through observation of the movements on videotapes, there was still a certain level of subjectivity which could not be eliminated.

Definitions of Terms

Digitizing. A technique involving automated digitizing of joint centers on film or video by computer software, or by hand held pen, cursor, or mouse, with the x,y coordinates of each point subsequently stored in a data file (Hall, 1991).

Flexibility. "The range of possible movement in a joint (as in the hip joint) or series of joints (as when the spinal column is involved)" (Devries, 1986, p.462).

Functional range of motion. The range of motion needed to perform various daily activities (Gajdosik & Bohannon, 1987).

Lateral flexion (often referred to as lateral bending). The bending of the spinal column in the coronal plane around the anterior posterior axis (Hay & Reid, 1988).

Peak motion analysis system. A measurement system which has the ability to perform accurate manual digitizing from standard National Television System Committee (NTSC) or Phase Alteration (PAL) format video (Peak Performance Manual, 1990).

Range of motion. "The angle through which a joint moves from the anatomical position to the extreme limit of segment motion in a particular direction" (Hall, 1991, p.134).

Rotation. A fundamental movement of turning about the vertical axis of the bone. Rotations to the left and right are directional terms used to describe rotation of the neck

and trunk (Hay & Reid, 1988).

Two operational definitions were used in this study:

Functional rotation. A movement of the back and neck regions working together and separately in the transverse plane.

Functional lateral flexion. A movement of the back and neck working together in the coronal plane.

Summary

Flexibility is an important factor affecting the quality of daily life, and is essential for performing daily tasks effectively (Althoff et al., 1988; Payne & Isaacs, 1991). Generally, functional movements occur in various combinations of the sagittal, horizontal and coronal planes (White, 1971). Functional fitness tests and general fitness programs include flexibility among their items (Clark, 1989; Ross et al., 1985; Jones, 1989). However, although rotational and lateral movements are involved in many functional movements, they are not examined in any of the flexibility tests. Furthermore, none of the tests measures the motion of the cervical region. While extensive work has been done on the flexibility of the spine in the sagittal plane (Adrichen & Krost, 1973; Balogun & Songonuga, 1990; Docherty & Bell, 1985; Hilton et al., 1979; Mellin, 1986), only limited attention has been devoted to rotational and

lateral movements of the spine. The few studies that have examined coronal and horizontal motions focused their research on small sections of the spine (Hilton, 1979; Pearcy & Tiberewal, 1974; Frost et al., 1982). Only a small number of studies considered the rotational movement of the spine with age (Einkauf et al., 1987; Munns, 1981; Rabb et al., 1988). However, these studies included subjects between 20 and 80 years old neglecting subjects from childhood and adolescence periods. The general motions of the whole spine in the horizontal and coronal planes, which are often used in daily tasks, have not been measured. The intention of this study was to examine the effects of age and gender on these functional movements.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Range of motion has been traditionally assessed by visual inspection. At the beginning of the 1930s, therapists and researchers indicated the need to establish measurement standards for range of motion (Wiechec & Krusen, 1939). At that time clinical instrumentation started to emerge. After the second World War there was a rapid growth in the field of Physical Medicine and Rehabilitation which promoted the design of more instruments and measurement methods. With the development in measuring techniques, many studies were conducted on the spinal movement (Defibaugh, 1964; Dunham, 1949; Leighton, 1966; Moore, 1949; Wiechec & Krusen, 1939; Wilmer & Elkins, 1947). The present study focuses on two spinal motions, rotation and lateral flexion. The review of related literature includes several sections: a) a brief review of relevant anatomy of the vertebral column, b) a description of spinal motion characteristics, c) a report on several methods and instrumentation used for measuring horizontal and coronal spinal motions, d) a description of the variability of spinal motions with age as presented in previous studies, and e) a summary.

Relevant Anatomy

The vertebral column consists of 33 vertebrae. The first 24 vertebral bodies are separated by fibrocartilaginous intervertebral discs. The sacrum and coccyx are fused together (Hay & Reid, 1987) (see Figure 1).

Figure 1. The spinal column.

From Anatomy, Mechanics, and Human Motion (p.103) by J. G. Hay, G. Reid, 1988, Englewood Cliff, New York: Prentice Hall. Reprinted by Permission.

The structure of adjacent articular processes of the apophyseal joints, and the thickness of the intervertebral discs modify the type and the amount of spinal motion at its various levels. For example, a special structure of the articular surfaces between the occiput and the first cervical vertebra permits 50% of the neck flexion (Hoppenfeld, 1976). Vertebral motions are greatest where the discs are thickest and the joint surfaces are largest. These two components exist in the lumbar spine between the L4 and L5 segments, and between the L5 and S1 segments. The vertebral bodies are bound together by anterior and posterior longitudinal ligaments which extend from the sacrum to the base of the occiput. The anterior ligament is stronger than the posterior. It limits the extension of the vertebral column. Ligamenta Flava occupies the space between the laminae of the adjacent vertebrae and helps to restore the vertebral column to its original position after bending movements. The interspinous ligaments connect the spinous processes and partially limit flexion and lateral bending (Moll & Wright, 1976). The erector spinae are a muscle group functioning as extensors and controllers of spinal flexion. The abdominal muscles are the flexors which bend the spine forward. To perform lateral flexion or rotation, the abdominal and back muscles on one side of the body contract simultaneously, while the muscles of the

opposite side are relaxed (Moll & Wright, 1976).

Spinal Motion Characteristics

The vertebral column combines the qualities of strength and flexibility by having rigid bony vertebrae with deformable cartilaginous discs. The synovial joints, the ligaments, and the muscles contribute to the vertebral column stability, as well as mobility.

Movements of the vertebral column are usually described in three planes of motion: the sagittal, the coronal, and the horizontal planes (Hay & Reid, 1988; White, 1971). The vertebral column permits four main movements, flexion, extension, lateral flexion, and rotation. Movements of the spine are largest in the cervical and lumbar regions, and more restricted in the thoracic region. Flexion occurs primarily in the cervical, the low thoracic, and the lumbar regions. Extension takes place mainly in the cervical and the lumbar spine, while rotation is most common in the cervical region though relatively restricted in the lumbar and thoracic regions.

Since this study concentrates on rotation and lateral flexion of the spine, only these motions will be described in detail. Hay and Reid (1987) defined rotation as the twisting of the spine in the transverse plane, and lateral flexion as the bending of the spine to one side or another

in the frontal plane. Of the cervical vertebrae, the atlanto-axial joint is most mobile. About 45 degrees of rotation occur at that joint (Hoppenfeld, 1976) (see Figure 2). The remaining rotation and other motions (lateral flexion, flexion, extension) occur at the joints of the cervical region below the second vertebra (Hay & Reid, 1987). In the thoracic region, the bony architecture of the facet joints, the closeness of the spinous processes to each other, and the ribs allow a small amount of flexion, a limited extension and lateral flexion. Rotation in this area is approximately 40 degrees to each side (Hay & Reid, 1987). Compared with the movements in the thoracic region,

Figure 2. The C1 and C2 vertebrae rotary motion.

From Physical Examination of the Spine and Extremities (p.103) by S. Hoppenfeld, 1976, Crofts, New York: Appleton-century. Reprinted by permission.

all four movements are larger in the lumbar region. The lower lumbar spine, where the discs are thicker and the articular joints have a larger surface area, is more mobile (Hoppenfeld, 1976). Although the 24 vertebrae do not provide a large range of motion individually, the total range of motion is considerable in a healthy individual (Hay & Reid, 1987)

Methods and Instrumentation Used to Measure the Mobility of the Spine in the Horizontal and Frontal Planes

Various methods and instrumentation have been used to measure the mobility of the spine. Three measuring concepts will be described in this chapter: direct measurement in living subjects using clinical instrumentation, radiographic studies, and theoretical studies based on mathematical models.

Direct Measurements in Living Subjects Using Clinical Instrumentation

Spinal range of motion has been traditionally assessed by a subjective visual inspection. Cleveland (1918) recommended visual estimation claiming that numerical measurements lead to confusion. He estimated the joint angle of a motion by a circular pattern. Some observers have introduced objectivity into the tests. For example,

lateral flexion was examined by measuring the distance between the third finger and the knee when the person being examined bent sideways, sliding his or her fingers down the homolateral thigh (Moll & Wright, 1976).

A simple and objective clinical method for measuring the thoraco lumbar lateral flexion of the back was presented by Moll and Wright (1971), and was used by Moran, Barr and Ansell (1979). They used a measuring tape to determine the distance between points which they marked on the skin of the subject's lateral trunk (see Figure 3).

Figure 3. Thoraco-lumbar lateral flexion.

From " Normal range of spinal mobility" by J.M.H. Moll and V. Wright, 1971, Annals of the Rheumatic Disease, 30, p. 382. Reprinted by permission.

The subject was asked to bend sideways by sliding the hand down the homolateral thigh. At the end of the movement, the distance between the marks was measured again. They reported a high correlation ($r=.79$) between radiological and clinical measurements. Frost et al. (1982) used a metal measuring tape to examine back rotation. They measured the distance between the left posterior clavicular prominence and the right greater trochanter before and after rotating the trunk (see Figure 4).

Figure 4. Trunk rotation and lateral flexion test using metal tape.

From "Reliability of Measuring Trunk Motions in Centimeters" by M. Frost, S. Stuckey, L.A. Smally, G. Dorma, 1982. Physical Therapy, 62, p. 1432. Reprinted by permission.

However, this technique showed low reliability and was determined to be ineffective (Frost et al. 1982). They measured the side bending movement by asking the subject to bend sideways and slide his or her hand down the thigh. The distance from the third fingertip to the floor was measured to indicate the range of lateral flexion. Frost et al. (1984) reported a good reliability ($r=.71$) of side bending measurements.

Leighton (1966) designed an instrument called the "Leighton Flexometer." This instrument consists of a weighted 360 degrees dial and a weighted pointer. The dial and the pointer can rotate freely and independently. The movement of each part is influenced by gravity (see Figure 5). Trunk rotation is measured in the supine position while the subject's shoulders are fixated, and the trunk is rotated passively by moving the subject's knees.

Figure 5. The Leighton Flexometer.

Movements of the pelvic region are not eliminated during the measurement. Lateral bending is measured in a standing position. The instrument is also used for measuring cervical rotation and lateral flexion. The Leighton Flexometer was found to be highly valid ($r=.913$), and highly reliable ($r=.901$ to $.983$) (Safrit, 1981).

Taylor and Twomey (1980) have studied the range of the sagittal and horizontal plane motions of the lumbar vertebrae in living subjects (20-60 years old) and in cadavers. To measure the rotational movement, a "Lumbar Rotameter," consisting of a protractor and a pointer, is firmly attached to the sacrum and the lumbar region by two belts. Pelvic and hip movements are not permitted (see Figure 6). When the subject turns, the range of rotation can be read on this protractor. This instrument was found to be accurate, quick to apply and easy to read. The results using this instrument correlated well ($r=.85$) with the results of rotation of lumbar spine obtained from a previous Twomey's study in 1979 (Twomey & Taylor, 1979). In 1986, Hoeger presented a simple device for measuring trunk rotation in a standing position. The device consists of a sliding panel attached to a measuring tape glued to the wall (see Figure 7). The subject, standing 2 to 3 feet from the wall, is asked to slide his or her hand along the measuring tape. The extension is measured in inches. Shoulder and

Figure 6. The Lumbar Rotameter. From "Sagittal and Horizontal Plane Movement of the Human Lumbar Vertebral Column in Cadavers and in the Living" by Taylor, J. & Twomey, L., 1980. Rheumatology and Rehabilitation, 19, p.225. Reprinted by permission.

pelvic girdles, knees and ankles are involved in the general rotation measured.

Cervical spine mobility, like back mobility, has been traditionally assessed by visual approximation (Cleveland, 1918). Moll and Wright (1976) stated that the visual estimation is the most popular technique for recording spinal mobility. A special head goniometer, which consists of the pendulum goniometer with an attached mouthpiece, was constructed by Defibaugh (1964). With any movement of the subject's head, the goniometer rotates and the angle of

Figure 7. Trunk rotation test using a sliding panel device. From Lifetime Physical Fitness Wellness (p.49) by W. W. K. Hoeger, 1986, Englewood, Colorado: Morton Publishing Company. Reprinted by permission.

motion is easily read. This method was found to be moderately to highly reliable ($r=.711$ to $.909$).

Two modern-day instruments used with increasing frequency for direct motion measurement and analysis are the video camera, and the 8mm and 16mm movie cameras (Hall, 1991). Both the 8mm and the 16mm movie cameras provide films with better picture resolution than is available through conventional video systems. A film camera can record at speeds of 500Hz while a basic video camera captures frames at 60Hz (Kennedy, Wright, & Smith, 1989). However, according to Kennedy et al. (1989) and Hall (1991), video recording methods are adequate for slow movement and global movement patterns such as the player's path during a

game. Kennedy et al. (1989) also indicated that for reasons such as low cost, ease to use, and short processing time, video has become an attractive alternative to using film. The pictures received through these two techniques, movie or video cameras, are analyzed with computer-linked equipment that enables the calculation of kinematic and kinetic quantities, such as velocity, acceleration, and joint motion (Peak Performance Manual, 1990).

The procedure for analyzing the film or video pictures involves a process called "digitizing." This includes marking a subject's joint centers or other points of interest with the X and Y coordinates of each point. The data gathered are stored in the computer. The Peak Motion Analysis System developed by Cheetham and Fcheirman in 1986 is a measurement system which has the ability to perform accurate manual digitizing from standard National Television System Committee (NTSC) and Phase Alteration Line (PAL) format video. Additionally it analyzes the video for velocity, acceleration, joint angles and other variables. The Peak System is compatible with high frame rate video systems currently on the market (Peak Performance Manual, 1990). Since the system is relatively new, only a few studies have used it. None has specifically addressed spinal motion.

Radiographic Studies

The use of radiographic films is one of the most objective and accurate methods for measuring joint motion. It facilitates the analysis of mobility patterns and their relation to structural abnormalities and pathological changes. However, this method is expensive and potentially dangerous over time (Defibaugh, 1964). Because of these limitations, the radiographic measurement method is mostly used on cadavers and usually small sections of the vertebral column are investigated. For example, Hilton et al. (1979) conducted a study on the sagittal mobility of the lumbar spine between T-11 and S-1 segments in 103 postmortem specimens with age range of 13 to 96 years. They found that all lumbar segments became less mobile up to the fifth decade. Between the fifth and the eighth decade the mobility of the fifth lumbar segment continued to decrease, whereas in other lumbar segments an increased mobility was observed. Hilton and associates also reported no significant gender difference in lumbar mobility. The reproducibility of the method was found to be within 10 percent of the total mobility between T-11 and L-5.

Movements of the occipito - atlanto - axial joint complex have been studied by Panjabi et al. (1988). They used roentgenograms of cadavers, and concluded that the greatest intervertebral motion in the cervical spine was the axial

rotation between the C-1 and C-2 vertebrae.

Yamamoto et al. (1989) investigated the three dimensional movements of the whole lumbar spine and lumbosacral joint in 10 fresh cadavers (between 25-63 years) using radiographic methods. They found the motion in the sagittal plane between the L-4 and L-5 segments was greater than the motion at the upper levels of the lumbar spine.

Radiologic techniques have also been used to analyze the motion in healthy volunteer subjects. Pearcy et al. (1984) used three dimensional X-rays to assess normal movements of the lumbar spine in 11 male volunteers between the ages 25-36 years. Results showed that in the sagittal plane, the lower levels of the lumbar spine move slightly more than the upper level. Analysis of the movements showed that there was a slight rotation and lateral flexion during flexion. Pearcy and Tiberewal (1984) used a three dimensional radiographic technique to investigate the active axial rotation and lateral flexion between the L-3 and S-1 segments in normal male volunteers (ranging between 21-30 years). They reported a slight increase in mobility between the L-4 and L-5 segments compared with the other joints, and a decrease in lateral flexion movement between L-4 and L-5.

Another example of a radiographic study in living subjects is the research of Gregersen and Lucas (1967). They inserted stienman pins into the spinous processes of

seven subjects using these as an indicator to record range of motion at the thoraco lumbar region. Gregersen and Lucas indicated that there was slight rotation at all intervertebral joints examined, but the maximum was in the mid thoracic region. Although the method was objective and precise, the inconvenience and discomfort experienced by the subjects severely limited its usefulness.

Theoretical studies based on mathematical models

Gracovetsky and Farfan (1984) studied "the optimum spine" using a mathematical model. They indicated that the most exact descriptions of the real world come in mathematical form, adding that the human body is a part of the real world and therefore should be investigated by mathematical modelling. Gracovetsky and Farfan described the human spine as a machine that performs complex tasks under various levels of stress. They derived the mechanical behavior of the joint from which they calculated the corresponding spinal motion and muscular responses. They formulated the musculoskeletal system at the spine as an energy optimization problem and developed theory of the function of the human spine explaining the energy transfer through the intervertebral joints during sagittal plane motion. Gracovetsky and Farfan also showed that changes in the location of the center of gravity are not a sign of

instability, but are purposely used to derive the energy for locomotion. Belytschko, Andriacchi, Schults and Galante (1973) also developed a mathematical model for a three-dimensional force analysis of the human vertebral column. They isolated a spinal ligament and examined its behavior under traction, lateral loads, and compression loads. Advantages of using the means of mathematical analogs in studies of the complex structure of the human spine were described. For example, changes can easily be made when working with mathematical models. Mathematical models may also be used to isolate important features of the biological system and to ascertain the influence of various parameters which cannot be controlled in a real experiment.

The variability of motion at the back and the neck with age

After measuring living subjects from a wide range of ages, several researchers described decreased mobility with age. However, these studies focused their investigations on sagittal plane movements of the spine. For example, Munns (1981) investigated the age difference in flexibility of the extremities and cervical rotation in a group of males, 18-71 years. He reported that the greatest flexibility in extremities and in spinal joints for men was at 23.5 years of age. For women, it was between 25 and 29 years. Adrian (1981) reported a decreased flexibility in the joints of the

extremities, with advancing age. This was mostly noticeable in hip rotation and extension and in shoulder lateral rotation.

Docherty and Bell (1985) reported that flexibility of boys (between 6-15 years) decreased with age for shoulder flexion and extension and arm extension. Girls were generally more flexible than boys at all ages and showed little change in trunk and hip flexibility in the sagittal plane with age. The variability of shoulder flexion with age has also been investigated by Blair (1987). The results showed the expected decline of flexibility after childhood. Both men and women have the greatest range of motion at the shoulder joint in their twenties with a decrease thereafter.

In most studies conducted on the horizontal and coronal movements, small sections of the spine were investigated with subjects generally being between 20 to 80 years. For example, Defibough (1964) measured the cervical mobility of seven subjects between 20 to 40 years of age. Pearcy, Portek, and Shepherd (1982) measured 11 male subjects between 20 to 40 years of age. Moll and Wright (1971) measured the sagittal and frontal motions of the thoraco lumbar region of a group of 11 to 80 year olds. They found a 50 percent decrease in mobility between young and old age. The study by Taylor and Twomey (1980) was the only one found dealing with the rotational motion of the spine relative to

age. This study examined 437 living subjects, 18 to 87 years old. The researchers measured the lumbar region and found a decrease in the ranges of sagittal and rotational movements between the ages of 25 and 69 years. Taylor and Twomey also investigated developmental variability of the range of motions in subjects under 20 years of age; however, the subjects were cadavers. Results showed a decline in the range of motion with increasing age. They determined that increasing age, between 25 to 69 years, is associated with a decrease in the mean value for the spinal rotation and flexion movements. Sagittal motion and age were found to be highly correlated for males ($r=.96$) and females ($r=.87$). Horizontal motion correlated with age was found to be high for both males ($r=.96$) and females ($r=.79$).

Unlike the studies described before which examined western population spinal range of motion with age (Blair, 1987; Moll & Write, 1971; Moran et al. 1979), the study of Balogun and Songonuga (1990) investigated the spinal flexibility of 150 Nigerian males with age. Using four types of flexibility tests: a modified Schober test, a sit-and-reach, a trunk-extension, and a shoulder-lift flexibility test, they determined that spinal flexibility increased with age to 40 years, but decreased thereafter. Balogun and Songonuga observed an initial increase in lumbar flexion from 15-24 years to 25 -34 years. This was followed

by a progressive decrease with age in both genders.

Summary

The literature review has revealed various methods used to measure the transverse and frontal spinal motions. Of the clinical instrumentation described, the Leighton Flexometer, the Lumbar Rotameter, and the measuring tape were found to be highly valid and reliable (Leighton, 1966; Taylor & Twomey, 1980; Frost et al. 1982). Modern-day instruments like cinematography and videography are increasingly used in measuring and analyzing human motions. The 8mm and 16mm movie cameras can record at significantly higher speeds than video cameras. The video camera, however, is adequate for slow motions and global movements (Hall, 1991). In addition, it offers many advantages over traditional film such as, cost and ease of use (Kennedy et al. 1989; Peak Performance Technologies, 1990). The use of radiological techniques were also found to be highly accurate. However, the cost and potential danger limits the use of this method. Studies which used radiography usually included cadavers as their subjects (Hilton et al. 1979; Panjabi et al. 1988; Yamamoto et al. 1989). The use of radiographic techniques enabled the study of motions between certain segments in the vertebral column. For example, the movement of the occipito - atlanto - axial joint complex

which was studied by Panjabi et al. (1988) and revealed that the greatest intervertebral motion in the cervical spine is the axial rotation between the C-1 and C-2 vertebra.

Mathematical models are another method used to examine the spinal motion (Belytschko et al. 1973; Gracovetsky & Farfan, 1984). These studies dealt with the mechanism of the musculoskeletal system at the spine explaining the energy transfer through the intervertebral joints during sagittal plane motion (Gracovetsky & Farfan, 1984). Most studies conducted on the horizontal and coronal movements focused their investigation on small sections of the spine (Panjabi et al. 1988; Pearcy & Tiberwal, 1984). Few studies examined the changes of motion with age (Adrian, 1981; Blair, 1987; Docherty & Bell, 1985; Taylor & Twomey, 1980). These studies showed a general decrease in spinal motion with age. Their subjects were between 20 to 80 years of age. None of the studies measured functional rotation and lateral flexion of the back and the neck, and none has included subjects from early childhood.

CHAPTER 3

METHODS

Introduction

The intent of this research was to examine the effects of age and gender on functional rotation and lateral flexion of the back and the neck. The study included two independent variables: age and gender, and three dependent variables: back and neck functional rotation, back and neck lateral motion, and rotational motion of the neck. In this chapter, characteristics of the subjects are detailed along with the measurement procedures, the instrumentation, and the statistical procedures.

Subjects

A total of 55 males and 55 females volunteered for this study. Each group consisted of 22 subjects, even number of both genders. Of the eleven age stages across the life-span described by Payne and Isaacs (1991), subjects from five of these age groups participated in this study. The groups included an equal number of males and females from: a) early childhood (6-8 years), b) adolescence (12-15 years), c) early adulthood (20-30 years), d) middle adulthood (40-50 years), and e) late adulthood (60-80). Infants and toddlers were not considered in this study since cooperation during

measurement and remeasurement procedures is difficult and may affect the reliability of the tests (Thomas & Nelson, 1990).

All subjects were free of back injuries or serious disease as determined by a short questionnaire administered to each subject before the test (Appendix A). Subjects were right handed and their weight did not exceed the 25th percentile of the recommended body weight for their height as determined in weight and height charts (Clayman, 1989; Mott, Fazekas & James, 1985; Wyngaarden & Smith, 1988). The subjects for this study were consenting students from first, second, sixth, and ninth grades in Palo Alto schools, and consenting adults from the Palo Alto community. They received a consent form explaining the purpose of the study, risks and benefits associated with this study, time they would be donating, and their rights as volunteer participants (Appendix B).

Instrumentation and Principles of Measurement

The Peak Two Dimensional Motion Measurement System, developed by Cheetham and Fcheirman in 1986, was used for measuring both lateral and rotational movements. These movements are used in basic daily activities such as getting out of bed and have rarely been the source of scientific investigation. The system has the capability to perform

accurate manual digitizing from standard National Television System Committee (NTSC) or Phase Alteration Line (PAL) format video. The recorded video image is imported into a computer where the movements in question are analyzed.

The Peak System consists of three hardware components: an IBM AT computer, the video system, and the Peak Two Dimensional Core. The video system includes a professional quality VCR (Peak Performance Technologies, 1990) which captures pictures at 60 Hz (60 fields per second) (Hall, 1991). A Panasonic AG450 camcorder was used for this study. The Two Dimensional Core hardware enables the Peak System software to control the video recorder to select the exact frame required for analysis.

In the current study, the Peak Two Dimensional system was used for measuring the angular displacement from the initial to the terminal positions. The system can measure angles in two ways: a) measuring the angle between two segments that have a common point, and b) measuring the angle between one segment and an internal reference, which is created by the system, and is the vertical or horizontal axis of the frame. The former approach can be regarded as a relative measurement, while the latter is an absolute measurement. Since the movement of one segment of the body was examined with respect to a fixed segment, the second method was used. Furthermore, any stationary line could be

used as a reference segment. In this research, the internal reference created by the Peak Two Dimensional System was used. During functional back and neck lateral flexion and during functional back and neck rotation, the moving segment included the back and the neck while the pelvic region was kept stationary. When performing neck rotation, the moving segment included the neck while the shoulder girdle, the back and the pelvis were kept stationary. The subjects wore a helmet when measurements were taken. Lateral flexion motion analysis was facilitated by placing a rod, marked at its two edges, on the helmet. Rotational motion analysis was facilitated by marking a line on the top of the helmet. Angular displacement of the movements in question was measured between the rod or the line marked on the helmet and a vertical reference created by the system. The positions before and after the motion are shown in Figure 8. The vertical axis is presented by the rod fixed to the wall and the angular displacement is marked.

The accuracy of a 60 Hz video in analyzing slow movements, like the movements in this research, has been found to be adequate both qualitatively and quantitatively (Hall, 1991; Kennedy et al. 1989). The instrument and the technique have met the criteria of validity and reliability: (1) a correlation between known angles and measured angles revealed high validity ($r=.99$), (2) intraclass correlation

between repeated measurements was .94.

Measurement Procedures

Introduction

Since this study dealt with functional motions, no warm-up was administered to the subjects before taking the measurements and only active movements were examined. Subjects performed three trials (three movements for each dependent variable). The trial which appeared to be most correctly performed was maintained for data analysis. The subjects were examined at least four hours after waking due to the body's tendency to be less flexible

Figure 8. Angular displacement measurement procedure.

earlier and more flexible later in the day after more activity had occurred at the joints (Devries, 1980). Although functional motions occur in various body positions the study was delimited to measurements taken only in the sitting position. To eliminate movements at the pelvic and hip regions the subjects were asked to sit astride a chair facing its back. Simple standardized instructions were administered to subjects to minimize misunderstanding (Appendix C). In addition, each motion was demonstrated prior to the test.

A preliminary study involving five subjects was conducted prior to the study to determine the feasibility of the procedure, the appropriate distance from the camera to the subject, and the appropriate light intensity. Since intratester reliability was found to be superior to intertester reliability (Gadjdosik & Bohannon, 1987), the subjects' motions were measured by only one researcher.

Procedures and General Principles in Videotaping

As recommended by Peak Performance technologies (1990), the axis of the camera lens was perpendicular to the plane of measured movement. Thus when back and neck rotational movements were videotaped, the camera was located above the subject's head, looking downwards. For lateral movement videotaping, the camera was located behind the subject's

back. The appropriate distance between the camera and the subject was found to be 1.5 and 4 meters for videotaping lateral and rotational movements, respectively. A stand was used to ensure the stability of the camera during taping. The taping was conducted indoors and the subjects were illuminated by additional artificial lighting.

Description of Neck and Back Rotation Testing

The subjects, with the helmet in place, sat astride a chair in an upright position facing the back of the chair. A 20cm straight line, pointing forward, was marked on the helmet (see Figure 9). The subjects were asked to maximally rotate their back and their neck to the right. Instructions given to subjects are presented in Appendix C.

Figure 9. Functional back and neck rotation test

Description of Neck Rotation Testing

To measure neck rotation, subjects sat erect, facing the back of the chair, wearing the marked helmet. To prevent shoulder movement during neck rotation, subjects were asked to put their hands behind their backs (see Figure 10). The subjects were instructed to fully rotate their heads to the right without moving their pelvis and back (see Appendix C).

Description of Neck and Back Lateral Flexion Testing

To measure functional back and neck lateral flexion, the subjects were asked to sit in an upright position facing the back of the chair wearing a helmet. A 30cm rod was

Figure 10. Neck rotation test.

Figure 11. Functional back and neck lateral flexion test.

strapped to the back of the helmet (see Figure 11). The subjects were instructed to bend their backs and necks sideways as far as they could (see Appendix C).

Peak Two Dimensional Motion Analysis Set Up

The motion analysis included four main stages:

a) spatial model and project setup, b) video recording, c) digitizing, and d) data analysis. Three spatial models were created: functional back and neck rotation, neck

rotation, and functional back and neck lateral flexion. The spatial models contained the number of points per picture, the label of each point, and the manner in which the points were connected (Peak Performance Technologies, 1990). Each spatial model included one segment, which was a rod strapped to the helmet the subjects wore, or a straight line marked on the top of the helmet. One event was analyzed on each spatial model, angle of rotation, or angle of lateral flexion. The angle was defined between the segment mentioned and the vertical, as was explained earlier in the instrumentation section.

Statistical Analysis

The two-way ANOVA was used to analyze the difference in range of motion among the five age groups and between the two genders. The .05 level of significance, which originally had been set, was later divided by three (number of ANOVAS), as recommended by Dunn (1961) to adjust for the otherwise inflating alpha resulting from repetition of ANOVA. Scheffé post hoc technique was used to determine which means were significantly different from one another. The desirable sample size was determined after calculating the statistical power of the study. A predicted effect size was developed from the preliminary study, and was used to calculate an apriori value for power as recommended by

Keppel (1982). Post hoc power was recalculated using the actual effect size. The formula used for power calculation is presented in Appendix D.

Summary

Using a simple stratified sampling method, 110 subjects were selected to participate in this study. The participants were divided into five age groups: a) early childhood (6-8 years), b) adolescence (12-15 years), c) early adulthood (20-30 years), d) middle adulthood (40-50 years), and e) late adulthood (60 and up). They were asked to read and sign a written consent letter before responding to a brief questionnaire regarding their back condition. All subjects were determined to be free of back injuries or disease. They were right handed and within the normal weight limits for their heights as recommended by Clayman (1989), Mott, Fazekas and James (1985), and Wyngaarden and Smith (1988). Functional rotational and lateral movements were examined. A preliminary study was conducted prior to the study to determine the feasibility of the testing procedure. Each test session included three movements from which the one which was most correctly performed was selected for inclusion in data analysis.

The Peak Two Dimensional Motion Measurement System was used to calculate the range of the functional rotation and

lateral movement of the back and the neck. After videotaping the subjects' movements, the "live image" from the VCR composited with an input "digitized image," was analyzed for the range of motion in question. Angles were defined between a rod strapped to the head and the vertical axis of the frame which was created by the system. The study included two independent variables, age and gender, and three dependent variables, functional back and neck rotation, functional back and neck lateral flexion, and neck rotation. The significance of the results were calculated by using two-way ANOVA followed by Scheffé post hoc analysis.

CHAPTER 4

RESULTS and DISCUSSION

The purpose of this study was to examine the effects of age and gender on functional rotation and lateral flexion of the back and the neck. Data were analyzed with the SPSS software and in this chapter, the results are presented and discussed.

Results

Three spinal movements were measured, neck rotation, back and neck rotation, and back and neck lateral flexion. A total of 55 males and 55 females served as subjects; they were divided into five age groups (see p.30). Descriptive and inferential statistics were applied. The means and standard deviations are summarized in Table 1, and presented graphically in Figure 12. Decreased spinal mobility with increasing age was indicated. Interestingly, the third group (young adults) performed almost five degrees more of neck rotation than the adolescents of the second group (see Table 1). Inspection of the data reveals that standard deviations of the fifth group's results were much larger than those obtained for the other groups (see Table 1 and Figure 12). To gain better insight into these findings, each standard deviation was normalized by the related mean

Table 1
Means and Standard Deviations of Rotation and Lateral Flexion (degrees)
by Age Groups

Group #	Age (years)	NROT		NBROT		NBLF	
		<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
1	6-8	89.2	8.7	141.9	10.5	111.7	7.4
2	12-15	77.9	8.5	132.2	12.8	108.7	13.8
3	20-30	82.5	6.4	133.7	11.5	103.7	10.7
4	40-50	78.0	5.9	119.9	9.9	97.1	12.7
5	60-80	65.1	10.1	96.69	15.4	75.0	16.0

NROT: Neck Rotation

NBROT: Neck and Back Rotation

NBLF: Neck and Back Lateral Flexion

Figure 12. Means and Standard Deviations (degrees) of Range of Motion (R.O.M) for: (a) Neck Rotation, (b) Neck and Back Rotation, (c) Neck and Back Lateral Flexion

Table 2

Standard Deviation Normalized by Mean ($100\text{SD}/\text{M}$)

Group #	Age (years)	NROT	NBROT	NBLF
1	6–8	9.7	7.4	6.6
2	12–15	10.9	9.7	12.7
3	20–30	7.7	8.6	10.3
4	40–50	7.6	8.3	13.1
5	60–80	15.5	16.0	21.3

NROT: Neck Rotation

NBROT: Neck and Back Rotation

NBLF: Neck and Back Lateral Flexion

value (see Table 2). Consequently, the normalized standard deviations of the fifth group ranged from 15.5% to 21.3% over the examined movements versus 6.6% to 13.1% for the other groups. This indicated greater variability in spinal mobility in older adults.

Comparison of performance by genders revealed only slight differences in means and standard deviations for all age groups (see Tables 3 and 4). In some movements females performed better than males while in others this was reversed. For example, the means for neck and back rotation of females and males of the fifth group were 100.1 and 93.2 degrees, respectively, while for the fourth group the means were 117.0 and 122.9 degrees, respectively.

To determine if significant differences existed between the means of the two genders and the five age groups, a two-way ANOVA was employed. The level of significance (alpha level) was set at .05. However, this was divided by three (number of ANOVAs conducted) to determine a new alpha, .01, as recommended by Dunn (1961). This modification was necessary to avoid an inflation of alpha due to multiple applications of ANOVA. ANOVA indicated that the difference in spinal mobility between genders was not significant, $F(1,100) = 6.9$, $p > .01$ (see Tables 5,6,7). The differences in spinal mobility due to age were found to be significant for the three tested movements, $F(4,100) = 3.51$, $p < .01$ (see

Tables 5,6,7). Interactions between the independent variables, gender and age and spinal flexibility were not significant, $F(4,100) = 3.51$, $p > .01$ (see Tables 5,6,7).

To identify which age group differed significantly from the others in spinal flexibility, a Scheffé post hoc comparison was conducted. Results showed that the oldest group differed significantly from the other age groups in the three tested movements. Significant differences were also found between the youngest group and the middle adults in the three tested movements. The youngest group also differed significantly from the young adults in the neck rotation test. The three middle age groups did not differ significantly from each other in any of the tested movements except for the neck and back rotation test in which middle adults differed significantly from children and adolescents (see Tables 8,9,10).

Following the statistical calculations, the practical significance of the findings was examined. Results showed that neck rotation, neck and back rotation, and neck and back lateral flexion were practically influenced by age by 70, 79, and 72%, respectively.

The statistical power of the study was calculated for each movement test separately using the effect size of the tested groups. High statistical power values namely, .97, .99 and .98 were found for neck rotation, neck and back

rotation, and neck and back lateral flexion, respectively.

Table 3
Means of Spinal Movements by Age Groups and Gender

Group #	Age (years)	Gender	NROT	NBROT	NBLF
1	6–8	F	92.0	142.1	110.0
		M	86.4	141.8	113.3
2	12–15	F	79.0	130.4	107.6
		M	76.8	134.0	109.7
3	20–30	F	84.3	135.9	107.7
		M	80.2	131.6	99.7
4	40–50	F	80.2	117.0	97.6
		M	75.7	122.9	96.7
5	60–80	F	65.8	100.1	75.7
		M	64.4	93.2	74.3

NROT: Neck Rotation

NBROT: Neck and Back Rotation

NBLF: Neck and Back Lateral Flexion

Table 4
Standard Deviations (degrees) of Spinal Movements
by Age Groups and Gender

Group #	Age (years)	Gender	NROT	NBROT	NBLF
1	6-8	F	7.9	10.4	7.9
		M	8.5	10.6	6.4
2	12-15	F	10.6	11.4	15.3
		M	5.6	13.8	11.9
3	20-30	F	4.2	11.9	7.2
		M	7.5	10.6	12.1
4	40-50	F	5.3	9.7	14.5
		M	5.6	9.2	10.6
5	60-80	F	10.0	19.0	17.9
		M	10.1	9.5	13.8

NROT: Neck Rotation

NBROT: Neck and Back Rotation

NBLF: Neck and Back Lateral Flexion

Table 5
Analysis of Variance
Neck Rotation by Age Groups and Gender

Source of Variation	Sum of Squares	DF	Mean Square	F	p
Main Effects	7187.790	5	1437.558	21.355	< .001
Age Group	6853.012	4	1713.253	*25.450	< .001
Gender	334.778	1	334.778	4.973	.028
2-Way Interactions	65.319	4	16.330	.243	.914
Age Group Gender	65.319	4	16.330	.243	.914
Explained	7253.110	9	805.901	11.972	< .001
Residual	6731.787	100	67.318		
Total	13984.897	109	128.302		

* $p < .01$

Table 6
Analysis of Variance
Neck and Back Rotation by Age Groups and Gender

Source of Variation	Sum of Squares	DF	Mean Square	F	p
Main Effects	27382.333	5	5476.467	34.850	< .001
Age Group	27377.771	4	6844.443	*43.555	< .001
Gender	4.561	1	4.561	.029	.865
2-Way Interactions	624.113	4	156.028	.993	.415
Age Group Gender	624.113	4	156.028	.993	.415
Explained	28006.446	9	3111.827	19.802	< .001
Residual	15714.353	100	157.144		
Total	43720.799	109	401.108		

* $p < .01$

Table 7
Analysis of Variance
Neck and Back Lateral Flexion by Age Groups and Gender

Source of Variation	Sum of Squares	DF	Mean Square	F	p
Main Effects	18887.807	5	3777.561	22.720	< .001
Age Group	18860.407	4	4715.102	*28.359	< .001
Gender	27.400	1	27.400	.165	.686
2-Way Interactions	431.140	4	107.785	.648	.629
Age Group Gender	431.140	4	107.785	.648	.629
Explained	19318.947	9	2146.550	12.910	< .001
Residual	16626.658	100	166.267		
Total	35945.606	109	329.776		

* $p < .01$

Table 8
Scheffé Analysis
of Neck Rotation by Age Groups

Mean	Group	5	4	3	2	1
65.0545	5					
77.9864	4	*				
82.4500	3	*				
77.8955	2	*				
89.2000	1	*	*	*		

Table 9
Scheffé Analysis
of Neck and Back Rotation by Age Groups

Mean	Group	5	4	3	2	1
96.6409	5					
119.9045	4	*				
133.7409	3	*	*			
132.1682	2	*	*			
141.9273	1	*	*			

Table 10
Scheffé Analysis
of Neck and Back Lateral Flexion by Age Groups

Mean	Group	5	4	3	2	1
74.9636	5					
97.1455	4	*				
103.7136	3	*				
108.6727	2	*				
111.6727	1	*	*			

Discussion

Two hypotheses were tested in this study. Each will be addressed separately with explanations based on the results. Hypothesis 1 stated that older adults would perform with significantly less rotational and lateral movements than younger adults and children. Based on the statistical analysis the null hypothesis was rejected, $p < .01$. Scheffé post hoc analysis revealed that the greatest differences in the spinal mobility occurred between the oldest age group and the other groups. These differences can be explained by a general tendency to become progressively inactive with advancing age (Brown et al. 1989; Rabb et al. 1987). The decline in physical activity with age is also seen in the oldest group of the present study. Of the 22 subjects in

this group, 9 reported walking as their only regular activity and 6 reported that they participated in gymnastics. However, walking is an activity involving mainly sagittal movements, and has little effect on spinal mobility in other planes of motion. Subjects of the other groups participated in a variety of physical activities such as swimming, aerobics, and tennis which involve movements in all planes of motion. The drastic decline in spinal flexibility found in older adults is in agreement with the results of many other studies (Adrian, 1980; Balogum & Songonuga, 1990; Einkauf, Gohdes, Jensen, & Jewell, 1987; Moll & Wright, 1971). Interestingly, the conclusions reported by other authors were based on data collected from different spinal tests in which neck and back rotational movements were not included. Thus, the results obtained from this study confirm and strengthen the conclusion regarding the effects of age on spinal flexibility in all planes of motion. The large standard deviation found in the oldest group may have been related to the subjects' level of activity or to the large range of ages (60 to 80 years) in this group.

The higher scores of spinal flexibility gained by the third group (young adults) versus the low scores obtained by the second group (adolescents) have also been indicated by Ross and Gilbert (1985) who presented the average scores for

genders by age on the sit-and-reach test. Results of the present study showed that these differences are not significant (see Tables 8,9,10). Because adolescents were less likely to volunteer to be subjects in this study, the slight differences found between the two groups may have been related to their lack of motivation.

The second hypothesis addressed in this study stated that females would perform with significantly greater functional rotation and lateral flexion than males. The null hypothesis was accepted, $p > .01$. The similar results obtained by the two genders were contrary to the general expectation that males would be less flexible than females due to their larger muscularity. The similar ability to rotate and bend the back and the neck found between the two genders may indicate that muscle mass does not have a significant impact on frontal and horizontal trunk motions, and that biologically females and males do not differ from each other in these motions. Gender differences with regard to spinal flexibility have also been noted by Hilton et al. (1979) and Moran et al. (1979). However, like the findings of the present study, the gender differences did not reach statistical significance.

CHAPTER 5

CONCLUSION

Summary

The purpose of this study was to examine the effects of age and gender on functional rotation and lateral flexion of the back and the neck. One hundred and ten volunteers served as subjects in this study; they were divided into five age groups ($n=22$). The Peak Two Dimensional Motion Measurement Analysis System was used to collect the data, and the SPSS software was used for the statistical analysis. Results revealed significant differences among age groups for the three tested movements (neck rotation, neck and back rotation, and neck and back lateral flexion) with the oldest and youngest groups showing the greatest differences from the other groups. Comparison of spinal flexibility by genders revealed no significant difference, $p>.01$. The interaction between gender and age with regard to spinal mobility also failed to achieve significance, $p>.01$. Inspection of the results obtained on the three movements tested indicated that spinal rotation and lateral flexion tend to decrease with age. Interestingly, the largest variability of results within groups was found in the oldest group.

Conclusions

Based on the results of this study the following conclusions may be drawn:

1. Spinal rotation and lateral flexion movements are reduced in older adults. However, the large diversity of the results found in the elderly indicates a large potential for improving and maintaining spinal flexibility.
2. Although adolescents are usually more involved in sports activities than middle adults, their ability to rotate the neck and bend the spine does not exceed that of individuals in their forties.
3. As usually expected, children between the ages of six and eight years are more flexible than older individuals.
4. Contrary to the popular belief that males are less flexible than females, the present study showed that genders do not differ on the ability to rotate and bend the back and the neck.
5. The Peak Two Dimensional Measurement Analysis System and the associated videotaping procedure is an accurate and objective method for measuring flexibility. It is convenient for the subject and easy for the researcher. However, due to its cost and the relatively long time needed for result processing it would not be an appropriate instrument for measuring range of motion in clinical

situations.

Recommendations

Based on the conclusions mentioned the following recommendations are made:

1. Therapists and trainers should emphasize functional rotation and lateral movements of the back and the neck when designing flexibility programs for the elderly.
2. Evaluation of fitness level should include spinal rotation and lateral movements rather than focus on sagittal motions only such as those measured on sit-and-reach test.
3. A particular emphasis should be placed on the cervical region when evaluating flexibility due to the strong decline in range of motion occurring at this region with age.
4. Further research is needed to detect the main cause for the large diversity of scores and the decreased spinal flexibility found in older adults. Following are two suggestions:
 - (a) To determine the effects of age on spinal mobility in older adults; this study can be repeated with a sample of elderly subjects (60-80 years) who would be further divided into more specific age groups.
 - (b) To determine the effects of physical activity on spinal flexibility in elderly, a variety of sports

activities, commonly performed by these individuals, should be examined with regard to their impact on spinal rotational movements.

5. This study should be repeated: (a) comparing the mobility of the right side of the body with that of the left, (b) to determine the spinal flexibility of left handed subjects, (c) using subjects from different geographic location and from heterogeneous population in which physical activity is less popular to achieve results that can be generalized.

6. To establish norms for rotational and lateral movements, a similar study with a much larger sample size is recommended.

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Appendix A

Medical Questionnaire

Name _____ Age _____ Date _____
Height _____ Weight _____ Male — Female —

Check X If Yes

- 1) Do you often have a feeling of dizziness ? ()
- 2) Do you often feel a headache at the back of your
head around the base of the skull ? ()
- 3) Do you often suffer from numbness of your fingers ? ()
- 4) Do you often suffer from neck pain ? ()
- 5) Do you often suffer from back pain ? ()
- 6) Have you had acute back or neck pain in the last
two months ? ()
- 7) Has your doctor ever told you that you have a bone
or joint problem such as arthritis that might be
aggravated with exercise ? ()
- 8) Do you currently practice any of the following physical
activities on a regular basis (> 2 times/week)
Gymnastics ()
Swimming ()
Tennis ()
Other _____
- 9) Are you left handed ? ()

Appendix B

INFORMED CONSENT FORM

You are invited to participate in a study of the effects of age and gender on rotational and lateral bending movements of the back and the neck. We hope to learn whether there is a difference in the range of these motions between five age groups, and find if there is a certain age in which the range of these motions is significantly changed. The purpose of the study is to extend the knowledge about the flexibility of the spine. The results obtained from this study may contribute to the design of physical fitness programs and flexibility testing procedures.

If you decide to participate, you will be introduced to the issue of spinal flexibility and its important role in human performance. At the end of this introduction you will be asked to perform three movements of the back and neck in a sitting position. You will be asked to rotate and bend your back and your neck to the side as far as possible. The necessary movements will be at a comfortable pace. If, for some reason you feel or notice pain, you may stop the movement. The probability and magnitude of harm or discomfort are no greater than encountered in daily life. The results obtained from the testing will provide valuable information about flexibility testing.

You will be asked to complete a brief medical questionnaire prior to the test. It is important that you do not participate in any sports activity two hours prior to the test.

Your participation will be videotaped. Calculation of your spinal range of motion will be done by using the videotape as a reference. Videotapes will be maintained at the researcher's home.

Your entire participation in this study should take approximately fifteen minutes.

If you have any doubts or questions about the procedure, you may ask for further explanation. Any question about your participation in this study will be answered by the researcher, Ofra Netzer, at (415)497-5631, or Dr. Greg Payne at (408) 924-3028, Department of Human Performance San Jose State University.

If you have any complaints about the procedure you may present them to Jim Bryant, Department Chair of Human Performance at (408)924-3010. For questions about research subjects rights, contact Serena Stanford (Associate Academic Vice President for Graduate Studies and Research) at (408)924-2480.

Your participation in this study is completely voluntary. You may refuse to participate in this study and may withdraw at any time without prejudice to your relations with San Jose State University. You are free to decline to answer any specific question on the medical questionnaire. The data generated may be used for scientific purposes including publication and presentation at professional meetings. Your name will not be revealed. I appreciate your cooperation very much.

I have read this form and I understand the test procedures that I will perform. I consent to participate in this project and I understand that I can withdraw any time. I have received a copy of this consent form for my files.

Signature:_____ Date: _____

Print Name:_____

Signature:_____ Date:_____

(Parent or legal guardian if minor)

Investigator's signature:_____ Date:_____

APPENDIX C

Instructions For The Tests

Neck Rotation Test

- 1) Sit straight and straddle the chair facing its back.
- 2) Put your hands behind your back at waist level.
- 3) Without moving your shoulders, slowly turn your head to the right looking as far as possible over your shoulder.
- 4) Slowly return your head to the starting position.

Functional Back and Neck Rotation Test

- 1) Sit straight and straddle the chair facing its back.
- 2) Put your hands on your thighs.
- 3) Slowly turn your neck and your back to the right, looking as far as possible over your shoulder.
- 4) Let your right hand slide over your right thigh while rotating your back.
- 5) Slowly return your neck and your back to the starting position.

Functional Back and Neck Lateral Flexion

- 1) Sit straight and straddle the chair facing its back.
- 2) Put your left hand on your left thigh and let your right arm hang down.

- 3) Keep your seat on the chair while bending to the side.
- 4) Slowly bend your neck and your back to the right as far as possible without rotating your back.
- 5) Keep looking forward while bending to the side.
- 6) Slowly return your neck and your back to the starting position.

Appendix D

Formula to Calculate Phi

The value for Φ is governed by the equation

$$\Phi^2 = \frac{S[\sum_{i=1}^a (\mu_i - \mu)^2]}{a\sigma^2}$$

where

a : number of groups

S : sample size

μ_i : mean of group “ i ”

μ : population mean

σ : population standard deviation

Source: Keppel, G. (1982).

Appendix E

Measurement Procedure

Starting position of spinal rotation tests

Neck rotation test

Neck and back rotation test

Starting position of neck and back lateral flexion test

Neck and back lateral flexion test