University of Alberta

Normal Range of Motion of Joints in Female Subjects in Different Age Groups

by

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A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Master of Science

Department of Physical Therapy

Edmonton, Alberta
Spring 2007

Your file Votre référence
ISBN: 978-0-494-29992-0
Our file Notre référence
ISBN: 978-0-494-29992-0

Dedication

I want to thank my family who supported me during my studies and gave me the chance to have this lifetime experience!

ABSTRACT

Background and Purpose: There is a lack of normative range of motion data for women. Thus, the purpose of this study was to develop normative active and passive ROM data of the upper and lower extremity for women in different age groups and to compare the range of motion between sides.

Methods: Active and passive range of motion of the ankle, knee, hip, shoulder, elbow and wrist were measured with a goniometer in a group of 90 caucasian women from 4 different age groups.

Results: There was no general decrease in range of motion with age, only some movements were found to decrease with age. There was a significant difference between right and left sides and dominant and non dominant sides only for some range of motions.

Conclusion: There are some ranges of motion that decrease with age and some ranges of motion that are different between right and left sides and dominant and non dominant sides.

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CHAPTER 1: INTRODUCTION

1.1 PROBLEM STATEMENT

The adequate movement of the human body is one of the most important components of the numerous activities of our daily life. Simple tasks such as eating to more complex activities such as playing sports depends of a number of factors that allow body movements. The International Classification of Functioning, Disability and Health (ICF) (2000)[20,74,77], divided function into three components; body functions, body structures, and activity and participation.[20] According to the ICF, body structures related to movement are tissues such as bones, joints, muscle, ligaments, capsule, bursae and mechanoreceptors. These structures are important components responsible for creating an adequate function. Body function can also be divided into categories such as strength, endurance, range of motion (ROM), proprioception and coordination.[33] The concept of these components may be understood in a dynamic as well as a linear way. However, the components should not be seen as a causal linear relationship but as an interactive framework where all components are related and influence one another.[20] The success of rehabilitation management is an understanding of the relationship between problems and impaired body structures and functions.[74] Many studies have attempted to relate the increase or decrease in functional components to the development of injuries and to risk factors for injuries.[23,78,48] However, the quality of many of these studies is poor and the generalizations are limited. It is notable that many authors have attempted to find answers for real problems but are forgetting to search for basic tools that could make the search for the answer for many of these problems easier. ROM is one of the most measured variables in health care of musculoskeletal disorders.[38,42,47,67,79] It is used to evaluate outcomes of treatments in the clinical and research fields, to evaluate disabilities, for diagnosis and to assess risk factors of musculoskeletal problems.[7,9,28,67,79] The validity and reliability of this factor has been widely studied in the literature. However there is a lack of normative data that will allow clinicians and researchers to better understand the changes occurring in each patient with different conditions. Many factors can affect range of motion, including different measuring techniques, age, gender and subject's level of activity. For this reason, normative data are difficult to estabilish.[34] Because of this, an important clinical consideration is to use the individual's opposite side as a normal value. However bilateral disorders are common and the use of the opposite side may not be adequate. There is also a suggestion that possible changes occur on the opposite side to compensate for deficits on the injured side.[24] For this reason the use of the opposite side is limited and normative values for both dominant and non dominant sides are required.[49]

There are few quality studies in the literature that have tried to create a database for ROM for different areas of the body. The studies of normative data found in the literature used different tools and techniques to measure the ROM, making it difficult to generalize or to allow comparisons. At the same time, the majority of these studies used older or male subjects. There is a lack of normative data especially for female subjects. Thus, the purpose of this study was to develop normative data of active and passive ROM of the upper extremity: shoulder, elbow and wrist, and lower extremity: hip, knee and ankle for women in different age groups.

1.2 DEFINITON OF TERMS

Range of Motion (ROM): is the distance through which a single joint/body part moves in a particular plane. [48]Joint ROM is usually measured by the number of degrees from the anatomical neutral position of a segment to its position at the end of its full range of movement.[34,58] The range of motion is joint specific and because one individual exhibits greater ROM at one joint or in one direction, he or she does do not necessarily have a good ROM in another joint or direction.

Flexibility: is the range of motion available in a joint or a series of joints. It is dependant upon the intrinsic properties of the body tissues such as muscles, capsule and ligaments. It includes the ability of the periarticular tissue and the musculo-tendinous tissues to deform and lengthen. Lengthening of these structures allows a joint to move or if their elongation is restricted, it can restrict the joint movement and the maximal available ROM.[50]

Standard Goniometer: is an instrument with movable arms, connected on one of its edges by a rivet or a screw, creating an axis of movement. The arms can have different length and are, in most cases, made of transparent plastic. The connected edges of the arms are rounded and each has a drawn circle with markings of 360 degrees, simulating a protractor. This circled part is used to register the angle in which one arm of the goniometer is located in relation to the other. When using this instrument to measure ROM, the axis of the goniometer is aligned to the axis of the joint to be measured and the arms of the goniometer are aligned to the proximal and distal parts of the segments linked through this joint. The angle formed between these segments is read in degrees on the goniometer.

End Feel: is the final resistance to movement during passive testing. It is the different sensation that the examiner perceives at the end of each passive movement.[59] It may give an indication of the factors restricting further motion. There are many possible types of normal and "abnormal" end feel. Normal end feel is the feel one would expect at the end of the ROM for that joint in that direction.

An "abnormal" end feel is a feel at the end of the ROM that one would not expect for that joint. This alteration is usually due to some pathology resulting in pain, spasm, contractures and scar tissue. There are three classifications of end-feel and they are demonstrated in Appendix 1.[59]

Physiological Barrier: is the end point of an active movement.

Anatomical Barrier: is the end point of a passive movement. Normally it occurs after the physiological barrier. In most cases, passive movement has slightly greater ROM than active movement.

1.3 OBJECTIVES OF THE STUDY

The objectives of this study were as follows:

1. To create a database of active and passive ROM for the lower and upper extremities in females from 18 to 59 years old from the city of Edmonton.

2. To compare the active ROM between age groups. The age groups were divided into 4 categories: 18 to 29, 30 to 39, 40 to 49, and 50 to 59.
3. To compare the passive ROM between age groups. The age groups were divided into 4 categories: 18 to 29, 30 to 39, 40 to 49, and 50 to 59.
4. To compare the active ROM between sides (left and right; dominant and non-dominant).
5. To compare the passive ROM between sides (left and right; dominant and non-dominant).

1.1 RESEARCH HYPOTHESIS

The following hypotheses were investigated in this study:

1. The active ROM will be different between the age groups with the younger group having a greater range of motion.
2. The passive ROM will be different between the age groups with the younger group having a greater range of motion.
3. There will be no difference between the left and right sides or between the dominant and non-dominant sides for active or passive ROM.

1.5 LIMITATIONS OF THE STUDY

This study was limited by:

1. The reliability of goniometric measurements
2. The ability of the researcher to apply the same procedure for every subject. This factor was controlled by:

- Training of the examiner
- Determining intrarater reliability of the examiner prior to the beginning of the data collection
- The same examiner assessed all subjects
- There was standardization of subject positioning for all joints tested
- There was standardization of examiner positioning for all joints tested
- There was standardization of the technique to measure range of motion for all joints tested
- The same instrumentation was used for all subjects
- The reliability of the goniometer was determined before data was collected
- The instructions to all the subjects in the study were the same

3. Potential researcher bias when reading and analyzing the results
4. Potential bias when using a convenience sample
5. The population of the study consisted of subjects who were residents in Edmonton and surrounding area and generalization of the data is limited
6. Factors that could potentially influence the ROM and have not been cited in the literature were not controlled on this study.

1.6 DELIMITATIONS OF THE STUDY

This study was delimited to:

1. the subjects being caucasian females
2. the subjects age being between 18 to 59 years old
3. the goniometer being the tool used to measure ROM
4. the joints to be tested being the ankle, knee, hip, shoulder, elbow and wrist

1.7 ETHICAL CONSIDERATIONS

The subjects enrolled in this research were invited to take part and the researcher explained what was involved in the research. Subjects were asked to present themselves in the lab with gym wear such as shorts, t-shirts and/or tank tops. Before the first interview, subjects read the information letter (see Appendix 2) and signed the consent form (see Appendix 3), in order to assure confidentiality and privacy of the participants. All procedures were non-invasive and the only potential risk which was exceedingly small might have been a strain to the tissue during the ROM data collection. The measurements were taken by a trained physical therapist and all of the procedures were standardized and performed carefully to avoid any potential injury.

Prior to the beginning of the study, the project was reviewed by the Health Research Ethics Board – Panel B from the University of Alberta and received approval on July13th of 2005 (see Appendix 4).

1.8 RELEVANCY

There is insufficient normative data on range of motion available in the literature. Most of the research available is on children, older adults over 60 years old and on male subjects. It is clear that there is a lack of ROM normative data in woman and it is necessary to develop this type of data. This research provides more information about female ROM in different age groups.

CHAPTER 2: LITERATURE REVIEW

2.1 PREVIOUS NORMATIVE DATA

The American Academy of Orthopaedic Surgeons (AAOS) is one of the most cited and used data bases for ROM.[24,30,49,71] This database was published in a handbook in 1965.[24] The authors of this database did not report the methodology used to create the database nor the characteristics of the sample. [24,30] This normative data has been used as the gold standard for range of motion but the values found by other normative studies have been consistently smaller than the ones from AAOS.[24,30,53] Because of the discrepancies when compared with other normative data, the use of these values may be inappropriate.

Another listing of normal ROM data often cited in the literature is the one created by Boone.[13] The author measured the ROM of the upper and lower extremities of 109 "normal" male subjects. She evaluated subjects from 18 months to 54 years old and divided them into 6 age groups. She found a significant difference in ROM between age groups for most of the joint motions tested. The younger group often had greater ROM than the older group. Fiebert[30] and Desrosiers[24] developed normative data for shoulder active ROM of people from 60 years and up These two authors used different protocols. Fiebert[30] used the protocol of Norkin and White[58] while Desrosiers[24] used the protocol from the AAOS. There are other papers in the literature that have tried to develop normal data for ROM. Studies determining normal ROM can be found for newborns and children [22,25,75], older subjects from 60 years old and up[24,30,41,42,71,79] and young adults from 18 to 60 years old [2,3,13,38,54,64]. Most of the young adult studies collected the data on male subjects.[2,13,38,64] There were 4 papers from the 18 to 59 age group that collected ROM in male and female subjects and no papers that collected data only on female subjects. The majority of the studies that included female subjects measured only one or two joint motions. There was one paper that measured only glenohumeral ROM, one that measured shoulder complex ROM, one paper that measured hip and knee ROM and one paper that measured shoulder, hip, wrist and thumb ROM.[3,54,58,65] Many of these studies did not report the sample characteristics nor the techniques used to measure the ROM. Different studies use different measurement or positioning techniques, different protocols, and different instruments, making the reproducibility and comparisons between their "normal" data difficult.

The most recent form of normative database for range of motion was created by Norkin and White[58] using the values available in the literature from many other studies (see Appendix 5). The tables they created for each joint specified the study from which the values were extracted and the number and age of the subjects. It is notable that most of these papers addressed ROM of the shoulder, hip and knee joints. Depending on the joint, different age groups were measured and the amount of data varies for each age group and for each joint. The studies that were used to create this table also used different techniques and protocols to measure the ROM and generalizations and comparisons between the values are inappropriate.

2.2 RANGE OF MOTION MEASUREMENTS

There are many methods and protocols described in the literature for measuring ROM in the different joints. The two most cited protocols are the American Academy of

Orthopaedic Surgeon's[4,14,24] and Norkin and White's guide to goniometry.[58] These two sources have been widely used in the literature and the techniques described by each are different and contain variations. The variations in the methods have an important impact on the range of motion found.[34,58] The position of the patients, the position of the goniometer, the stabilization of the patients and whether the measurements were taken at the end of active or passive movement are examples of variations on the methods of ROM measurement.[16] Another important factor that influences ROM during data collection is the avoidance of any type of movement compensations at the joint being measured or at the adjacent joints. Awan[7] compared techniques used to measure range of motion of the shoulder and found that stabilization of the scapula avoided compensatory movements and increased the inter and intra examiner reliability of the measurement.

The standardization of methods can increase the reliability of ROM measurements.[32] It is important that the methods used to measure ROM are validated and reliable and that when comparing measurements, the same procedure and type of tool is used. Comparison between measurements can only be performed if there is no significant variation between the testing techniques. [12,26,67] Because the protocol of ROM measurement described by Norkin and White has often been used and cited in the literature[30] and because it is well designed, taking into consideration an important number of reliability studies and the stabilization concept, their method was used to measure ROM in this study.

The measurement of range of motion has several possible sources of error. Placement of the goniometer and the subject and reading of the goniometer are just some examples of these factors. In an attempt to gain a better understanding of the values of range of motion and allow comparisons between other studies, some authors have attempted to find the difference in the scores derived from variability between and within examiners. Mayerson[52] found that the values between examiners fell within approximately 4 degrees of each other regardless of how the different scores were derived. He calculated this value constructing 95% confidence intervals around average differences scores across all joints and positions measured in the study. Major joints of upper and lower extremities were measured, consisting of 22 separate joint positions. Walker[79], when trying to create normative data for older subjects, found that the mean error between measurements of the upper and lower extremity was 5 degrees. Ekstrand[26], when analyzing the goniometric reliability of the lower extremity range of motion, found that the mean error between the measurements was 7 degrees. The standard error of measurement for the measurements of the present study was calculated in the pilot study (see section 3.7.3).

2.3 FACTORS THAT CAN INFLUENCE THE MEASUREMENT OF RANGE OF MOTION

There are many factors suggested in the literature that may affect range of motion. These factors include age, gender, dominant side, occupation, level of physical activity, and the measurement technique used.[9] Many studies have tried to control these factors when measuring range of motion. However, the poor quality of many studies related to the difference between populations and the difference among measurements techniques does not allow a firm conclusion on the quality of the measurements.[9]

- Age

ROM is generally assumed to reduce with age because of the numerous changes occuring during the aging process, such as connective tissue changes that lead to loss of elasticity. [30,42] The clinical significance of these changes is still not well understood because of a lack of clinical research. The findings about changes in range of motion in different age groups are controversial. Kalscheur[41], Barnes[9] and Youdas[84] reported a decline of upper extremities range of motion with age. Desrosiers[24] and Fiebert[30] reported no significant difference between age groups. However, these studies measured only older subjects and the changes after 60 years of age may not be significant. There is enough data in the literature to conclude that there is a decrease in range of motion with age between newborns and 18 years of age.[73,75] Young children are very mobile and lose their mobility as the age increases. However there is not enough data on the changes occurring after maturity of the body.[73,75] The effect of age on ROM is still not well established.

- Gender

Many studies have shown that women generally have greater range of motion than men.[3,7,9,24,30,41,75,84] Most of the studies did not find that all joints had different values between men and women nor were the joints found to have the highest difference between genders the same for all studies. In addition, most of the differences found were less than 10 degrees and could have been due to measurement error. Most of the joints used to study gender ROM differences were large joints that normally have greater ROM and differences of less than 10 degrees may not be clinically significant. Therefore the effect of gender on the range of motion has still not been determined.

- Level of activity

Some studies have shown the amount of movement at a joint varied according to the type of physical activity performed by the subjects.[8,27,45] Athletes from the same sports normally have the same pattern of range of motion showing that the amount of range of motion available has a high probability of depending on the type of activity performed.[8,27,45] However no studies have shown that, independent of the type of physical activity, active and non active people have different ranges of motion.

Some studies examined shoulder range of motion in athletic populations.[8,27] Among the findings encountered in these selected populations were an increase in shoulder external rotation and a decrease in shoulder internal rotation in the dominant extremity. [8,27] However Barnes (2001) studied a non-athletic population and found the same pattern of ROM even in a young group.[9] These findings do not allow one to conclude that the changes seen were solely the result of physical activity.

- Hormones

Hormones can directly influence many tissues and systems.[80] Estrogen affects soft tissue strength, muscle function, and the central nervous system. Progesterone can act as a central nervous system anesthetic and relaxin can drastically diminish collagen tension.[80] Wojtys[80] found an association between the menstrual cycle and anterior cruciate ligament injuries. He did not find any association with hormonal contraceptives. Wreje[82] studied collagen metabolism markers during the menstrual cycle and oral contraceptive (OC) use. He concluded that the collagen turnover, especially the synthesis but also the breakdown of collagen type I, may be reduced in OC users. From these findings, the action of hormones on joint laxity and range of motion seems to be important but is not yet well understood.

The hypothesis that sex hormones may play an important role in joint laxity raises the importance of the hormonal changes and replacements occurring to the female system such as hormonal contraceptive therapy, menopause and hormone replacement therapy.

Hormonal contraceptives consist of female sex hormones: estrogen and progesterone (synthetic progesterone is commonly referred to as "progestin"). The most popular hormonal contraceptive is the combination pill or oral contraceptive. Other hormonal contraceptives include injected progestins, subdermal implants that release progestins, transdermal patch, and a vaginal ring. [81]

1. Oral contraceptives, also known as “the pill”, usually contain two types of hormones - estrogen and progestin. The most commonly used brands of hormone medication in Canada are available on the Appendix 6.
2. The most common injectable hormonal contraceptive is Depo-Provera® (depot-medroxyprogesterone acetate).
3. Subdermal implants, also known as contraceptive implants, are matchstick-sized, hollow, rubber rods filled with synthetic progestin. Norplant® is the most commonly used brand.
4. Transdermal administration (Birth Control Patch) is a form of hormonal contraception that delivers a steady level of the hormones norelgestromin/ethinyl estradiol (progestin and estrogen) into the bloodstream through the skin.

5. Etonogestrel – Ethinyl Estradiol Vaginal Ring (NuvaRing®) is a once-a-month form of hormonal contraception that delivers steady levels of etonogestrel and ethinyl estradiol into the body.

Menopause is a stage of the reproductive lifecycle that every woman goes through at some point in her life, usually in the fifth or sixth decade, where the ovaries stop producing estrogen and progesterone. This causes the reproductive system to gradually shut down and alters hormone levels drastically. As the body adapts to the changing levels of natural hormones, symptoms such as hot flashes, mood-swings, vaginal dryness, increased depression and anxiety, and increasingly scanty and erratic menstrual periods are common.

Menopause takes place gradually over a number of years. The average onset of menopause is 50.5 years, but some women enter menopause at a younger age, especially if they have suffered from cancer or another serious illness and have undergone chemotherapy.

By definition, a woman is menopausal after her periods have stopped for one year. However, this term have been used as the process that occurs from when a woman starts experiencing lower levels of hormones until she has actually stopped her periods.

Diagnosis is usually made from the woman's medical history and supporting symptoms. A blood test can be used to measure estrogen levels. The test considered most accurate for the diagnosis of menopause is the measurement of follicle stimulating hormone (FSH).

Hormone replacement therapy (HRT) uses estrogens and progestin (synthetic progesterone) to ease the symptoms of menopause. The hormones are available in a variety of forms: pills, vaginal creams, vaginal ring inserts, implants, injections, and patches worn on the skin. [18]

1. Conjugated estrogens are a mixture of estrogens. Common brands are Premarin®, Premarin Vaginal Cream® and Cenestin®.
2. Esterified estrogens (Estratab®, Menest®) are estrogenic substances consisting of 75-85% natural estrogens and 15-25% equine (mare urine) estrogens.
3. Estradiol is one of the three major estrogens made by the human body and is the major estrogen secreted during the menstrual years. It is available as an oral pill (Estrace®), transdermal skin patch (Climara®, Estraderm®, Vivelle®), vaginal tablet (Vagifem®), and vaginal cream (Estrace Vaginal Cream®).
4. Estropipate (estrone) is an estrogenic substance derived from estrone, one of the three major estrogens produced by the body. Estrone is produced from estradiol and is a less potent estrogen. It is available in pill form (e.g. Ogen®, Ortho-Est®).
5. Ethinyl estradiol (i.e. Estinyl®) is a synthetic nonsteroidal estrogen available as a tablet that is prescribed to treat hot flashes (a vasomotor symptom). It is administered on a cyclical basis (i.e. 3 weeks on and 1 week off) with attempts to discontinue or taper at 3- to 6-month intervals.

- Sides (left and right)

Gunal[38] studied the upper extremity ROM in military recruits and found that the ROM of the non-dominant side was generally greater than the dominant side. However, most of the differences were smaller than 7 degrees and this difference could be due to measurement error according to the "normal" goniometer standard error of measurement. Boone[13] studying the shoulder, elbow, forearm, wrist, hip, knee, ankle and foot and Roaas[13,64] studying the hip, knee and ankle, when creating normative male data, found that the range of motion between sides were similar. These authors concluded that the non-injured side could be used as a reference for comparison if the presenting pathology was unilateral.[13,64] Allander[3] found that the range of motion of the right wrist was significantly less that the left side. He concluded that because most of the people were right handed, they normally had more stress and microtrauma to that hand and consequently less range of motion. Stefanyshyn[72] found that there was no significant difference between sides when analyzing ankle range of motion. The findings of these studies lead one to conclude that any differences between sides are minimal. However there still needs to be more research to confirm this hypothesis.

2.4 ACTIVE AND PASSIVE RANGE OF MOTION

There are two possible ways to measure ROM: active or passive. Active range of motion is the measurement based upon the voluntary motion of the subject's body parts through its full range, without assistance of someone applying an external force. Active ROM is a better indicator of the actual motion used during normal activities of daily life and function. However, this measurement is strongly dependent on the subjects and can be influenced by many factors such as muscle strength, pain, individual's threshold for pain, effort, motivation and attitude.[33]

Passive range of motion occurs when the examiner moves the subject's body parts through their full range. This position may exceed the functional (active) range of motion, but it has been reported to be a better indicator of the actual ROM available in a joint. However, passive range of motion is greatly influenced by the amount of external force applied by the examiner and it is hard to standardize.[33] The passive range of motion is influenced by the ability of the examiner to consistently determine the end range through the end feel of the joint motion or the compensations happening at a joint or its consecutive joints.[58]

Few studies have compared the reliability of measuring the active and passive ROM. There is insufficient evidence to justify the use of one or another. Sabari[68] found very high reliability of both passive and active range of motion measurements when analyzing shoulder range of motion. Because there is no consensus as to which method is most reliable for measuring range of motion and because the active range of motion is measured at the physiological barrier (end of active movement) and the passive at the anatomical barrier (end of passive movement), both active and passive were measured in this study.

2.5 TOOLS TO MEASURE RANGE OF MOTION

There are different instruments that can be used to measure range of motion. They vary from simple and cheap such as the standard goniometer, to sophisticated and expensive such as a three dimensional motion system and electrogoniometer.[39,66] These instruments have been used in the clinical and research fields and some of their properties have been studied. Some studies have examined the reliability between devices and found poor results showing that the tools should not be used interchangeably.[5,11,12,66]

The most cited and used instrument is the universal/standard goniometer, followed by the inclinometer. The inclinometer has been reported to have a good intrarater reliability[62] and poor interrater reliability.[76] The inclinometer has also been found to have a lack of sensitivity to measuring the thoracic spine due to a failure to track the progression between flexion and extension.[46] The studies that analyzed the properties of the goniometer showed that this tool had a good intrarater reliability but a poorer interrater reliablity[32,37,63] Because the tools cannot be used interchangeably, the most used tool in the literature and in the clinical practice should be the one used to create normative data. For this reason, the standard goniometer was the tool chosen to be used in this study.

2.6 VALIDITY OF GONIOMETRIC MEASUREMENTS

Criterion validity compares a tool to a gold standard. In the case of the standard goniometer, a radiographic technique to measure ROM has been used as the gold standard.[58] Brosseau[15,16] found in two studies that the measurements taken with the universal/standard goniometer were from moderate to strongly correlated ($r= 0.73$ and $r = 0.97$) with radiographic measurements.[15] Gogia[37] also found the universal goniometer to be strongly correlated ($r = 0.97$) with radiographic measurements. Based on the above findings, the standard goniometer can be considered to be a valid instrument to measure ROM.

2.7 RELIABLITY OF GONIOMETRIC MEASUREMENTS

There are many studies available in the literature concerning the reliability of goniometric measurements. Generally, the studies concluded that the level of reliability was acceptable, and that intrarater reliability was higher than interrater reliablity.[14,28,32,37,43,63,68,83] Given the variety of designs and measurement techniques, it is difficult to compare many of the studies.

Gogia[37] analyzed interater reliability of the knee flexion goniometric measurements. He found excellent interrater reliability (ICC=0.99) showing that this procedure was reliable. However, the examiners of this study did not position the knee into maximal ROM for the measurements. A second examiner positioned the knee at random angles and the examiner measured those angles. This study measured the validity and interrater reliability of the goniometer but not the real ROM measurements. The real ROM is harder to measure and can be influenced by many factors such as examiner positioning and the subject's pain, stiffness and other factors already mentioned. According to the study, the goniometer could be considered a reliable tool to measure predetermined ROM but not necessarily to measure the maximal ROM available at a joint.

The reliability of goniometric measurements vary somewhat between joints and motion.[2,14,32,63] This difference may be due to difficulties in palpating bony landmarks, passively moving heavy bony parts, and adequately isolating the movement.[7,14,32,68] Rothstein[67] found excellent intrarater reliability when measuring knee and elbow flexion and extension (ICC>0.91) and an excellent interrater reliability for knee flexion, and elbow extension and flexion (ICC>0.90). He found moderate interrater reliability

(ICC>0.64) for knee extension. Riddle[63] tested both intra and inter rater reliability for passive range of motion of seven shoulder motions. He found an excellent intra rater reliability of all the shoulder motions (ICC>0.87), a good inter rater reliability for shoulder flexion and abduction (ICC>0.84), and a poor inter rater reliability of the shoulder extension, horizontal abduction, horizontal adduction and medial rotation (ICC>0.30). Youdas[83] studied the intra and inter rater reliability of active ankle plantar and dorsiflexion using a goniometer and visual estimation. Based on his findings, he concluded that active ankle dorsiflexion and plantar flexion measured with the goniometer had a moderate to excellent intra rater reliability (ICC >0 .64) but a poor inter rater reliability (ICC> 0.28).

Some studies have evaluated the reliability of the goniometric measurements in a clinical setting, with no standardization of measurements including subject positioning.[29,63,67] They found, in most cases, that there was a good intra rater reliability (ICC>0.84) and a moderate to poor inter rater reliability (ICC>0.30). When analyzing the data that the examiners collected with the subjects in the same position, the inter rater ICC values improved but never to a point where the reliability was comparable with the intra rater reliablity.[29,63,67] The findings of these studies suggest that well trained physical therapists can measure the range of motion of specific joints with a higher degree of reliability. The inter rater reliability of these studies showed that different techniques could lead to different ROM values and that inter rater reliability could be improved when examiners used consistent methods and testing positions.

It is evident that a number of factors can affect the measurement of range of motion. Standardized techniques, instrument calibration, and well standardized stabilization are necessary to produce highly reliable results when the ROM is tested by the same examiner.[5,7,68]

CHAPTER 3: MATERIALS AND METHODS

3.1 SUBJECTS

The subjects included in this study were caucasian women aged 18 to 59 years. This age group was selected because they include an adult population and exclude pediatric and geriatric subjects. Subjects over 60 years of age have more joint and soft tissue modifications due to age.[21] The variation of ROM between different races has not been studied. The selection of only caucasian subjects avoided a possible confounder and guaranteed the homogeneity of the sample. Caucasian was defined according to the "Random House Webster's: College dictionary" (1997)[1]: "*Designating or characteristics of one of the traditional racial divisions of humankind, marked by fair to dark skin, straight to curly hair, and light to very dark eyes and origin inhabiting Europe, parts of North Africa, West Asia, and India*", (p 208).

The subjects were divided into 4 age groups: 18 to 29, 30 to 39, 40 to 49 and 50 to 59. The groups were divided this way to follow the normal procedures by allocating subjects into different decades.[9,13,64] The sample size calculation for the objective of analyzing the ROM differences between age groups (using α= 0.01, effect size= 0.25 and power = 0.96);(see calculation details in Appendix 7) (Keppel 1991)[44] resulted in 20 subjects per group. A total of 90 subjects were used in this study, 20 subjects for the 30 to 39, 40 to 49 and 50 to 59 age groups and 30 subjects for the 18 to 29 age group. Because the main objective of this study was to add to the database for women ROM, there was a need to test whether 20 subjects would give a consistent result for the values in ROM. Thirty subjects were used in the 18 to 29 age group. Four randomly selected groups of 20 subjects from these 30 subjects were created. These four groups were found to have no significant differences in the values of ROM. For this reason the sample size of 20 subjects per groups previously calculated for the objective of comparing age groups was used.

3.2 INCLUSION CRITERIA

To be included in this study, the subjects had to:

- be caucasian women between 18 to 59 years old
- be healthy with no chronic pain, clinical pathology, or previous surgery related to the musculoskeletal system.

3.3 EXCLUSION CRITERIA

Subjects were excluded if they had:

- neurological, systemic, peripheral or rheumatic pathologies, disease or injury that might affect the musculoskeletal system and ROM[32]
- any history of musculoskeletal injury in the past year [40]
- had any type of surgery that may have affected the musculoskeletal system
- had physical therapy treatment in the last year or any type of therapy that included stretching or manual therapy
- been pregnant or were pregnant in the past year[51]
- been involved in a high level or professional level of sports activities in the past year [27]
- had surgery or had any diseases that might affect the level of the body hormones.

3.4 SUBJECT RECRUITMENT

Subjects for this study were recruited using advertisement direct at the population attending the University of Alberta (students and staff) and the population around the University area. (see Appendix 8) During the initial phone call or e-mail contact, the subjects were informed by the examiner about the nature of the study. Questions about the inclusion and exclusion criteria were asked (see Appendix 9). If the subjects were willing to participate, met the inclusion and were not excluded because of the exclusion criteria, an appointment was scheduled.

All subjects were required to give informed consent in accordance with the University of Alberta's policies on research using human subjects (see Appendix 3).

3.5 STUDY DESIGN

This study was an observational cross sectional study. This design allowed the researcher to create a normative database of women's ROM for different age groups and allowed a better understanding of the different factors that might or might not influence the range of motion, such as age and side dominance.

3.6 INSTRUMENT

Two standard transparent plastic goniometers with arm lengths of 20 cm and 25 cm and a protractor portion divided into 2 degree segments were used to measure the range of motion. Previous research has shown that different sizes of goniometer are reliable and can be used interchangeably.[29,63,67]

Before the study, the accuracy of the goniometer was determined using 10 randomly selected computer-generated angles between 0 and 180 degrees. The angles were created randomly on a computer program called ALcimage that gave the exact value of each angle created. The examiner used the goniometer to measure these angles and tested the precision of the goniometer protractor and its reliability. The goniometers used in this study measured exactly the same angle created by the computer. The goniometers tested that did not meet this criterion were discarded. Six goniometers were tested in total. Two were discarded because they presented measurement error while 4 were accurate but only 3 were used in the data collection. Two goniometers were chosen to be used in the beginning of the data collection, one with 20 cm arm length and one with 25 cm arm length. Because the center of the goniometer with 20 cm arm length became loose during the data collection, it was replaced by another 20 cm arm goniometer found to be accurate in the beginning of the study.

3.7 DATA COLLECTION

When the subjects phoned or e-mailed indicating an interest in the study and when it was determined they met the inclusion and were not excluded by the exclusion criteria, they were informed about the time and place of data collection. They were instructed to wear shorts or gym pants and tank top or t-shirt that allowed full movement of the shoulder, elbow, wrist, hip, knee and ankle and permited the localization of the body landmarks. They were also instructed to avoid any exercise 24 hours before testing.[66]

The range of motion measurements were performed in Corbett Hall at the University of Alberta in the Sports Therapy Research Lab. All the measurements were taken during the same time of the day because activities and water changes in the collagen tissue can alter the characteristics of the tissues and influence the range of motion.[60] The time used to measure the ROM was between 10:00 and 16:00. Subjects attended one session of approximately two hours in which all measurements were taken.

Subjects were given no opportunity to warm up because warm up could change the biomechanical characteristics of the collagen, change the viscoelastic properties of the muscles[55], and influence the range of motion available in a joint. The use of a warm-up could induce different physiological changes among subjects and could induce different temperature changes that could affect the reliability of the range of motion measurements.[35] There was a rest period of at least 15 minutes from the time of the subject arrival until the beginning of the ROM measurement. This period of rest was to stabilize body temperature. During this rest period, the information letter and consent form were given to the subject. Questions were answered if they were raised. After the consent form was filled out and signed, a questionnaire was completed by the subjects (see Appendix 9). Before the ROM measurements were taken, the body core temperature was measured by an oral thermometer (see section 3.7.2). Previous studies have shown a relationship between core body temperature and intramuscular temperature. This relationship is linear with the intramuscular temperature increasing more than 0.5 degrees than the core body temperature.[69]

The ROM was evaluated for 30 different motions (see section 3.7.4) and on both sides, consisting of a total of 60 measurements. The 60 motions were grouped according to joints. The order of the joints to be measured was randomly selected using the "draw out of a hat" method. The order of the side and the motion to be measured on each joint were also randomly selected using the "draw out of a hat" method. This means that when one motion and side was selected the same motion on the other side was not performed consecutively but in a random order. The active and passive movements were measured consecutively for each motion to avoid change in patient position. The order of the active and passive range of motion measurements was randomly selected using the "drawing out of a hat" method. All measurements were taken once actively and once passively for each joint on each side. The performance of one measurement of each motion avoided any carryover effect due to stretching or viscoelastic changes on the tissues and followed what is normally done on the clinical field.[56]

3.7.1 DEMOGRAPHIC DATA COLLECTION

All the subjects were asked to complete a questionnaire (see Appendix 10) to help better characterize the sample being examined. The questionnaire included the following questions:

1. age (18 to 29, 30 to 39, 40 to 49, 50 to 59)

2. weight. The weight was measured on the day of the data collection using a regular beam scale (Health-o-meter®). The weight was measure with the subject wearing the examination clothes and no shoes.

3. height. The height was measured with the subjects standing without shoes, feet together, trunk and hips fully upright, head in neutral and horizontal gaze.

4. dominant upper and lower extremity. The dominant upper extremity was determined as the arm that the subject used to write. The lower dominant extremity was the leg of choice to kick a ball.

5. whether they had entered menopause or if they were undergoing hormone replacement therapy.

6. If they were in use of any hormonal contraceptive method and for how long.

The occupation of the subjects of the study was asked and classified according to the National Occupational Classification (NOC) developed by Human Resources Development Canada in 1993. The classification was performed according to skill types. There are 10 possible skill types according to NOC: a) management occupations; b) business, finance and administrative occupations; c) health occupations; d) occupations in social science, education, government service and religion; e) occupations in art, culture, recreation and sports; f) sales and services occupations; g) natural and applied sciences and related occupations; h) trades, transport and equipment operators and related occupations; i) occupations unique to primary industry; j) occupations unique to processing, manufacturing and utilities. The website http://workinfonet.bc.ca was used as reference for the classifications. The website had a list with the different types of occupations and the skill type groups that they included. The intensity of the work related activities was determined with the short form of the International Physical Activity Questionnaire (see Appendix 11) because it measured the level of physical activity during recreational and work related activities.

The short form of the International Physical Activity Questionnaire (see Appendix 11) was used to measure the level of physical activity for 7 days prior to the testing. The validity of the "usual week" and "last 7 days" reference periods have been shown to be similar.[19] The questionnaire has been found to have an overall test-retest reliability of the correlation coefficient of about 0.80.[19] The criterion validity of this tool is acceptable ($p \approx 0.30$) when comparing with CSA accelerometer for minutes of moderate, vigorous, walking, and sedentary behaviours.[19] The scoring system used was based on a categorical score that divided the subjects into inactive, minimally active and HEPA active (see Appendix 12).

3.7.2 TEMPERATURE MEASUREMENT

There is no external site to measure temperature that accurately measures the pulmonary artery temperature known as the gold standard. The oral method is the most commonly used method yet its accuracy is known to be influenced by many external factors. However between the four clinical possible sites of oral, tympanic, rectum and axillar, the oral is the one that responds quickest to internal changes and is considered be the most appropriate for this study.[31,69]

The temperature was measured with a digital oral thermometer (AdtempII 413 Digital Oral Thermometer, with an accuracy of 0.1 Celsius) that was used according to manufacturer's instructions. An oral specific protection for the thermometer was used to avoid any type of cross-infection.[31] Before and after the measurement of the temperature on each subject the thermometer was cleaned with alcohol.

The temperature was measured on each subject before the measurement of ROM and at least 15 minutes after the subject's arrival for data collection. The data collection started after the body core temperature reached between 35.8 to 37.8 degrees Celsius (normal temperature).[10,70]

3.7.3 PILOT STUDY – RELIABILITY

Prior to beginning the data collection, the examiner practiced all measurements and performed a pilot study to determine the intrarater reliability. Reliability is the consistency of the measurement, or the degree to which an instrument measures the same way each time it is used under the same conditions with the same subjects.[61] A measurement that has high reliability has little measurement error and can be used in the clinical and research field with a confidence that under the same conditions similar values will be found.

The measurement of the 60 different active and passive ROMs was performed twice consecutively in 12 subjects. The sample size calculation for the reliability of the pilot study was based on an adapted table from Cohen (1998).[61] Using $\alpha = 0.01$, a power of 0.80 and an effect size of 0.80, 12 subjects were necessary (see Appendix 13).

To prevent bias, the goniometers were covered with a white adhesive and the examiner was not able to see the values recorded on the goniometer. A second examiner was responsible for reading the values on the goniometer and recording them. This ensured blinding of the first examiner and avoided bias for the pilot study.

3.7.4 JOINTS AND MOVEMENTS TO BE MEASURED

The passive range of motion measurements was performed according to the method of Norkin and White 2003.[58] The active range of motion was measured using the same protocol as that used for the passive ROM but the subjects actively performed the movement towards the maximal range of motion measured. During the active ROM data collection, no stabilization was performed by the examiner except for glenohumeral shoulder measurements. The glenohumeral stabilization for the active test was the same as for the passive test. For the other ROMs measured, the examiner watched for compensatory movements. If the subjects used compensatory movements, the motion was corrected. If the subject could not correct the compensatory movement, it meant that the end range had been achieved and compensatory movements were occurring to provide more movement. In this case, the range of motion was measured to the point before the compensation occurred. All the ROM measurements were recorded on a data collection sheet (see Appendix 14).

3.7.4.1 ANKLE RANGE OF MOTION

3.7.4.1.1 DORSIFLEXION (TALOCRURAL JOINT)

- **Starting position**

The subject was placed in sitting in position on a table with the knee flexed to 90 degrees and the foot in 0 degrees of inversion and eversion.[58]

- **Stabilization**

The examiner stabilized the tibia and fibula, holding it with one hand above the malleolus to prevent knee motion and hip rotation.[58]

- **Passive motion testing**

The examiner moved the foot into dorsiflexion by pushing the bottom of the foot up. Pressure on the lateral border of the foot under the fifth metatarsal and the toes was avoided. The end of the ROM was determined when the resistance to further motion caused knee extension.[58]

The opposite limb was tested in a similar fashion.

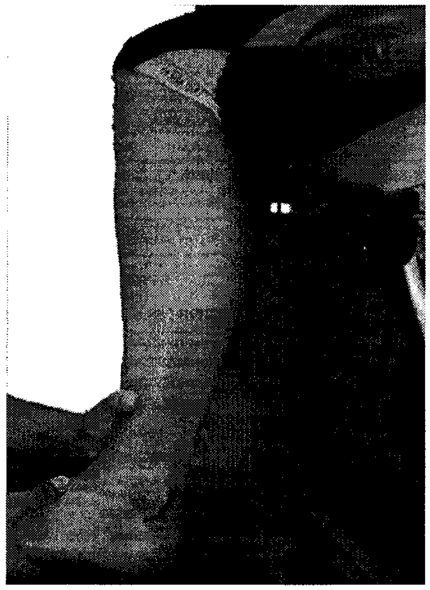

Figure 1: The examiner held the distal portion of the lower leg with one hand to prevent knee motion and used the other hand to produce dorsiflexion

- **Active motion testing**

The subject was asked to move the foot towards the ceiling maintaining the knee flexed. She was asked to move the foot as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused knee extension.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over the lateral aspect of the lateral malleolus.

2. The proximal arm was aligned with the lateral midline of the fibula using the head of the fibula as reference.

3. The distal arm was aligned parallel to the lateral aspect of the fifth metatarsal.

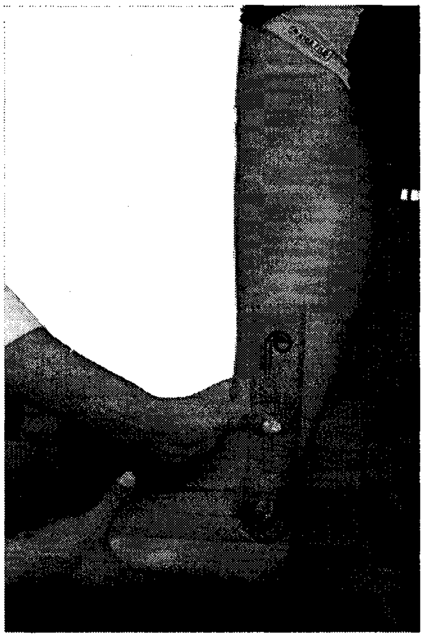

Figure 2: At the end of dorsiflexion range of motion the examiner used one hand to align the proximal arm of the goniometer while the other hand maintained dorsiflexion and aligned the distal arm of the goniometer.

3.7.4.1.2 PLANTAR FLEXION (TALOCRURAL JOINT)

- **Starting position**

The subject were placed in the sitting position on a table with the knee flexed to 90 degrees and the foot in 0 degrees of inversion and eversion.[58]

- **Stabilization**

The tibia and fibula were stabilized to prevent knee flexion and hip rotation.[58]

- **Passive motion testing**

The examiner moved the foot into plantarflexion by pushing the foot down. Pressure on the toes and inversion and eversion movements were avoided. The end of the ROM was determined when resistance to further motion caused knee flexion.[58]

The opposite limb was tested in a similar fashion.

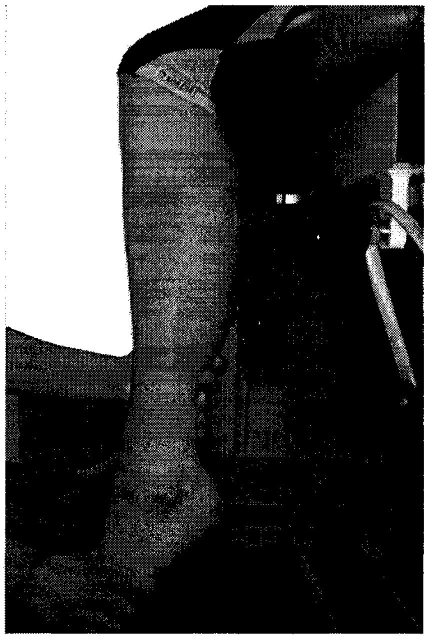

Figure 3:The examiner held the distal portion of the lower leg with one hand to prevent knee motion and used the other hand to produce plantar flexion.

- **Active motion testing**

The subject was asked to move the foot towards the floor while maintaining the knee flexed. She was asked to move the foot as far as possible and maintain the position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused knee flexion.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over the lateral aspect of the lateral malleolus.

2. The proximal arm was aligned with the lateral midline of the fibula using the head of the fibula as reference.

3. The distal arm was aligned parallel to the lateral aspect of the fifth metatarsal.

Figure 4: At the end of plantar flexion range of motion the examiner used one hand to align the proximal arm of the goniometer while the other hand maintained plantar flexion and aligned the distal arm of the goniometer.

3.7.4.1.3 EVERSION (TARSAL JOINT)

- **Starting position**

The subject was placed in supine position on a table with the knee extended and hip in 0 degrees of rotation, abduction and adduction. The foot was positioned over the edge of the supporting surface.[58]

- **Stabilization**

The tibia and fibula were stabilized to prevent lateral rotation and flexion at the knee and adduction at the hip.[58]

- **Passive motion testing**

The examiner moved the forefoot laterally into abduction and upward into dorsiflexion, turning the forefoot into pronation. The end of the ROM was determined when resistance to further motion caused lateral rotation at the knee and medial rotation and adduction at the hip.[58]

The opposite limb was tested in a similar fashion.

Figure 5: The examiner held the distal portion of the lower leg with one hand to prevent knee and hip motion while the other hand was used to produce eversion.

- **Active motion testing**

The subject was asked to move the lateral side of the foot towards the lateral side of the leg. She was asked to move the foot as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused lateral rotation at the knee or medial rotation or adduction at the hip.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over the anterior aspect of the ankle midway between the malleoli.

2. The proximal arm was aligned with the anterior midline of the lower leg using the tibial tuberosity as reference.

3. The distal arm was aligned with the anterior midline of the second metatarsal.

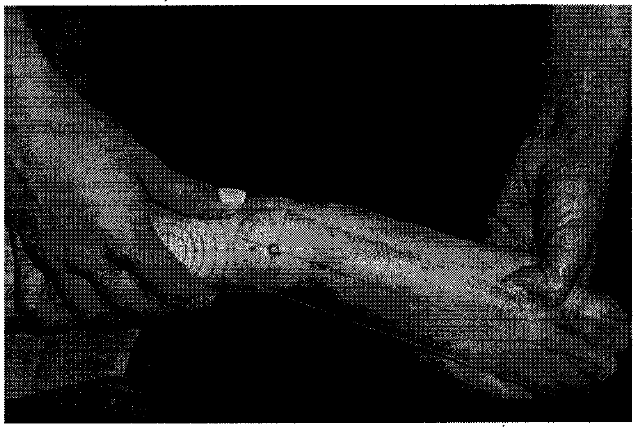

Figure 6: At the end range of eversion the examiner used one hand to align the proximal arm of the goniometer while the other hand maintained eversion and the alignment of the distal arm of the goniometer.

3.7.4.1.4 INVERSION (TARSAL JOINT)

- **Starting position**

The subject was placed in supine position on a table with the knee extended and hip in 0 degrees of rotation, abduction and adduction. The foot was positioned over the edge of the supporting surface.[58]

- **Stabilization**

The tibia and fibula were stabilized to prevent lateral rotation and abduction of the hip.[58]

- **Passive motion testing**

The examiner moved the forefoot downward into plantarflexion, medially into adduction and turned the sole of the foot medially into supination. The end of the ROM was determined when resistance to further motion caused medial rotation of the knee or lateral rotation or abduction of the hip.[58]

The opposite limb was tested in a similar fashion.

Figure 7 : The examiner held the distal portion of the lower leg with one hand to prevent knee and hip motion while the other hand was used to produce inversion.

- **Active motion testing**

The subject was asked to move the medial side of the foot towards the medial side of the leg. She was asked to move the foot as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused medial rotation at the knee or lateral rotation or abduction at the hip.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over the anterior aspect of the ankle midway between the malleoli.

2. The proximal arm was aligned with the anterior midline of the lower leg using the tibial tuberosity as reference.

3. The distal arm was aligned with the anterior midline of the second metatarsal.

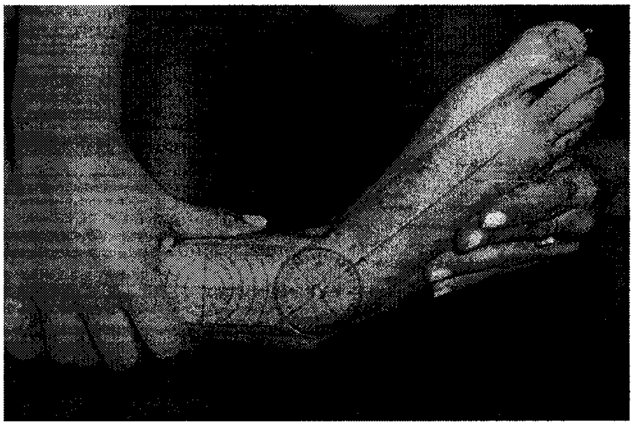

Figure 8: At the end range of inversion the examiner used one hand to align the proximal arm of the goniometer while the other hand maintained inversion and the alignment of the distal arm of the goniometer.

3.7.4.2 KNEE RANGE OF MOTION

3.7.4.2.1 KNEE FLEXION

- **Starting position**

The subject was placed in supine on a table with the knee in extension and the hip in 0 degrees of extension, abduction and adduction.[58]

- **Stabilization**

The examiner stabilized the femur, holding it with one hand positioned just above the femur condyles, to prevent rotation, abduction and adduction of the hip.[58]

- **Passive motion testing**

The examiner moved the thigh to 90 degrees of hip flexion and the ankle joint towards the thigh producing knee flexion. The end of the ROM was determined when the resistance to further motion caused additional hip flexion.[58]

The opposite limb was tested in a similar fashion.

Figure 9: The examiner used one hand to move the subject's thigh to 90 degrees of hip flexion and then stabilized the femur to prevent further flexion. The examiner used the other hand to move the lower leg through full knee flexion.

- **Active motion testing**

The subject was asked to move the thigh towards her body trying to point the knee to the ceiling. At the same time she was asked to bring her foot toward her thigh. She was asked to move the thigh until she could point the knee to the ceiling and move the foot towards the thigh as far as possible maintaining that position while the examiner measures the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused additional hip flexion.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over the lateral epicondyle of the femur.

2. The proximal arm was aligned with the lateral midline of the femur using the greater trochanter as reference.

3. The distal arm was aligned with the lateral midline of the fibula using the lateral malleolus and fibular head as a reference.

Figure 10: At the end of knee flexion range of motion the examiner used one hand to maintain knee flexion and keep the distal arm of the goniometer aligned with the lateral midline of the leg while used the other hand to align the proximal arm of the goniometer and keep the hip in 90 degrees of hip flexion.

3.7.4.2.2 KNEE EXTENSION

- **Starting position**

The subject was placed in supine with the knee in extension; the hip in 0 degrees of extension, abduction or adduction. A towel roll was placed under the ankle to allow the knee to extend as much as possible.[58]

- **Stabilization**

The examiner stabilized the femur by holding it with one hand just above the femoral condyles to prevent rotation, abduction or adduction of the hip.[58]

- **Passive motion testing**

The subject was asked to relax her leg while the leg rested on a rolled towel at the ankle which allowed the gravity to passively take the knee into extension.

The opposite limb was tested in a similar fashion.[58]

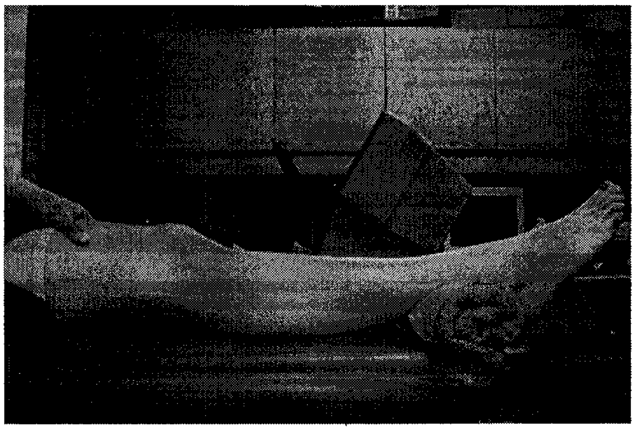

Figure 11: The examiner used one hand to stabilize the femur preventing hip movements to occur.

- **Active motion testing**

The subject was asked to contract her quadriceps keeping the leg straight. She was asked to keep this position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over the lateral epicondyle of the femur.

2. The proximal arm was aligned with the lateral midline of the femur using the greater trochanter as a reference.

3. The distal arm was aligned with the lateral midline of the fibula using the lateral malleolus and fibular head as reference.

Figure 12: At the end range of knee extension the examiner used both hands to align the goniometer.

3.7.4.3 HIP RANGE OF MOTION

3.7.4.3.1 HIP ABDUCTION

- **Starting position**

The subject was positioned in supine on a table, with the knees extended and both hips in 0 degrees of abduction, adduction and rotation.[58]

- **Stabilization**

The examiner stabilized the pelvis by positioning one hand over the ipsilateral anterior superior iliac spine (ASIS). The examiner prevented lateral tilting and rotation of the pelvis. The trunk was observed to ensure lateral flexion was avoided.[58]

- **Passive motion testing**

The hip was abducted by sliding the lower extremity laterally. Lateral rotation and flexion of the hip was avoided. The end of passive ROM was determined when the resistance to further motion caused lateral pelvic tilting, pelvic rotation, or lateral flexion of the trunk.[58]

The opposite limb was tested in a similar fashion.

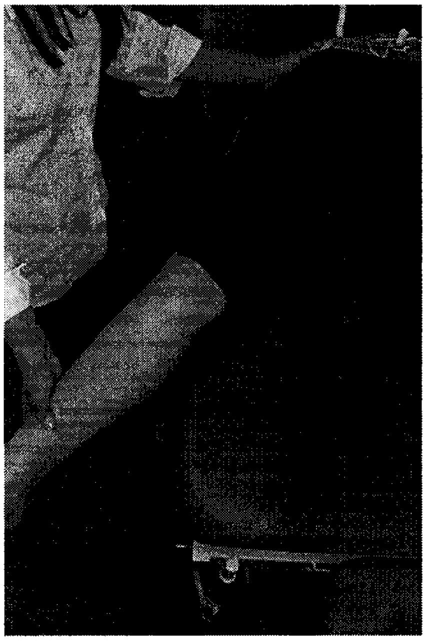

Figure 13 : The examiner used one hand to pull the subject's leg into abduction while the other hand was used not only to stabilize the pelvis but to detect pelvic motion.

- **Active motion testing**

The subject was asked to abduct her leg away from the other leg while keeping the toes pointing towards the ceiling. She was asked to move the leg as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused pelvic lateral tilting, pelvic rotation, or lateral flexion of the trunk.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over the anterior superior iliac spine (ASIS) of the extremity being measured.

2. The proximal arm was aligned with the imaginary horizontal line extending from one ASIS to the other.

3. The distal arm was aligned with the anterior midline of the femur using the patella as reference.

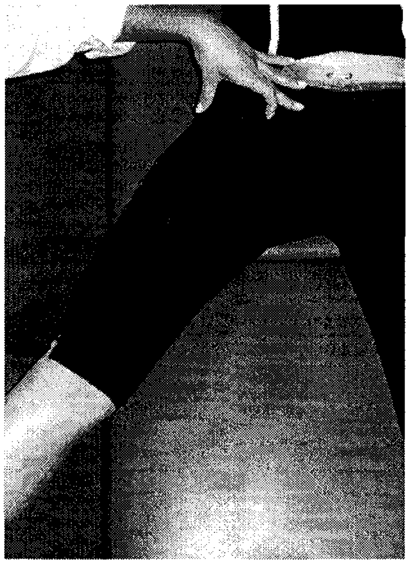

Figure 14: After determining the abduction range of motion, the examiner used the hand that was stabilizing the pelvis to align the goniometer.

3.7.4.3.2 HIP ADDUCTION

- **Starting position**

The subject was positioned in supine on a table with both knees straight and the hip to be tested in 0 degrees of flexion, extension and rotation. The contralateral extremity was abducted about 45 degrees to provide sufficient space to complete the full ROM in adduction.[58]

- **Stabilization**

The examiner stabilized the pelvis using one had over the ipsilateral anterior superior iliac spine (ASIS) to prevent lateral tilting and rotation of the pelvis.[58]

- **Passive motion testing**

The examiner adducted the hip sliding the lower extremity medially towards the contralateral abducted lower extremity. One hand was positioned on the knee to move the extremity and to maintain the hip in neutral position while the other hand was over the ASIS to provide stabilization. The end of ROM was determined when resistance to further motion could be felt or caused lateral pelvic tilting, pelvic rotation, and/or lateral trunk flexion.[58]

The opposite limb was tested in a similar fashion.

Figure 15: The examiner moved the hip into adduction with one hand while stabilized the pelvis with the other hand.

- **Active motion testing**

The subject was asked to move her leg towards the other leg while keeping the toes pointing to the ceiling. She was asked to adduct the leg as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused pelvic lateral tilting, pelvic rotation, or lateral flexion of the trunk.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over the anterior superior iliac spine (ASIS) of the extremity being measured.

2. The proximal arm was aligned with the imaginary horizontal line extending from one ASIS to the other.

3. The distal arm will be aligned with the anterior midline of the femur using the patella as a reference.

Figure 16: At the end range of hip adduction the examiner used one hand to hold the goniometer over the subject's anterior superior iliac spine and the other hand to prevent hip motion by grasping firmly on the subject's leg.

3.7.4.3.3 HIP FLEXION

- **Starting position**

The subject was positioned in supine on a table, with the knees extended and both hips in 0 degrees of abduction, adduction and rotation.[58]

- **Stabilization**

The pelvis was stabilized to prevent posterior tilt or rotation. The opposite leg was kept on the examining table to provide additional stabilization.[58]

- **Passive motion testing**

The examiner flexed the hip by lifting the thigh off the table. The knee was passively flexed during the motion to lessen the tension on the hamstrings. The end of the ROM was determined when the resistance to further motion caused posterior tilting of the pelvis.

The opposite limb was tested in a similar fashion.[58]

Figure 17: The examiner used one hand to flex the hip while the other hand stabilized the pelvis and detect pelvic motion.

- **Active motion testing**

The subject was asked to flex the thigh towards her body as far as possible. At the same time, she was asked to bring her foot toward her thigh to flex the knee. She was asked to flex the thigh as far as possible not worrying with the amount of knee flexion. At the end of this movement, she was asked to hold the position while the examiner measured the range of motion. The end of the ROM was determined by the resistance to further motion stopping the movement or causing posterior tilting of the pelvis.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned with the lateral aspect of the hip joint over the greater trochanter.
2. The proximal arm was aligned with the midline of the pelvis.
3. The distal arm was aligned with the lateral midline of the femur using the epicondyle as a reference.

Figure 18: At the end of hip flexion range of motion the examiner used one hand to maintain hip flexion while the other hand was used to align the goniometer.

3.7.4.3.4 HIP EXTENSION

- **Starting position**

The subject was positioned in prone on a table with the knee extended and both hips in 0 degrees of abduction, adduction and rotation.[58]

- **Stabilization**

The examiner stabilized the pelvis by positioning one hand over the ASIS. The hand prevented anterior tilt or rotation of the pelvis. The opposite leg was kept on the examining table to provide additional stabilization. [58]

- **Passive motion testing**

The hip was extended by lifting the thigh off the table. The knee was passively maintained in extension to ensure that the rectus femoris muscle did not limit the ROM.

The end of the ROM was determined when the resistance to further motion caused anterior tilting of the pelvis or extension of the lumbar spine.[58]

The opposite limb was tested in a similar fashion.

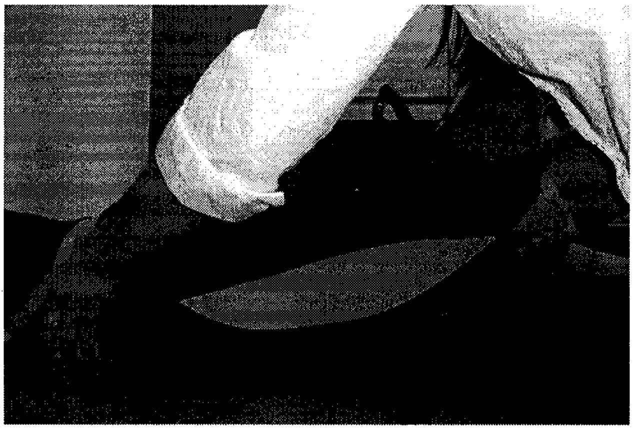

Figure 19: The examiner used one hand to support the distal femur and produce extension while the other hand was used to detect pelvic motion by grasping the pelvis at the level of the anterior superior iliac spine.

- **Active motion testing**

The subject was asked to lift the thigh off the table while maintaining the knee straight. She was asked to move the thigh as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused anterior tilting of the pelvis or extension of the lumbar spine.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned with the lateral aspect of the hip joint over the greater trochanter.

2. The proximal arm was aligned with the midline of the pelvis.

3. The distal arm was aligned with the lateral midline of the femur using the epicondyle as a reference.

Figure 20: At the end of hip extension range of motion the examiner used one hand to hold the proximal arm of the goniometer and used the other hand to support the subject's femur.

3.7.4.3.5 HIP INTERNAL (MEDIAL) ROTATION

- **Starting position**

The subject was sitting on the table with the knees flexed to 90 degrees over the end of the table. The hip was in 0 degrees of abduction and adduction and 90 degrees of flexion. A pad was positioned under the distal end of the femur to maintain the hip in a horizontal plane.[58]

- **Stabilization**

The examiner held the distal end of the femur with one hand to prevent abduction, adduction or further flexion of the hip. The trunk was observed and rotation and lateral tilting of the pelvis was also avoided.[58]

- **Passive motion testing**

The examiner placed one hand at the distal femur to provide stabilization and one hand at the distal tibia to move the lower leg laterally. The hand performing the motion was also holding the lower leg in neutral position preventing rotation at the knee joint. The end of ROM was determined when resistance to further motion stopped the movement or caused tilting of the pelvis or lateral flexion of the trunk.[58]

The opposite limb was tested in a similar fashion.

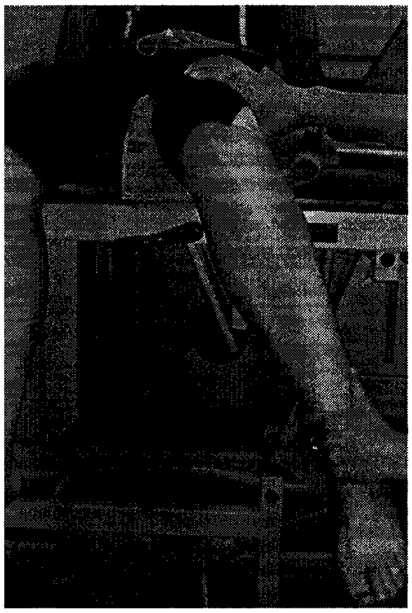

Figure 21: The examiner used one hand to stabilize the femur preventing hip flexion and abduction while the other hand was used to produce medial rotation.

- **Active motion testing**

The subject was asked to move the foot and lower leg away from the opposite leg. She was asked to maintain the knee in flexion and the thigh in contact with the table. She was asked to medially rotate the leg as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused tilting of the pelvis or lateral flexion of the trunk.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over anterior aspect of the patella.
2. The proximal arm was aligned parallel to the supporting surface or perpendicular to the floor.
3. The distal arm was aligned with the anterior midline of the tibia using as reference the midline between the two malleoli.

Figure 22: At the end of hip medial rotation range of motion the examiner used one hand to hold the leg in medial rotation and used the other hand to align the goniometer.

3.7.4.3.6 HIP EXTERNAL (LATERAL) ROTATION

- **Starting position**

The subject was sitting with the knees flexed to 90 degrees over the end of the table. The hip was in 0 degrees of abduction and adduction and 90 degrees of flexion. A pad was positioned under the distal end of the femur to maintain the thigh in a horizontal plane.[58]

- **Stabilization**

The examiner held the distal end of the femur with one hand to prevent abduction, adduction or further flexion of the hip. The trunk was observed and rotation and lateral tilting of the pelvis was avoided.

- **Passive motion testing**

The examiner placed one hand at the distal femur to provide stabilization and one hand at the distal fibula to move the lower leg medially. The hand performing the motion also held the lower leg in the neutral position preventing rotation at the knee joint. The end of ROM was determined when resistance to further motion was felt or attempts at further motion caused tilting of the pelvis or lateral flexion of the trunk.[58]

The opposite limb was tested in a similar fashion.

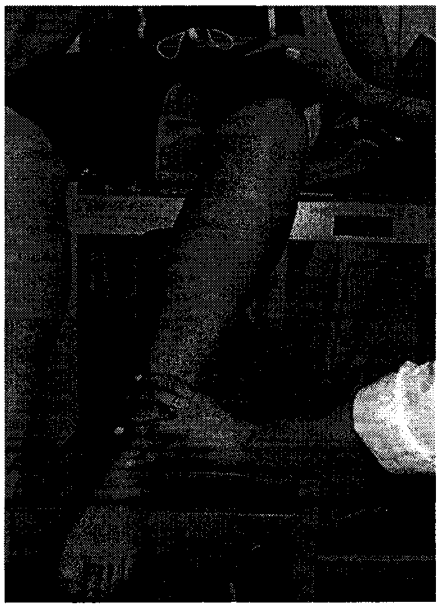

Figure 23: The examiner used one hand to stabilize the femur preventing hip flexion and abduction while the other hand was used to produce hip lateral rotation.

- **Active motion testing**

The subject was asked to move the foot and lower leg in the direction of the opposite leg. She was asked to maintain the knee in flexion and the thigh in contact with the table. She was asked to move the leg as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused tilting of the pelvis or lateral flexion of the trunk.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was positioned over anterior aspect of the patella
2. The proximal arm was aligned parallel to the supporting surface or perpendicular to the floor.
3. The distal arm was aligned with the anterior midline of the tibia using as reference the midline between the two malleoli.

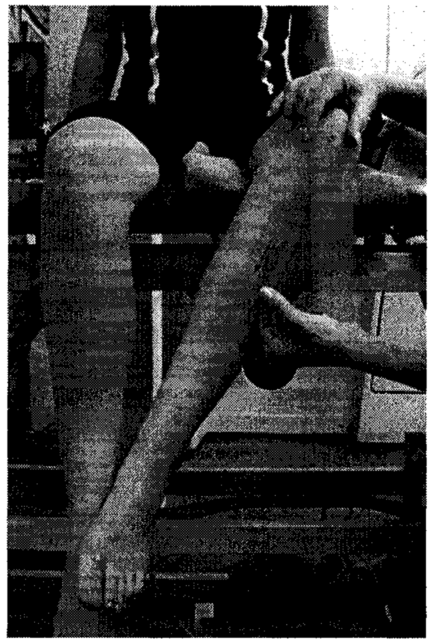

Figure 24: At the end of hip lateral rotation range of motion the examiner used one hand to hold the leg in lateral rotation and used the other hand to align the goniometer.

3.7.4.4 SHOULDER RANGE OF MOTION

The shoulder complex is composed by four articulations: the scapulothoracic joint, the sternoclavicular joint, the acromioclavicular joint and the glenohumeral joint. These four joints work interdependently to provide shoulder movement.[57]

The shoulder range of motion can be divided into types: the shoulder complex range of motion and the glenohumeral range of motion. The shoulder complex ROM is the one that takes into account the movement happening at all of the structures and articulations that form the shoulder complex. The glenohumeral ROM takes into consideration the movement happening only at the glenohumeral joint, not considering the movements happening at the other joints of the shoulder complex. For this reason, the ROM of the shoulder was divided into glenohumeral ROM and shoulder complex ROM.

3.7.4.4.1 SHOULDER ABDUCTION

- **Starting position**

The subject was positioned in supine on a table with the shoulder in lateral rotation and 0 degrees of flexion and extension so that the palm of the hand faces anteriorly. With the humerus in lateral rotation, contact between the greater tubercle of the humerus and the upper portion of the glenoid fossa or the acromion was avoided. The elbow was extended so the long head of the triceps would not limit the motion.[58]

3.7.4.4.1.1 GLENOHUMERAL ABDUCTION

- **Stabilization**

The examiner placed one hand over the lateral border of the scapula and prevented upward rotation and elevation of the scapula by resisting scapular movement.[58]

- **Passive motion testing**

The shoulder was abducted by moving the humerus laterally away from the body. The upper extremity was maintained in lateral rotation, neutral flexion and extension during the motion. The end of ROM was determined when the resistance to further motion was felt or attempts to overcome the resistance caused upward rotation or elevation of the scapula.[58]

The opposite limb was tested in a similar fashion.

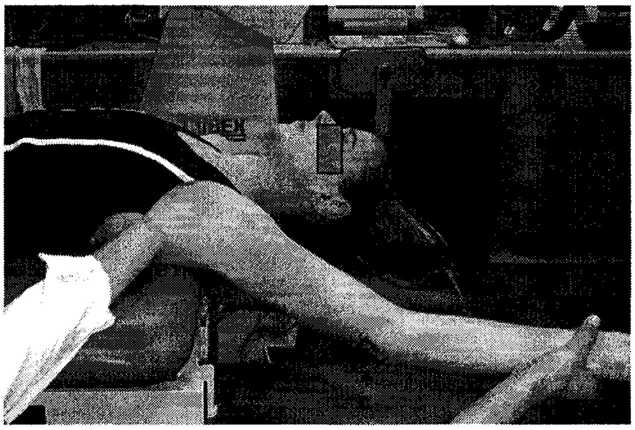

Figure 25: The examiner stabilized the lateral border of the scapula with one hand to detect and prevent upward rotation.

- **Active motion testing**

The subject was asked to abduct her arm away from the body in the direction of the head. She was asked to raise the arm keeping it aligned to the side of the body. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused the scapula to rotate upward or elevate.

The opposite limb was tested in a similar fashion.

3.7.4.4.1.2 SHOULDER COMPLEX ABDUCTION

- **Stabilization**

The examiner used one hand over the rib cage on the side to be tested to prevent lateral flexion of the spine by resisting this movement.[58]

- **Passive motion testing**

The examiner abducted the shoulder by moving the humerus laterally away from the body. The upper extremity was maintained in lateral rotation, neutral flexion and extension during the motion. The end of ROM was determined when the resistance to further motion was felt or attempts to overcome the resistance caused lateral flexion of the spine.[58]

The opposite limb was tested in a similar fashion.

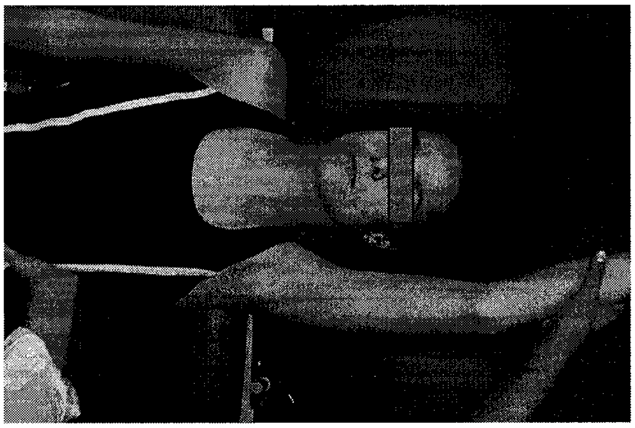

Figure 26: The examiner stabilized the subject's trunk and ribs with one hand to detect and prevent lateral flexion of the spine and movement of the ribs.

- **Active motion testing**

The subject was asked to abduct her arm away from the body in the direction of the head. She was asked to raise the arm, keeping it aligned to the side of the body. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused lateral flexion of the spine.

The opposite limb was tested in a similar fashion.

- **Goniometer Alignment**[58]

1. The center of the goniometer was aligned close to the anterior aspect of the acromion process.
2. The proximal arm was parallel to the midline of the anterior aspect of the sternum.
3. The distal arm was aligned with the anterior midline of the humerus using the lateral epicondyle as a reference.

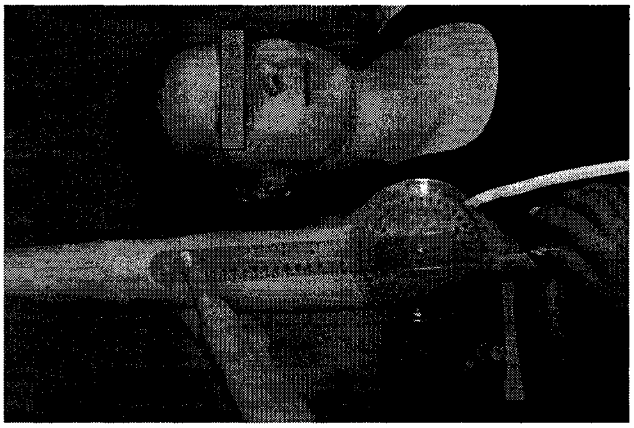

Figure 27: The extremity was maintained at the end range by the examining table, the examiner hand or the subject's muscle contraction. The examiner aligned the goniometer distal arm with the anterior midline of the humerus and released the scapular stabilization to hold the proximal arm of the goniometer parallel to the sternum.

3.7.4.4.2 SHOULDER FLEXION

- **Starting position**

The subject was positioned in supine on a table, with the knees flexed to flatten the lumbar spine. The shoulder was positioned in 0 degrees of abduction, adduction and rotation. The elbow was in extension so the tension on the long head of the triceps would not limit the motion. The forearm was in 0 degrees of supination and pronation so that the palm of the hand faced the body.[58]

3.7.4.4.2.1 GLENOHUMERAL FLEXION

- **Stabilization**

The examiner placed one hand over the lateral border of the scapula and prevented posterior tilting, upward rotation or elevation of the scapula by resisting scapular movement.[58]

- **Passive motion testing**

The shoulder was forward flexed by lifting the humerus off the examining table, bringing the hand up over the subject's head. The arm was kept in neutral abduction and adduction. The end of the movement was determined when resistance to further motion was felt and attempts to overcome the resistance caused upward rotation, posterior tilt or elevation of the scapula.[58]

The opposite limb was tested in a similar fashion.

Figure 28: The examiner stabilized the lateral border of the scapula with one hand and detected attempts of the scapula to move anteriorly and laterally.

- **Active motion testing**

The subject was asked to forward flex her arm away from the body in the direction of the head. She was asked to raise the arm keeping it in front (anteriorly) of the body. She was asked to move the arm as far as possible and to maintain the end position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused the scapula to upwardly rotate, posteriorly tilt or elevate.

The opposite limb was tested in a similar fashion.

3.7.4.4.2.2 SHOULDER COMPLEX FLEXION

- **Stabilization**

The examiner placed one hand over the rib cage on the side to be tested to prevent movement of the spine or the ribs.[58]

- **Passive motion testing**

The examiner forward flexed the arm by lifting the humerus off the examining table, bringing the hand up over the subject's head. The arm was kept in neutral abduction and adduction. The end of the shoulder complex flexion ROM was determined when resistance to further motion was felt and attempts to overcome the resistance caused extension of the spine or motion of the ribs [58]

The opposite limb was tested in a similar fashion.

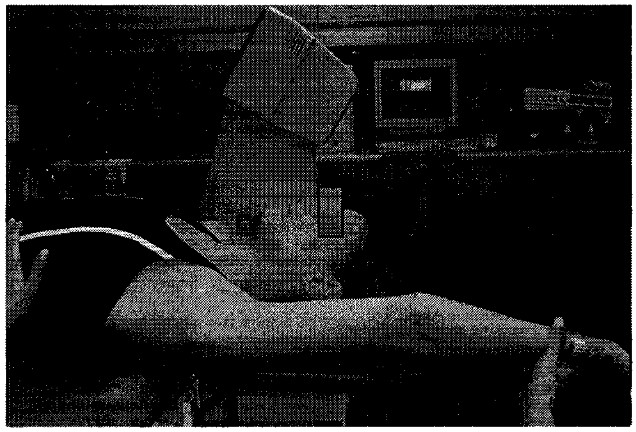

Figure 29: The examiner stabilized the subject's trunk and ribs with one hand detecting attempts of the spine to extend and the ribs to move.

- **Active motion testing**

The subject was asked to forward flex her arm away from the body in the direction of the head. She was asked to raise the arm keeping it in front (anteriorly) of the body. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistances to further motion stopped the movement or caused extension of the spine or motion of the ribs.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned over the lateral aspect of the greater tubercle.
2. The proximal arm aligned to the midaxillary line of the thorax.
3. The distal arm aligned with the lateral midline of the humerus and the lateral epicondyle.

Figure 30: The extremity was maintained at the end range by examiner hand or the subject's muscle contraction. The examiner aligned the distal arm of the goniometer with the lateral epicondyle and the proximal arm of the goniometer with the lateral midline of the thorax.

3.7.4.4.3 SHOULDER EXTENSION

- **Starting position**

The subject was positioned in prone on a table, with the face turned away from the shoulder being tested. A pillow was not used under the head. The shoulder was placed in 0 degrees of abduction, adduction and rotation. The elbow was slightly flexed so that the tension on the long head of the biceps muscle would not restrict the motion. The forearm was in 0 degrees of supination and pronation so that the palm of the hand faces the body.[58]

3.7.4.4.3.1 GLENOHUMERAL EXTENSION

- **Stabilization**

The examiner placed one hand over the inferior angle of the scapula to prevent elevation or anterior tilting of the scapula by resisting scapular movement.[58]

- **Passive motion testing**

The examiner extended the arm off the examining table maintaining the arm in neutral abduction and adduction during the motion. The end of ROM was determined when the resistance to further motion was felt and attempts to overcome the resistance caused anterior tilting or elevation of the scapula.[58]

The opposite limb was tested in a similar fashion.

Figure 31: The examiner stabilized the scapula with one hand and detected attempts of the scapula to anteriorly tilt and to elevate.

- **Active motion testing**

The subject was asked to extend her arm away from the body in the direction of the head. She was asked to raise the arm lifting it behind the body. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stoped the movement or caused anterior tilting or elevation of the scapula.

The opposite limb was tested in a similar fashion.

3.7.4.4.3.2 SHOULDER COMPLEX EXTENSION

- **Stabilization**

The examining table and the weight of the body stabilized the thorax preventing forward flexion of the spine.[58]

- **Passive motion testing**

The examiner lifted the shoulder off the examining table maintaining the arm in neutral abduction and adduction during the motion. The end of ROM was determined when the resistance to further motion was felt and attempts to overcome the resistance caused forward flexion or rotation of the spine.[58]

The opposite limb was tested in a similar fashion.

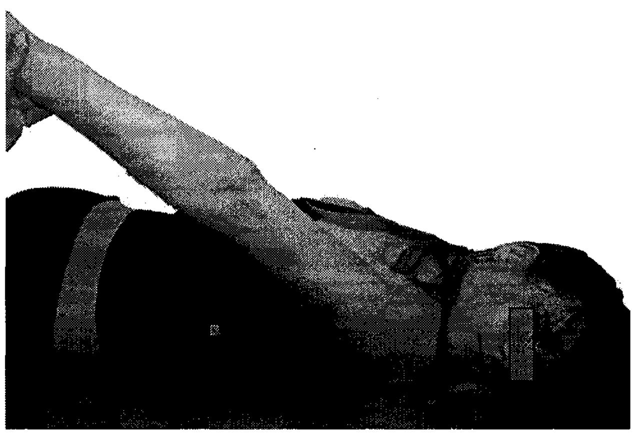

Figure 32: The examining table stabilized the subject's body preventing forward flexion of the trunk.

- **Active motion testing**

The subject was asked to extend her arm behind her body. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused forward flexion or rotation of the spine.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned over the lateral aspect of the greater tubercle.
2. The proximal arm parallel to the midaxillary line of the thorax.
3. The distal arm aligned with the lateral midline of the humerus, using the lateral epicondyle of the elbow as reference.

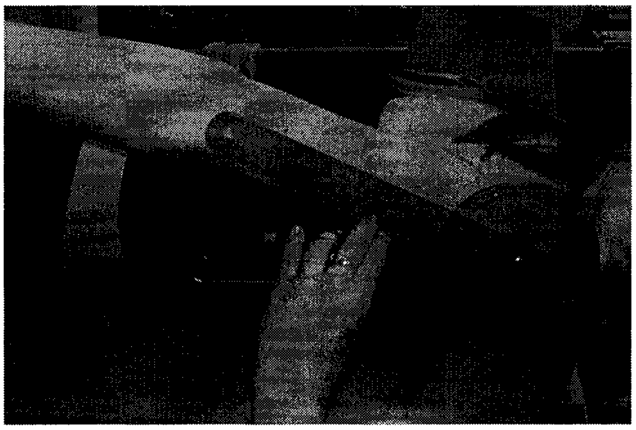

Figure 33: The extremity was maintained at the end range by the examiner hand or the subject's muscle contraction. The examiner aligned the proximal arm of the goniometer with the axilar midline and the distal arm of the goniometer with the lateral midline of the humerus, using the lateral epicondyle of the elbow as reference.

3.7.4.4.4 SHOULDER INTERNAL (MEDIAL) ROTATION

- **Starting position**

The subject was positioned in supine on the table, with the arm being tested in 90 degrees of shoulder abduction. The forearm was perpendicular to the supporting surface and in 0 degrees of supination and pronation so that the palm of the hand faced the feet.

The humerus was resting on the examining table. A pad was placed under the humerus so the humerus was leveled with the acromion process.[58]

3.7.4.4.4.1 GLENOHUMERAL INTERNAL (MEDIAL) ROTATION

- **Stabilization**

The examiner placed one hand over the superior (upper) trapezius muscle positioning the thumb over the clavicle and the corocoid process and the other fingers over the spine of the scapula. This hand prevented anterior tilting and protraction of the scapula by resisting scapular movement.[58]

- **Passive motion testing**

The examiner medially rotated the shoulder by moving the forearm anteriorly bringing the palm of the hand toward the floor. The shoulder was maintained in 90 degrees of abduction and the elbow in 90 degrees of flexion during the whole motion. The end of ROM was determined when the resistance to further motion was felt or attempts to overcome the resistance caused anterior tilt or protraction of the scapula.[58]

The opposite limb was tested in a similar fashion.

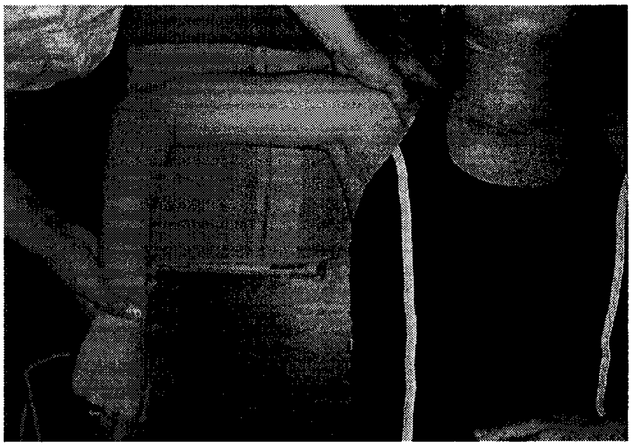

Figure 34: The examiner stabilized the acromion and the coracoid process of the scapula and detected attempts of the scapula to anteriorly tilt or protract.

- **Active motion testing**

The subject was asked to rotate the arm bringing the palm of the hand to face the floor. She was asked to keep the elbow in flexion and the shoulder abducted. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused anterior tilt or protraction of the scapula.

The opposite limb was tested in a similar fashion.

3.7.4.4.4.2 SHOULDER COMPLEX INTERNAL (MEDIAL) ROTATION

- **Stabilization**

The subject's body weight was used to stabilize the thorax preventing the spine from flexing or rotating.

- **Passive motion testing**

The examiner medially rotated the shoulder by moving the forearm anteriorly bringing the palm of the hand toward the floor. The shoulder was maintained in 90 degrees of abduction and the elbow in 90 degrees of flexion during the whole motion. The end of ROM was determined when the resistance to further motion was felt or attempts to overcome the resistance caused flexion or rotation of the spine.[58]

The opposite limb was tested in a similar fashion.

Figure 35: The examiner stabilized the distal end of the humerus maintaining the shoulder in 90 degrees of abduction and the elbow in 90 degrees of flexion.

- **Active motion testing**

The subject was asked to rotate the arm bringing the palm of the hand to face the floor. She was asked to keep the elbow in flexion and the shoulder abducted. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused flexion or rotation of the spine.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned with the most protuberant part of the olecranon.
2. The proximal arm was aligned perpendicular to the floor.
3. The distal arm was aligned with the ulna using the olecranon process and the ulnar styloid process as reference.

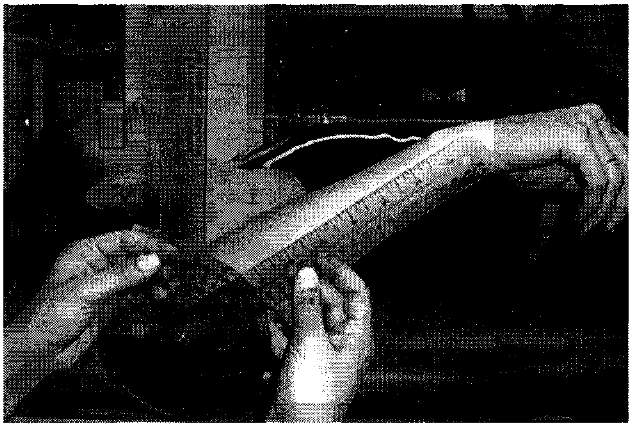

Figure 36: The extremity was maintained at the end range by the examiner hand or the subject's muscle contraction. The examiner aligned the proximal arm of the goniometer perpendicular to the floor and the distal arm with the ulna using the olecranon process and the ulnar styloid process as reference.

3.7.4.4.5 SHOULDER EXTERNAL (LATERAL) ROTATION

- **Starting position**

The subject was positioned in supine on a table, with the arm being tested in 90 degrees of shoulder abduction. The forearm was perpendicular to the supporting surface and in 0 degrees of supination and pronation so that the palm of the hand faced the feet. The humerus was resting on the examining table. A pad was place under the humerus so that the humerus was leveled with the acromion process.[58]

3.7.4.4.5.1 GLENOHUMERAL EXTERNAL (LATERAL) ROTATION

- **Stabilization**

The examiner placed one hand over the superior (upper) trapezius muscle, over the clavicle, the corocoid process and over the spine of the scapula. This hand prevented movement of the clavicle and scapula by resisting posterior tilting or retraction of the scapula.[58]

- **Passive motion testing**

The examiner laterally rotated the shoulder by moving the forearm posteriorly bringing the dorsal surface of the hand toward the ceiling. The shoulder was kept in 90 degrees of abduction and the elbow in 90 degrees of flexion during the whole motion. The end of ROM was determined when the resistance to further motion was felt or attempts to overcome the resistance caused posterior tilt or retraction of the scapula.[58]

The opposite limb was tested in a similar fashion.

Figure 37: The examiner stabilized the scapula detecting attempts of the scapula to retract or posteriorly tilt.

- **Active motion testing**

The subject was asked to rotate the arm bringing the palm of the hand to face the ceiling. She was asked to keep the elbow in flexion and the shoulder abducted. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused posterior tilt or retraction of the scapula.

The opposite limb was tested in a similar fashion.

3.7.4.4.5.2 SHOULDER COMPLEX EXTERNAL (LATERAL) ROTATION

- **Stabilization**

The examining table and the weight of the body stabilized the thorax preventing rotation of the spine.[58]

- **Passive motion testing**

The examiner laterally rotated the shoulder by moving the forearm posteriorly bringing the dorsal surface of the hand toward the floor. The shoulder was kept in 90 degrees of abduction and the elbow in 90 degrees of flexion during the whole motion. The end of ROM was determined when the resistance to further motion was felt or attempts to overcome the resistance caused extension or rotation of the spine.[58]

The opposite limb was tested in a similar fashion.

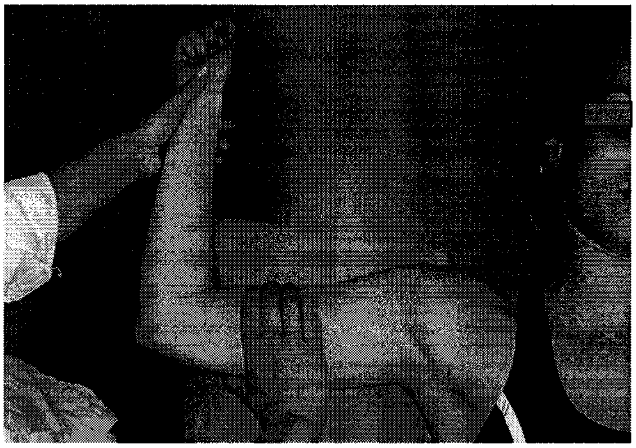

Figure 38: The examiner stabilized the distal end of the humerus maintaining the shoulder in 90 degrees of abduction and the elbow in 90 degrees of flexion.

- **Active motion testing**

The subject was asked to rotate the arm bringing the palm of the hand to face the ceiling. She was asked to keep the elbow in flexion and the shoulder abducted. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused extension or rotation of the spine.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned with the most protuberant part of the olecranon.
2. The proximal arm was aligned perpendicular to the floor.
3. The distal arm was aligned with the ulna using the olecranon process and the ulnar styloid process as reference.

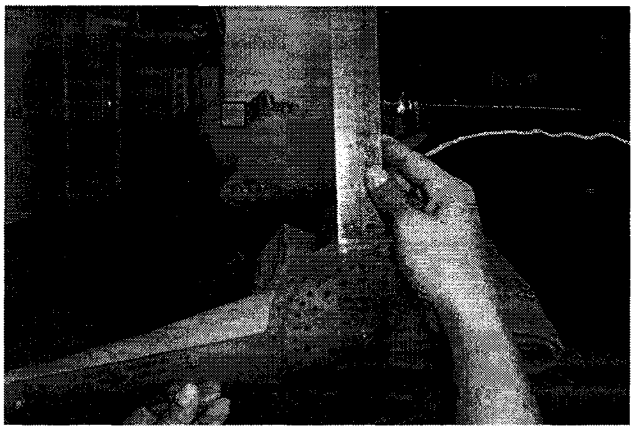

Figure 39: The extremity was maintained at the end range by the examiner hand or the subject's muscle contraction. The examiner aligned the proximal arm of the goniometer perpendicular to the floor and the distal arm with the ulna using the olecranon process and the ulnar styloid process as reference.

3.7.4.5 ELBOW RANGE OF MOTION

3.7.4.5.1 ELBOW FLEXION

- **Starting position**

The subject was positioned in supine with the shoulder in 0 degrees of flexion, extension, and abduction so that the arm was close to the side of the body. A pad was place under the humerus so that the humerus was leveled with the acromion process. The forearm was fully supinated with the palm of the hand facing the ceiling.[58]

- **Stabilization**

The examiner held the humerus with one hand to prevent shoulder flexion from occuring.[58]

- **Passive motion testing**

The examiner flexed the elbow by moving the hand towards that shoulder. The forearm was maintained in supination during the whole motion. The end of ROM was determined when the resistance to further motion was felt or attempts to overcome the resistance caused flexion of the shoulder.[58]

The opposite limb was tested in a similar fashion.

Figure 40: The examiner stabilized the humerus with one hand in a position so it would not limit the motion.

- **Active motion testing**

The subject was asked to flex the elbow by bringing the hand towards the shoulder keeping the arm by the side of the body. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused flexion of the shoulder.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned with the lateral epicondyle of the elbow.
2. The proximal arm was aligned with the lateral midline of the humerus using the center of the acromion process as reference.
3. The distal arm was aligned with the lateral midline of the radius, using the radial head and radial styloid process as references.

Figure 41: The proximal arm of the goniometer was aligned with the lateral midline of the humerus and the distal arm with the lateral midline of the radius using the radial styloid process as reference.

3.7.4.5.2 ELBOW EXTENSION

- **Starting position**

The subject was positioned in supine on a table with the shoulder in 0 degrees of flexion, extension, and abduction so that the arm was close to the side of the body. A pad was place under the humerus so that the humerus was leveled with the acromion process. The forearm was fully supinated with the palm of the hand facing the ceiling.[58]

- **Stabilization**

The examiner held the humerus with one hand to prevent shoulder flexion from occuring.[58]

- **Passive motion testing**

The examiner extended the elbow by moving the hand dorsally toward the examining table. The end of ROM was determined when the resistance to further motion was felt or attempts to overcome the resistance caused extension of the shoulder.[58]

The opposite limb was tested in a similar fashion.

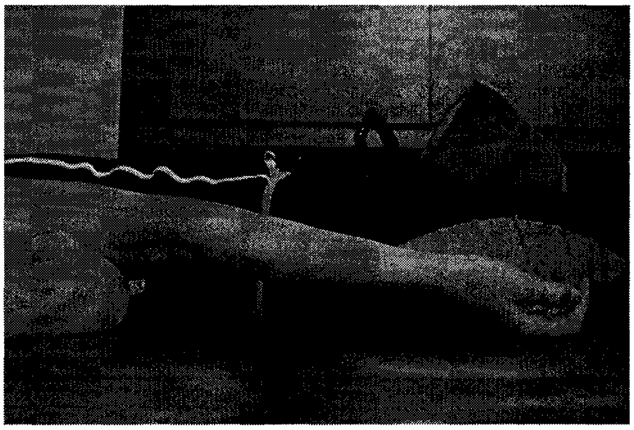

Figure 42: The examiner used a towel under the humerus to allow the elbow to fully extend. The examiner stabilized the humerus to prevent rotation, abduction and extension of the humerus.

- **Active motion testing**

The subject was asked to extend the elbow by moving the hand towards the examining table. She was asked to move the arm as far as possible and to maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused extension of the shoulder

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned with the lateral epicondyle of the elbow.
2. The proximal arm was aligned with the lateral midline of the humerus using the center of the acromion process as reference.
3. The distal arm was aligned with the lateral midline of the radius, using the radial head and radial styloid process as references.

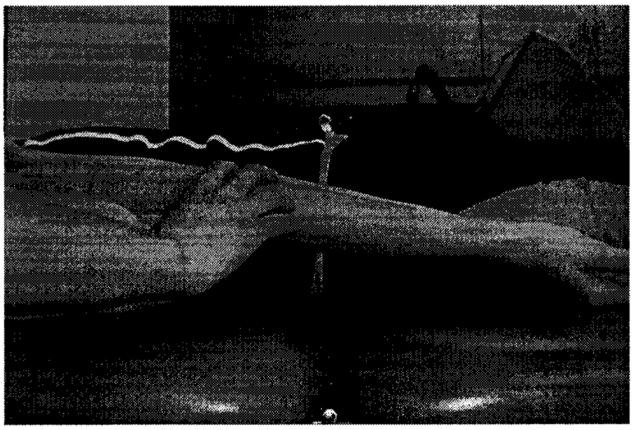

Figure 43: The proximal arm of the goniometer was aligned with the lateral midline of the humerus and the distal arm with the lateral midline of the radius using the radial styloid process as reference.

3.7.4.5.3 FOREARM PRONATION

- **Starting position**

The subject was sitting on a table, with the shoulder in 0 degrees of flexion, extension, abduction, adduction, and rotation so that the arm was close to the body. The elbow was flexed to 90 degrees and the forearm supported by the examiner. The hand was positioned midway between pronation and supination so the thumb pointed towards the ceiling.[58]

- **Stabilization**

The examiner held the humerus with one hand to prevent shoulder medial rotation and abduction from occuring.[58]

- **Passive motion testing**

The examiner pronated the forearm by moving the distal radius in a circular direction so that the palm of the hand faced the floor. The end of ROM was determined when resistance to further motion was felt or attempts to overcome the resistance caused medial rotation or abduction of the shoulder.[58]

The opposite limb was tested in a similar fashion.

Figure 44: The examiner used one hand to hold the elbow close to the subject's body in 90 degrees of elbow flexion, helping to prevent medial rotation and abduction of the shoulder.

- **Active motion testing**

The subject was asked to rotate the forearm bringing the palm of the hand to face the floor while maintaining the elbow flexed and the arm close to the body. She was asked to move the arm as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused medial rotation or abduction of the shoulder.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned laterally and proximally to the ulnar styloid process.
2. The proximal arm of the goniometer was parallel to the anterior midline of the humerus.
3. The distal arm was aligned with the dorsal aspect of the forearm just proximal to the styloid process of the radius and ulna, where the forearm was most leveled and free of muscle bulk. The distal arm was parallel to the styloid process of the radius and ulna.

Figure 45: The examiner aligned the proximal arm of the goniometer parallel to the anterior midline of the humerus and the distal arm of the goniometer parallel to the styloid process of the radius and ulna.

3.7.4.5.4 FOREARM SUPINATION

- **Starting position**

The subject was sitting on a table, with the shoulder in 0 degrees of flexion, extension, abduction, adduction, and rotation so that the arm was close to the body. The elbow was flexed to 90 degrees and the forearm supported by the examiner. The hand was positioned midway between pronation and supination so the thumb pointed towards the ceiling.[58]

- **Stabilization**

The examiner held the distal end of the humerus to prevent shoulder lateral rotation and adduction.[58]

- **Passive motion testing**

The examiner supinated the forearm by moving the forearm in a dorsal direction so that the palm of the hand faced the ceiling. The end of the ROM was determined when resistance to further motion occurred or attempts to overcome the resistance caused lateral rotation or adduction of the shoulder.[58]

The opposite limb was tested in a similar fashion.

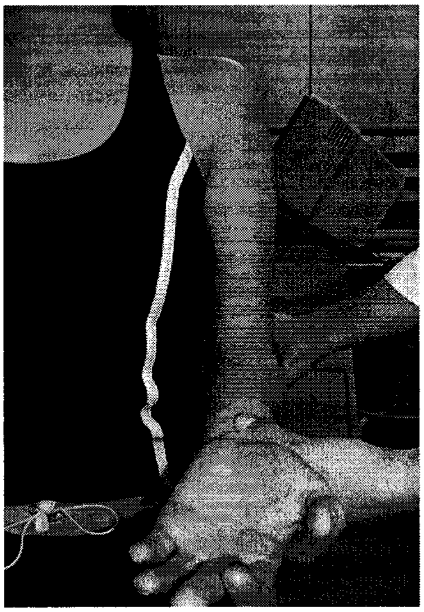

Figure 46: The examiner used one hand to hold the elbow close to the subject's body in 90 degrees of elbow flexion, helping to prevent lateral rotation and adduction of the shoulder.

- **Active motion testing**

The subject was asked to rotate the forearm bringing the back of the hand to face the floor while maintaining the elbow flexed and arm close to the body. She was asked to move the arm as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused lateral rotation or adduction of the shoulder.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned medially and proximally to the ulnar styloid process.
2. The proximal arm of the goniometer was parallel to the anterior midline of the humerus.
3. The distal arm was aligned with the anterior aspect of the forearm just proximal to the styloid process of the radius and ulna, where the forearm was most leveled and free of muscle bulk. The distal arm was parallel to the styloid process of the radius and ulna.

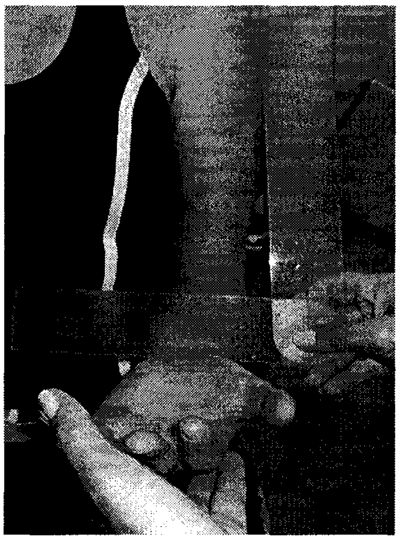

Figure 47: The examiner aligned the proximal arm of the goniometer parallel to the anterior midline of the humerus and the distal arm of the goniometer parallel to the styloid process of the radius and ulna.

3.7.4.6 WRIST RANGE OF MOTION

3.7.4.6.1 WRIST FLEXION

- **Starting position**

The subject was sitting next to a support surface with the shoulder abducted to 90 degrees and the elbow flexed to 90 degrees. The forearm was positioned midway between pronation and supination in a way that the palm of the hand faced the floor. The forearm was resting on the supporting surface and the hand was free to move.[58]

- **Stabilization**

The examiner held the radius and ulna to prevent supination and pronation of the forearm.[58]

- **Passive motion testing**

The examiner flexed the wrist by pushing the dorsal surface of the third metacarpal towards the floor. The examiner avoided ulnar and radial deviation and finger flexion while moving the hand to minimize muscle restrictions. The end of ROM was determined as the point where resistance to further motion was felt and attempts to overcome the resistance caused the forearm to lift off the supporting surface.[58]

The opposite limb was tested in a similar fashion.

Figure 48: The subject's forearm was supported by the examining table leaving sufficient space for the hand to complete the motion.

- **Active motion testing**

The subject was asked to flex the wrist by bringing the palm of the hand in the direction of the floor, keeping the forearm resting on the table and elbow flexed. She was asked to move the arm as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused the forearm to lift off the supporting surface.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned with the lateral aspect of the wrist over the triquetrum.

2. The proximal arm was aligned with the midline of the ulna using the olecranon and the ulnar styloid process as reference.

3. The distal arm was aligned with the lateral midline of the fifth metacarpal.

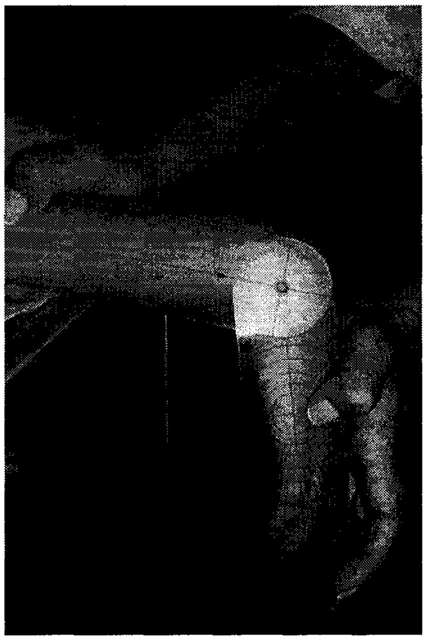

Figure 49: The examiner aligned the proximal arm of the goniometer with the midline of the ulna and the distal arm with the lateral midline of the fifth metacarpal bone.

3.7.4.6.2 WRIST EXTENSION

- **Starting position**

The subject was sitting next to a support surface with the shoulder abducted to 90 degrees and the elbow flexed to 90 degrees. The forearm was positioned midway between pronation and supination in a way that the palm of the hand faced the floor. The forearm was resting on the supporting surface and the hand was free to move.[58]

- **Stabilization**

The examiner held the radius and ulna preventing pronation and supination of the forearm to occur.[58]

- **Passive motion testing**

The examiner extended the wrist by pushing evenly across the palmar surface of the metacarpals, moving the dorsal part of the hand in the direction of the ceiling. The examiner avoided ulnar and radial deviation and finger flexion while moving the hand to minimize muscle restrictions. The end of ROM was determined as the point where resistance to further motion was felt and attempts to overcome the resistance caused the forearm to lift off the supporting surface.[58]

The opposite limb was tested in a similar fashion.

Figure 50: The subject's forearm was supported by the examining table leaving sufficient space for the hand to complete the motion.

- **Active motion testing**

The subject was asked to extend the wrist by bringing the dorsal part of the hand in the direction of the ceiling, keeping the forearm resting on the table and elbow flexed. She was asked to move the arm as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused the forearm to lift off the supporting surface.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned with the lateral aspect of the wrist over the triquetrum.

2. The proximal arm was aligned with the midline of the ulna using the olecranon and the ulnar styloid process as reference.

3. The distal arm was aligned with the lateral midline of the fifth metacarpal.

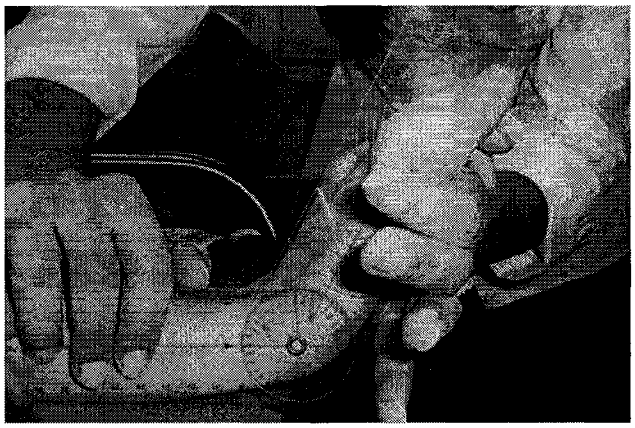

Figure 51: The examiner aligned the proximal arm of the goniometer with the midline of the ulna and the distal arm with the lateral midline of the fifth metacarpal bone.

3.7.4.6.3 WRIST ULNAR DEVIATION

- **Starting position**

The subject was sitting next to a support surface with the shoulder abducted to 90 degrees and the elbow flexed to 90 degrees. The forearm was positioned midway between pronation and supination in a way that the palm of the hand faced the floor. The forearm and hand was resting on the supporting surface.[58]

- **Stabilization**

The examiner held the radius and ulna preventing pronation and supination of the forearm and elbow flexion beyond 90 degrees to occur.[58]

- **Passive motion testing**

The examiner performed ulnar deviation by moving the hand towards the little finger. The end of ROM was determined as the point where resistance to further motion was felt and attempts to overcome the resistance caused the elbow to flex or extend.[58]

The opposite limb was tested in a similar fashion.

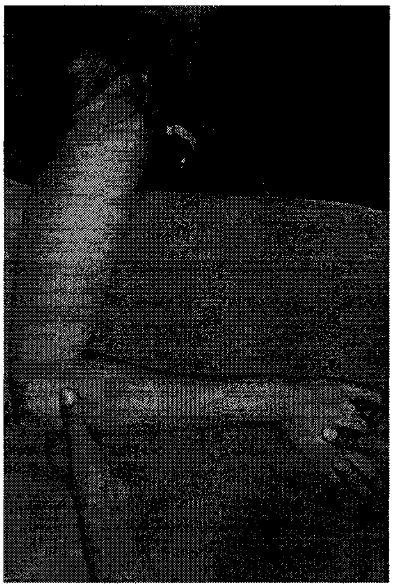

Figure 52: The examiner stabilized the subject's forearm to prevent extension of the elbow beyond 90 degrees. The examiner avoided moving the wrist into either flexion or extension.

- **Active motion testing**

The subject was asked to move her hand towards the little finger keeping the wrist in neutral between flexion and extension, the forearm resting on the table and elbow flexed. She was asked to move the arm as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stoped the movement or caused the elbow to flex or extend.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**

1. The center of the goniometer was aligned with the dorsal aspect of the wrist over the midpoint of the radio carpal joint.

2. The proximal arm was aligned with the dorsal midline of the forearm using the lateral epicondyle as reference.

3. The distal arm was aligned with the dorsal midline of the third metacarpal.

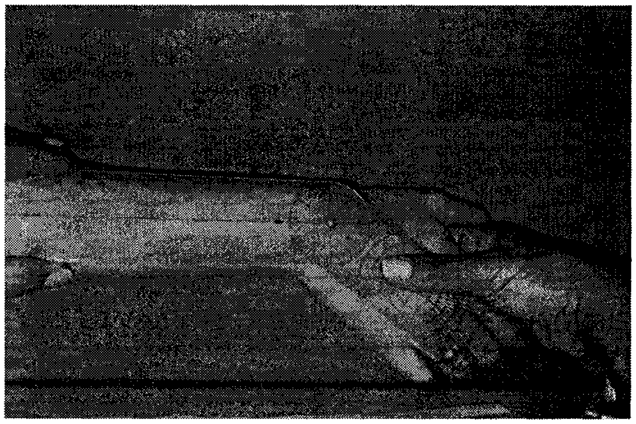

Figure 53: The examiner aligned the proximal arm of the goniometer with the dorsal midline of the forearm and the distal arm of the goniometer with the dorsal midline of the third metacarpal bone.

3.7.4.6.4 WRIST RADIAL DEVIATION

- **Starting position**

The subject was sitting next to a support surface with the shoulder abducted to 90 degrees and the elbow flexed to 90 degrees. The forearm was positioned midway between pronation and supination in a way that the palm of the hand faced the floor. The forearm and hand were resting on the supporting surface.[58]

- **Stabilization**

The examiner held the radius and ulna to prevent supination and pronation of the forearm and elbow flexion beyond 90 degrees.[58]

- **Passive motion testing**

The examiner performed radial deviation by moving the hand towards the thumb. The end of ROM was determined as the point where resistance to further motion was felt and attempts to overcome the resistance caused the elbow to flex or extend.[58]

The opposite limb was tested in a similar fashion.

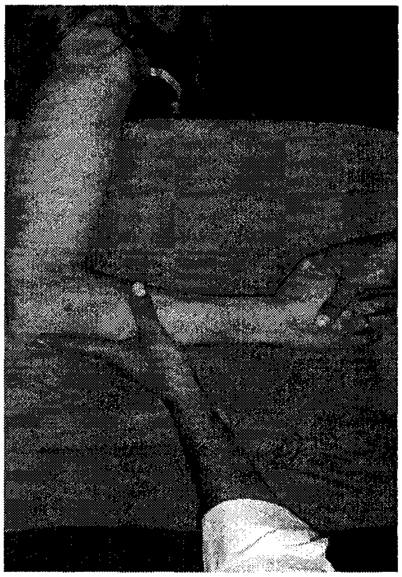

Figure 54: The examiner stabilized the subject's forearm to prevent flexion of the elbow beyond 90 degrees. The examiner avoided moving the wrist into either flexion or extension

- **Active motion testing**

The subject was asked to move the hand towards the thumb keeping the wrist in neutral between flexion and extension, the forearm resting on the table and elbow flexed. She was asked to move the arm as far as possible and maintain that position while the examiner measured the range of motion. The end of the ROM was determined when the resistance to further motion stopped the movement or caused the elbow to flex or extend.

The opposite limb was tested in a similar fashion.

- **Goniometer alignment**[58]

1. The center of the goniometer was aligned with the dorsal aspect of the wrist over the midpoint of the radio carpal joint.

2. The proximal arm was aligned with the dorsal midline of the forearm using the lateral epicondyle as reference.

3. The distal arm was aligned with the dorsal midline of the third metacarpal.

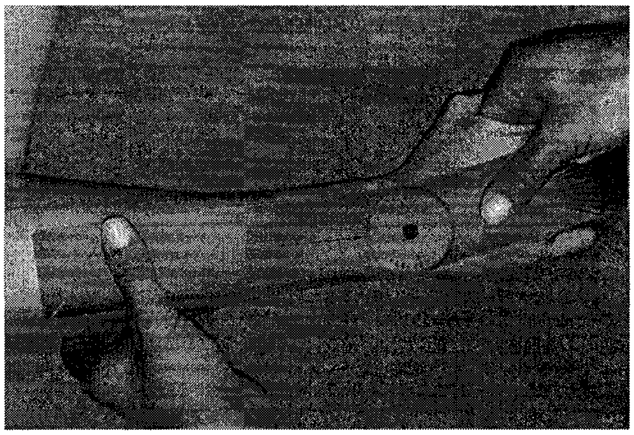

Figure 55: The examiner aligned the proximal arm of the goniometer with the dorsal midline of the forearm and the distal arm of the goniometer with the dorsal midline of the third metacarpal bone.

CHAPTER 4: RESULTS

4.1 STATISTICAL ANALYSIS

The statistical program SPSS 13.0 for Windows was used for all data analyses.

Descriptive analysis (mean, standard deviation, range and 95% confidence interval) of the values of range of motion for each age group were performed. Descriptive analysis was also used to analyze the occupation, type of physical activity, upper and lower extremity dominance, use of hormonal contraceptive method, and hormone replacement therapy. A one-way ANOVA with a Bonferroni post hoc test was used to see if there was a significant difference between height and weight for the different age groups. A t-test was used to analyze differences of the ROM values between one east Indian subject and the values of ROM for age groups. This analysis was performed to test if there was a difference between the ROM values for the east Indian subjects and white subjects.

An intraclass correlation coefficient two way mixed (ICC 3,1) was used to analyze the intrarater reliability. The model (ICC3,1) was selected because it is used to test intrarater reliability with multiple scores from the same rater.[61] The ICC was used because it reflected both agreement within and between subjects taking into consideration variations in the measurement systems such as characteristics of the rater and/or subjects.[61]. The standard error of measurement (SEM) was calculated using an F-test. The F-test (variance) is normally used to calculate ICC and the SEM is calculated taking the square root of the total difference within subjects. The standard error of measurement (SEM) represents the random error due to biological or mechanical variation.[6] For clinical purposes, an ICC of 0.75 is considered excellent, a range from 0.40 to 0.75 is considered fair to good, and a range from 0 to 0.40 is considered poor.[7]

A comparison between the values of ROM of both sides of the body (right and left) and the age groups was analyzed using a two-way ANOVA. The ANOVA was the statistical analysis of choice because it allowed comparisons between means and allowed the performance of interaction testing between independent groups.[36] A Bonferroni post hoc test was performed to see if there was a difference between each age group for each side (right and left) separately and if there was a difference between sides (right and left) for each age group separately. A value of $p<0.01$ was determined as a statistical significant difference.

A conservative alpha value of 0.01 was adopted for this study to avoid a type error I.[36] Confidence intervals were reported for all comparisons to confirm that statistically significant results did not contained zero in their confidence interval.

A two-way ANOVA and a Bonferroni post hoc test were also used to analyze if there was a significant difference in ROM between dominant and non-dominant sides for each age group separately. A value of $p<0.01$ was determined as a statistical significant difference.

Post hoc power calculation was performed for the interaction between age groups and interaction between sides. Power was given by SPSS for the two-way ANOVA output.

4.2 PILOT STUDY

The Intraclass Correlation Coefficient (ICC) for intrarater reliability was greater than 0.70 for almost all ranges of motion measured. Only six motions had an ICC of less than 0.70. These motions were: left passive eversion ICC= 0.62, right active and passive inversion ICC= 0.68 and ICC=0.65 respectively, left active knee extension ICC= 0.66, left passive knee extension ICC= 0.69, left active elbow flexion ICC= 0.66. All of the standard errors of measurement (SEM) were smaller than 7.28 degrees showing variability within the one expected as measurement error for the goniometer.[14,26,52,79] The values of ICC and SEM (standard error of measurements) are available on Table 1.

4.3 DEMOGRAPHICS

There were 90 women assessed in this study from 4 different age groups. There were 30 women in the 18 to 29 year age group, 20 in the 30 to 39 year age group, 20 in the 40 to 49 year age group and 20 in the 50 to 59 year age group

The descriptive characteristics of the groups regarding weight, height, level of physical activity (IPAQ), amount of time spent sitting per day, number of women who had gone through menopause, used hormonal replacement therapy, used a hormonal contraceptive and the length of time they used hormonal contraceptive are presented on Table 2.

Table 1: Intraclass correlation coeficient (ICC) and standard error measurement (SEM) values.

JOINT MOVEMENTS	ACTIVE				PASIVE			
	RIGHT		LEFT		RIGHT		LEFT	
	ICC	SEM	ICC	SEM	ICC	SEM	ICC	SEM
Ankle range of motion								
Dorsiflexion (talocrural joint)	0.86	1.91	0.72	2.96	0.75	2.77	0.82	2.16
Plantarflexion (talocrural joint)	0.97	2.70	0.97	2.80	0.88	5.37	0.93	3.83
Eversion (tarsal joint)	0.96	2.70	0.94	4.45	0.75	4.94	0.62*	7.28
Inversion (tarsal joint)	0.68*	4.12	0.87	2.83	0.65*	4.70	0.78	2.97
Knee range of motion								
Flexion	0.95	1.41	0.80	2.50	0.74	2.73	0.70	2.39
Extension	0.92	1.79	0.66*	2.51	0.84	1.51	0.69*	1.51
Hip range of motion								
Abduction	0.98	3.41	0.91	2.57	0.99	2.87	0.87	3.36
Adduction	0.91	1.47	0.90	1.30	0.94	1.22	0.88	1.47
Flexion	0.99	1.27	0.99	2.00	0.99	2.34	0.98	3.09
Extension	0.81	2.29	0.72	1.81	0.72	2.66	0.84	1.88
Internal rotation	0.88	2.52	0.93	1.78	0.86	2.51	0.93	1.89
External rotation	0.97	1.55	0.89	1.44	0.92	2.33	0.76	2.18
Shoulder range of motion								
Abduction								
Glenohumeral abduction	0.98	3.52	0.97	4.60	0.92	5.80	0.88	5.72
Shoulder complex abduction	0.92	2.21	0.98	2.25	0.93	3.18	0.95	3.71
Flexion								
Glenohumeral flexion	0.99	2.67	0.97	6.63	0.99	4.70	0.99	4.12
Shoulder complex flexion	0.97	2.18	0.96	2.35	0.98	2.11	0.97	1.70
Extension								
Glenohumeral extension	0.97	1.74	0.89	3.18	0.87	2.81	0.72	6.31
Shoulder complex extension	0.96	2.85	0.91	3.63	0.96	2.65	0.92	2.59
Internal (medial) rotation								
Glenohumeral internal rotation	0.78	5.69	0.97	3.21	0.96	2.53	0.97	3.02
Shoulder complex internal rotation	0.94	3.56	0.86	5.08	0.99	1.28	0.95	3.28
External (lateral) rotation								
Glenohumeral external rotation	0.96	3.38	0.93	3.57	0.76	7.16	0.92	3.22
Shoulder complex external rotation	0.91	3.39	0.83	5.74	0.94	3.06	0.96	2.59
Elbow range of motion								
Flexion	0.93	2.88	0.66*	5.81	0.87	3.85	0.94	1.41
Extension	0.81	3.03	0.72	2.53	0.87	2.05	0.89	1.93
Pronation	0.87	2.61	0.89	2.89	0.75	3.98	0.91	2.52
Supination	0.95	2.41	0.97	2.45	0.94	2.55	0.95	2.77
Wrist range of motion								
Flexion	0.75	3.29	0.76	2.82	0.84	3.39	0.81	4.32
Extension	0.90	3.16	0.92	2.80	0.73	3.31	0.90	2.55
Ulnar deviation	0.85	4.41	0.97	1.87	0.83	4.00	0.87	3.91
Radial deviation	0.88	3.15	0.81	2.88	0.82	2.67	0.79	3.31

*** values with ICC smaller than 0.70**

The descriptive characteristics of the groups regarding weight, height, level of physical activity (IPAQ), amount of time spent sitting per day, number of women who had gone through menopause, used hormonal replacement therapy, used a hormonal contraceptive and the length of time they used hormonal contraceptive are presented on Table 2.

The results of the one way ANOVA showed that there was no statistically significant difference in weight between age groups (p=0.384). There was a statistically significant difference in height between age groups (p=0.001). A Bonferroni post hoc test showed statistically significant difference only between the 18 to 29 and 50 to 59 age groups (p=0.001), however, there was a trend to decrease height with an increase in age.

According to the definition of Caucasian women[1], west Asian and east Indian individuals could be included in this study. One east Indian women from the 40 to 49 age group was included in this study. A T-test was used to see if there was a significant difference between her ROM values and the average of the results found for her age group. There was no statistical significant difference between the values (p=0.038) of her ROM and the mean of the population.

The demographics for occupation categorized according to the National Occupational Classification (NOC) developed by Human Resources Development Canada in 1993 is presented in Table 3.

Table 2: Descriptive statistics of sample characteristics. The percentages presented in the table are: percentage of women who had gone through menopause, percentage of women who used hormonal replacement therapy and percentage of women who used a hormonal contraceptive.

	18-29		30-39		40-49		50-59		OVERALL	
	n=30		n=20		n=20		n=20		n=90	
Demographics	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Age	23.6	2.7	32.4	2.6	45.5	2.7	54.3	2.8	37.2	12.4
Weight	62.8	10.6	68.0	16.9	66.8	12.5	68.5	11.9	66.1	12.9
Height	167.5	5.7	165.8	6.4	162.8	4.8	161.1	5.9	164.6	6.2
Level of Physical Activity	2.6	0.7	2.4	0.7	2.0	0.5	2.0	0.7	2.3	0.7
Hours per day sitting	6.8	3.0	6.5	2.9	6.3	2.3	5.9	3.1	6.8	3.0
Menopause	0		0		10% (n=2)		65% (n=13)		16.7% (n=15)	
Use of Hormonal Replacement Therapy	0		0		10% (n=2)		0		2.2% (2)	
Use of Hormonal Contraceptive	56.7% (n=17)		20% (n=4)		10% (n=2)		0		25.6% (n=23)	
Years of Use of Contraceptive	4.8	2.9	6.8	5.1	7.0	1.4	x	x	5.3	3.3

Table 3: National Occupational Classification for all the participants for each age group. (Values presented in number of people).

	Age Groups			
National Occupational Classification	**18-29**	**30-39**	**40-49**	**50-59**
0 management occupations				2
1 business, finance and administration occupations		1		
2 natural applied occupations			1	2
3 health occupations	1		1	5
4 occupations in social science, education, government service and religion	1	2	11	5
5 occupations in art, culture, recreation and sport		1		4
6 sales and service occupations	5		2	
7 trade, transport and equipment operators and related occupations				
8 occupations unique to primary industry				
9 occupations unique to processing, manufacturing and utilities				
RETIRED				1
STUDENT	23	16	5	1

4.4 RANGE OF MOTION

The primary objective of this study was to add to the data base of women's range of motion for each age group. Tables with the mean, standard deviation of the ROM for each side (right, left and overall mean between right and left) and for each age group and an overall group (all age groups combined) are presented on Table 4, 5, 6, 7, 8, 9, 10.

The results of this study did not show a significant difference in ROM between age groups for the majority of motions. The p values and confidence interval for this comparison are presented in Tables 11, 12, 13, 14 for active and Tables 15, 16, 17, 18 for passive motions. The results are presented for each motion for each side separately (right and left) and for the overall ROM (mean of right and left side).

There were some ranges of motion that were significantly different between age groups. The majority of these changes occurred between the 20's age group and the 50's age group. The results showed that, for some motions, there was a decrease in ROM with age but this change was small throughout the years and was only significant when comparing the younger group with the older group

Table 4: Mean and standard deviation (SD) for active and passive ankle ROM for each side (right and left) separately and for both sides overall.

			Age Groups									
			18-29		30-39		40-49		50-59		OVERALL	
			n=30		n=20		n=20		n=20		n=90	
Ankle ROM			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Dorsiflexion (talocrural joint)		right	11.2	6.3	16.6	10.2	13.4	7.0	16.8	8.4	14.1	8.1
	passive	left	9.3	8.7	12.6	13.3	12.8	8.1	13.9	8.0	11.8	9.7
		overall	10.3	7.6	14.6	11.9	13.1	7.5	15.3	8.2	13.0	9.0
		right	8.6	5.8	12.1	11.5	10.4	7.0	11.2	8.9	10.3	8.3
	active	left	8.5	7.0	10.6	12.9	7.5	5.7	11.2	9.5	9.3	8.9
		overall	8.6	6.4	11.3	12.1	8.9	6.5	11.2	9.1	9.8	8.6
Plantarflexion (talocrural joint)		right	51.1	21.3	57.6	16.5	62.5	6.5	60.9	8.4	57.2	15.9
	passive	left	55.5	24.9	61.4	16.8	66.9	5.5	61.5	11.2	60.6	17.7
		overall	53.3	23.1	59.5	16.6	64.7	6.4	61.2	9.8	58.9	16.9
		right	50.4	21.5	53.0	18.3	58.5	8.9	59.7	7.8	54.9	16.4
	active	left	52.5	24.9	61.4	16.2	64.2	6.9	59.6	12.3	58.6	17.9
		overall	51.5	23.1	57.2	17.6	61.3	8.4	59.6	10.2	56.7	17.2
Eversion (tarsal joint)		right	31.8	8.3	33.0	13.2	29.0	7.7	39.3	10.9	33.1	10.5
	passive	left	35.8	10.2	33.7	11.4	29.3	8.4	33.8	8.3	33.4	9.9
		overall	33.8	9.5	33.3	12.2	29.1	8.0	36.5	9.9	33.3	10.2
		right	30.8	12.3	26.5	14.3	21.4	9.7	33.2	9.4	28.2	12.3
	active	left	31.3	11.8	27.6	12.4	21.4	8.3	30.9	11.3	28.2	11.6
		overall	31.1	12.0	27.0	13.2	21.4	8.9	32.0	10.3	28.2	11.9
Inversion (tarsal joint)		right	42.6	7.1	47.4	8.3	52.3	9.9	48.9	9.2	47.2	9.1
	passive	left	43.9	7.8	46.2	8.4	51.3	8.4	45.7	9.8	46.4	8.8
		overall	43.3	7.4	46.8	8.3	51.8	9.0	47.3	9.5	46.8	9.0
		right	43.9	9.0	44.5	9.0	47.7	9.2	45.7	9.1	45.2	9.0
	active	left	41.9	10.1	42.6	8.1	48.3	11.2	44.0	10.6	43.9	10.2
		overall	42.9	9.5	43.5	8.5	48.0	10.1	44.8	9.8	44.6	9.6

Table 5: Mean and standard deviation (SD) for active and passive knee ROM for each side (right and left) separately and for both sides overall.

			Age Groups									
			18-29		30-39		40-49		50-59		OVERALL	
			n=30		n=20		n=20		n=20		n=90	
Knee ROM			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Flexion		right	149.8	7.3	150.0	7.0	148.4	4.9	147.3	4.1	149.0	6.1
	passive	left	148.2	5.3	146.9	7.0	147.5	4.9	145.7	5.6	147.2	5.7
		overall	149.0	6.4	148.4	7.1	147.9	4.9	146.5	4.9	148.1	6.0
		right	143.6	7.2	143.2	5.7	141.0	5.5	139.9	4.9	142.1	6.1
	active	left	141.3	6.4	141.1	5.9	140.8	5.2	136.6	5.8	140.1	6.1
		overall	142.4	6.9	142.1	5.8	140.9	5.3	138.2	5.5	141.1	6.2
Extension		right	0.8	10.0	1.0	17.2	5.8	4.2	4.3	4.9	2.7	10.4
	passive	left	2.5	4.0	2.5	17.1	6.7	3.8	5.4	6.2	4.1	9.1
		overall	1.6	7.6	1.8	16.9	6.2	4.0	4.9	5.5	3.4	9.8
		right	4.7	4.9	2.3	17.7	7.1	4.2	6.2	5.5	5.0	9.4
	active	left	4.0	5.2	4.3	18.4	7.6	4.3	7.6	6.1	5.6	9.8
		overall	4.3	5.0	3.3	17.8	7.3	4.2	6.8	5.8	5.3	9.6

Table 6: Mean and standard deviation (SD) for active and passive hip ROM for each side (right and left) separately and for both sides overall.

			Age Groups									
			18-29		30-39		40-49		50-59		OVERALL	
			n=30		n=20		n=20		n=20		n=90	
Hip ROM			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Abduction		right	60.7	8.4	62.1	6.1	62.8	6.0	66.6	7.1	62.8	7.4
	passive	left	60.0	8.8	61.2	5.4	60.6	6.5	63.8	6.4	61.2	7.2
		overall	60.3	8.5	61.6	5.7	61.7	6.3	65.2	6.8	62.0	7.3
		right	61.7	9.5	64.8	5.4	64.6	7.5	65.4	7.9	63.8	8.0
	active	left	59.3	10.6	61.3	4.8	61.5	8.2	64.6	6.0	61.4	8.2
		overall	60.5	10.1	63.0	5.4	63.0	8.0	65.0	6.9	62.6	8.2
Adduction		right	15.0	11.0	15.3	4.5	14.3	4.2	12.9	3.9	14.4	7.2
	passive	left	15.5	12.1	14.8	7.2	12.7	3.8	12.7	5.1	14.1	8.3
		overall	15.3	11.5	15.1	6.0	13.5	4.0	12.8	4.5	14.3	7.8
		right	17.4	10.4	14.2	5.6	15.3	6.2	14.8	3.5	15.6	7.4
	active	left	16.3	12.0	12.5	4.3	12.1	5.7	12.4	6.1	13.6	8.3
		overall	16.9	11.1	13.4	5.0	13.7	6.1	13.6	5.1	14.6	7.9
Flexion		right	131.2	9.8	132.5	8.6	130.4	6.8	123.3	6.6	129.5	8.8
	passive	left	134.6	11.2	129.3	10.8	129.4	7.0	125.0	5.7	130.1	9.8
		overall	132.9	10.6	130.9	9.8	129.9	6.8	124.1	6.1	129.8	9.3
		right	123.3	16.7	118.3	12.0	116.5	6.6	113.1	6.5	118.4	12.4
	active	left	122.5	16.9	110.9	7.6	113.4	5.1	110.8	7.8	115.3	12.3
		overall	122.9	16.7	114.6	10.6	114.9	6.0	111.9	7.1	116.8	12.4
Extension		right	13.2	5.5	13.1	4.0	12.2	4.8	12.7	4.1	12.8	4.7
	passive	left	14.9	3.9	14.3	3.5	13.3	5.8	13.1	4.2	14.0	4.4
		overall	14.1	4.8	13.7	3.8	12.8	5.3	12.9	4.1	13.4	4.6
		right	13.1	5.6	11.9	4.6	10.9	4.8	11.3	5.8	11.9	5.2
	active	left	13.7	5.3	13.8	5.9	11.1	5.9	12.3	4.4	12.8	5.4
		overall	13.4	5.4	12.8	5.3	11.0	5.3	11.8	5.1	12.4	5.3
Internal rotation		right	44.1	7.1	43.2	7.6	42.0	6.6	41.2	6.5	42.8	6.9
	passive	left	41.5	7.3	39.2	5.9	41.4	7.2	40.5	6.9	40.7	6.8
		overall	42.8	7.2	41.2	7.0	41.7	6.8	40.8	6.6	41.7	6.9
		right	36.2	8.6	36.2	7.5	34.6	5.9	36.6	7.9	35.9	7.6
	active	left	32.4	7.2	33.8	4.5	33.4	6.3	33.3	9.1	33.1	6.9
		overall	34.3	8.1	35.0	6.2	34.0	6.0	34.9	8.6	34.5	7.4
External rotation		right	37.6	8.4	36.1	6.9	33.8	6.9	30.9	4.8	34.9	7.4
	passive	left	38.2	5.8	35.7	6.1	32.0	7.1	33.8	5.9	35.3	6.6
		overall	37.9	7.2	35.9	6.4	32.9	7.0	32.3	5.5	35.1	7.0
		right	25.4	7.6	21.8	6.3	22.0	6.4	21.5	6.7	23.0	7.0
	active	left	28.7	6.5	26.2	7.3	25.3	6.5	25.4	4.7	26.6	6.4
		overall	27.0	7.2	24.0	7.1	23.6	6.6	23.4	6.0	24.8	6.9

Table 7: Mean and standard deviation (SD) for active and passive shoulder ROM (abduction, flexion and extension) for each side (right and left) separately and for both sides overall .

			Age Groups									
			18-29		30-39		40-49		50-59		OVERALL	
			n=30		n=20		n=20		n=20		n=90	
Shoulder ROM			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Abduction												
Glenohumeral abduction		right	92.0	17.0	81.5	17.7	80.4	8.7	85.0	25.7	85.5	18.5
	passive	left	89.3	16.2	79.6	18.3	80.7	8.9	85.2	29.5	84.3	19.4
		overall	90.7	16.5	80.6	17.8	80.6	8.7	85.1	27.3	84.9	18.9
		right	87.5	17.1	79.3	18.4	79.6	14.0	83.9	26.3	83.1	19.2
	active	left	83.8	18.4	77.7	22.0	74.7	12.1	78.9	27.7	79.3	20.5
		overall	85.7	17.7	78.5	20.0	77.1	13.2	81.4	26.8	81.2	19.9
Shoulder complex abduction		right	188.0	8.2	187.2	4.2	188.0	4.8	182.0	27.5	186.5	14.1
	passive	left	191.8	11.1	193.0	3.1	190.2	6.1	184.1	25.6	190.0	14.2
		overall	189.9	9.9	190.1	4.7	189.1	5.5	183.1	26.2	188.2	14.2
		right	189.4	6.6	188.3	5.1	187.2	4.5	182.5	26.1	187.1	13.3
	active	left	189.2	11.6	187.5	24.7	189.6	6.4	183.8	26.4	187.7	18.3
		overall	189.3	9.4	187.9	17.6	188.4	5.6	183.1	25.9	187.4	16.0
Flexion												
Glenohumeral flexion		right	48.6	13.9	36.4	13.3	41.6	13.4	36.9	14.1	41.7	14.5
	passive	left	45.2	14.0	40.2	15.2	37.1	10.7	40.9	16.8	41.3	14.4
		overall	46.9	14.0	38.3	14.3	39.3	12.2	38.9	15.4	41.5	14.4
		right	39.1	16.0	37.5	15.3	34.7	14.4	36.8	13.3	37.3	14.8
	active	left	41.7	19.1	38.1	14.2	34.4	11.1	38.6	18.1	38.6	16.3
		overall	40.4	17.5	37.8	14.6	34.5	12.7	37.7	15.7	37.9	15.6
Shoulder complex flexion		righ	190.7	12.0	187.6	11.3	186.1	9.7	189.6	7.2	188.7	10.4
	passive	left	193.5	10.5	189.9	9.8	184.7	10.2	187.6	7.9	189.4	10.2
		overall	192.1	11.3	188.7	10.5	185.4	9.8	188.6	7.5	189.1	10.3
		right	187.2	11.5	183.9	8.5	181.5	8.5	185.2	8.4	184.7	9.7
	active	left	186.7	10.5	184.2	8.9	181.0	9.4	183.7	7.9	184.2	9.5
		overall	186.9	10.9	184.1	8.6	181.3	8.9	184.4	8.1	184.5	9.5
Extension												
Glenohumeral extension		right	26.7	9.0	24.4	7.3	25.2	5.9	22.6	6.4	24.9	7.5
	passive	left	29.7	10.5	28.7	6.7	27.0	10.9	27.4	8.5	28.4	9.4
		overall	28.2	9.8	26.6	7.2	26.1	8.7	25.0	7.8	26.6	8.6
		right	24.6	8.8	23.2	5.1	21.0	6.9	21.8	5.8	22.8	7.1
	active	left	27.2	8.8	26.9	7.8	24.2	9.1	24.5	8.5	25.9	8.6
		overall	25.9	8.8	25.0	6.8	22.6	8.2	23.2	7.3	24.3	8.0
Shoulder complex extension		right	72.8	9.9	65.8	11.6	67.4	13.9	64.9	12.7	68.3	12.1
	passive	left	73.5	13.4	70.1	11.1	70.3	12.7	68.4	11.4	70.9	12.3
		overall	73.2	11.7	67.9	11.4	68.9	13.2	66.6	12.0	69.6	12.3
		right	57.1	12.8	51.6	11.4	54.3	11.2	50.1	15.0	53.7	12.8
	active	left	60.3	11.9	54.5	14.0	57.7	11.1	52.8	12.3	56.7	12.5
		overall	58.7	12.4	53.0	12.7	56.0	11.1	51.4	13.6	55.2	12.7

Table 8: Mean and standard deviation (SD) for active and passive shoulder ROM (internal rotation and external rotation) for each side (right and left) separately and for both sides overall.

			Age Groups									
			18-29		30-39		40-49		50-59		OVERALL	
			n=30		n=20		n=20		n=20		n=90	
Shoulder ROM			**MEAN**	**SD**	**MEAN**	**SD**	**MEAN**	**SD**	**MEAN**	**SD**	**MEAN**	**SD**
Internal rotation												
Glenohumeral internal rotation	passive	right	61.2	16.6	58.6	10.9	56.9	11.0	63.1	11.9	60.1	13.3
		left	70.4	17.0	62.7	10.1	65.9	10.3	69.5	15.2	67.5	14.0
		overall	65.8	17.3	60.6	10.6	61.4	11.5	66.3	13.9	63.8	14.1
	active	right	57.4	17.1	58.9	11.5	57.4	11.9	60.3	8.9	58.4	13.1
		left	64.0	16.3	62.5	9.8	64.8	10.5	66.2	12.9	64.3	13.0
		overall	60.7	16.9	60.7	10.7	61.1	11.7	63.2	11.4	61.4	13.3
Shoulder complex internal rotation	passive	right	89.4	16.0	90.7	12.1	91.4	16.4	92.9	11.3	90.9	14.2
		left	95.1	16.5	96.3	12.5	99.7	11.5	101.4	12.7	97.8	13.8
		overall	92.2	16.3	93.5	12.5	95.6	14.6	97.2	12.6	94.3	14.4
	active	right	88.7	15.3	86.1	11.5	85.4	14.7	90.7	10.1	87.8	13.3
		left	92.0	15.1	91.4	10.6	94.1	13.4	97.8	12.4	93.6	13.3
		overall	90.4	15.1	88.8	11.2	89.7	14.6	94.2	11.7	90.7	13.5
External rotation												
Glenohumeral external rotation	passive	right	103.6	10.2	92.2	12.5	94.4	14.0	87.4	10.1	95.4	13.0
		left	97.0	11.5	92.2	9.0	90.0	11.0	85.8	7.6	91.9	10.8
		overall	100.3	11.3	92.2	10.7	92.2	12.6	86.6	8.9	93.6	12.1
	active	right	98.4	12.4	88.8	13.2	91.6	13.9	85.6	8.5	91.9	13.0
		left	92.1	11.7	85.3	8.0	83.5	12.4	80.1	9.6	86.0	11.5
		overall	95.2	12.4	87.0	10.9	87.5	13.6	82.8	9.3	88.9	12.6
Shoulder complex external rotation	passive	right	113.5	8.5	109.8	11.5	111.0	14.9	103.1	9.6	109.8	11.6
		left	108.2	10.8	108.8	9.4	107.3	13.5	100.8	9.8	106.5	11.2
		overall	110.8	10.0	109.3	10.4	109.1	14.2	102.0	9.6	108.1	11.5
	active	right	106.5	8.9	104.5	10.2	101.9	12.5	96.8	9.5	102.9	10.7
		left	97.6	11.3	100.6	7.8	95.1	13.0	89.8	10.2	95.9	11.3
		overall	102.1	11.0	102.5	9.2	98.5	13.1	93.3	10.4	99.4	11.5

Table 9: Mean and standard deviation (SD) for active and passive elbow ROM for each side (right and left) separately and for both sides overall.

Elbow ROM			Age Groups 18-29 n=30 MEAN	SD	30-39 n=20 MEAN	SD	40-49 n=20 MEAN	SD	50-59 n=20 MEAN	SD	OVERALL n=90 MEAN	SD
Flexion		right	147.1	8.0	148.0	9.2	148.8	5.3	149.4	4.5	148.2	7.1
	passive	left	150.3	6.6	151.3	3.5	150.2	4.9	147.1	16.0	149.8	8.9
		overall	148.7	7.5	149.6	7.1	149.5	5.1	148.3	11.7	149.0	8.1
		right	145.3	7.9	146.9	6.5	146.2	5.2	145.7	4.6	145.9	6.3
	active	left	147.9	6.5	148.0	6.2	147.0	5.0	147.0	7.2	147.5	6.2
		overall	146.6	7.3	147.4	6.3	146.6	5.1	146.3	6.0	146.7	6.3
Extension		right	2.6	4.5	1.8	4.5	0.7	4.9	-0.2	5.8	1.4	4.9
	passive	left	2.9	6.1	3.5	5.9	1.6	3.7	-1.1	4.8	1.9	5.5
		overall	2.8	5.3	2.7	5.3	1.1	4.3	-0.7	5.3	1.6	5.2
		right	4.5	5.5	3.9	3.1	1.8	3.0	0.4	4.5	2.9	4.6
	active	left	4.9	5.4	3.7	4.9	3.3	3.8	0.9	4.8	3.4	5.0
		overall	4.7	5.4	3.8	4.0	2.6	3.4	0.7	4.6	3.1	4.8
Pronation		right	92.9	4.8	89.9	8.9	92.9	7.7	92.5	5.6	92.1	6.7
	passive	left	92.7	6.8	92.0	8.3	90.6	7.4	91.3	5.8	91.8	7.0
		overall	92.8	5.8	90.9	8.6	91.7	7.5	91.9	5.6	91.9	6.9
		right	90.9	6.9	88.9	10.7	91.1	8.7	91.2	7.2	90.6	8.2
	active	left	92.9	7.8	90.5	6.9	87.6	8.0	91.8	8.3	90.9	7.9
		overall	91.9	7.4	89.7	8.9	89.3	8.4	91.5	7.7	90.8	8.1
Supination		right	95.5	11.3	97.1	9.8	93.8	11.4	90.6	8.7	94.4	10.6
	passive	left	97.4	11.3	99.6	8.5	99.0	10.5	95.7	8.2	97.9	9.8
		overall	96.5	11.2	98.3	9.2	96.4	11.1	93.1	8.7	96.1	10.3
		right	94.9	11.9	95.0	9.4	91.2	9.9	87.9	8.8	92.5	10.5
	active	left	96.7	13.1	97.3	9.0	95.7	8.5	90.7	9.1	95.3	10.6
		overall	95.8	12.5	96.2	9.2	93.4	9.4	89.3	8.9	93.9	10.6

Table 10: Mean and standard deviation (SD) for active and passive wrist ROM for each side (right and left) separately and for both sides overall.

			Age Groups									
			18-29		30-39		40-49		50-59		OVERALL	
			n=30		n=20		n=20		n=20		n=90	
Wrist ROM			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Flexion		right	92.3	8.7	94.2	8.3	90.8	9.7	92.7	5.8	92.4	8.2
	passive	left	93.5	7.4	93.8	9.3	91.7	7.4	92.1	6.1	92.8	7.5
		overall	92.9	8.0	94.0	8.7	91.2	8.5	92.4	5.9	92.6	7.8
		right	86.4	7.3	87.6	8.3	85.6	10.1	88.7	8.0	87.0	8.3
	active	left	85.7	8.0	87.0	9.6	83.0	7.8	83.7	7.2	84.9	8.2
		overall	86.0	7.6	87.3	8.9	84.3	9.0	86.2	7.9	86.0	8.3
Extension		right	86.0	5.9	84.0	8.9	84.2	7.5	80.8	7.7	84.0	7.5
	passive	left	87.9	7.4	86.0	7.9	89.5	7.0	87.7	8.4	87.8	7.6
		overall	87.0	6.7	85.0	8.4	86.8	7.6	84.2	8.7	85.9	7.8
		right	74.8	9.1	71.5	7.6	75.5	12.8	66.8	15.0	72.4	11.5
	active	left	79.1	9.1	74.1	9.4	75.9	10.8	72.2	13.8	75.7	10.9
		overall	76.9	9.3	72.8	8.5	75.7	11.7	69.5	14.5	74.1	11.3
Ulnar deviation		right	38.4	8.1	41.8	7.1	41.5	6.2	39.3	9.6	40.0	7.9
	passive	left	40.8	9.0	41.8	7.9	42.0	6.5	42.0	7.7	41.5	7.9
		overall	39.6	8.6	41.8	7.4	41.7	6.3	40.6	8.7	40.8	7.9
		right	39.6	7.8	42.4	5.7	42.4	6.4	39.4	8.7	40.8	7.3
	active	left	43.1	7.2	43.8	8.7	43.4	6.9	42.3	8.3	43.1	7.6
		overall	41.3	7.7	43.1	7.3	42.9	6.6	40.8	8.5	41.9	7.6
Radial deviation		right	16.0	6.1	15.7	5.5	12.6	5.2	15.9	7.5	15.2	6.2
	passive	left	21.1	5.2	20.1	6.3	20.2	5.3	21.0	8.7	20.6	6.3
		overall	18.5	6.2	17.9	6.2	16.4	6.5	18.5	8.4	17.9	6.8
		right	18.2	5.4	16.8	5.6	14.6	6.9	17.6	8.8	16.9	6.7
	active	left	25.5	11.4	22.2	6.0	19.8	6.8	22.8	8.3	22.9	8.9
		overall	21.9	9.6	19.5	6.4	17.2	7.3	20.2	8.9	19.9	8.4

Table 11: Difference between the amounts of ankle and knee active range of motion for each age group (p-value and 99% confidence interval).

MOTIONS	AGE GROUPS					
	(18-29) x (30-49)	(18-29) x (40-49)	(18-29) x (50-59)	(30-39) x (40-49)	(30-39) x (50-59)	(40-49) x (50-59)
	p-value (99% confidence interval)					
ANKLE						
Dorsiflexion						
Overall	1.000(-20.56, 10.06)	1.000(-19.10, 12.84)	1.000(-21.04, 11.44)	1.000(-13.85, 18.09)	1.000(-15.79, 16.69)	1.000(-18.53, 15.19)
Right	1.000(-21.58, 8.68)	1.000(-21.02, 10.55)	1.000(-21.21, 10.89)	1.000(-14.57, 17.00)	1.000(-14.76, 17.34)	1.000(-16.60, 16.74)
Left	1.000(-20.09, 11.99)	1.000(-17.76, 15.70)	1.000(-21.45, 12.57)	1.000(-13.71, 19.75)	1.000(-17.40, 16.62)	1.000(-21.07, 14.26)
Plantarflexion						
Overall	1.000(-20.85, 9.39)	0.223(-24.98, 5.26)	0.500(-23.28, 6.96)	1.000(-20.69, 12.44)	1.000(-18.99, 14.14)	1.000(-14.86, 18.26)
Right	1.000(-17.71, 12.57)	0.524(-23.21, 7.07)	0.301(-24.41, 5.87)	1.000(-22.08, 11.08)	1.000(-23.28, 9.88)	1.000(-17.78, 15.38)
Left	0.505(-25.43, 7.63)	0.148(-28.18, 4.88)	1.000(-23.58, 9.48)	1.000(-20.86, 15.36)	1.000(-16.26, 19.96)	1.000(-13.51, 22.71)
Inversion						
Overall	1.000(-8.73, 7.48)	0.277(-13.15, 3.05)	1.000(-10.00, 6.20)	0.655(-13.30, 4.45)	1.000(-10.15, 7.60)	1.000(-5.73, 12.03)
Right	1.000(-9.13, 7.86)	0.911(-12.28, 4.71)	1.000(-10.28, 6.71)	1.000(-12.45, 6.15)	1.000(-10.45, 8.15)	1.000(-7.30, 11.30)
Left	1.000(-10.04, 8.81)	0.194(-15.74, 3.11)	1.000(-11.44, 7.41)	0.459(-16.02, 4.62)	1.000(-11.72, 8.92)	1.000(-6.02, 14.62)
Eversion						
Overall	1.000(-5.56, 13.61)	* 0.009(.11, 19.29)	1.000(-10.54, 8.64)	0.498(-4.83, 16.18)	0.766(-15.48, 5.53)	* 0.009(-21.15, -.15)
Right	1.000(-6.62, 15.26)	0.038(-1.52, 20.36)	1.000(-13.32, 8.56)	1.000(-6.88, 17.08)	0.438(-18.68, 5.28)	0.012(-23.78, .18)
Left	1.000(-6.72, 14.18)	0.016(-.47, 20.43)	1.000(-9.97, 10.93)	0.479(-5.20, 17.70)	1.000(-14.70, 8.20)	0.051(-20.95, 1.95)
KNEE						
Flexion						
Overall	1.000(-5.54, 4.90)	1.000(-6.76, 3.68)	0.065(-9.41, 1.03)	1.000(-6.94, 4.49)	0.183(-9.59, 1.84)	0.816(-8.37, 3.07)
Right	1.000(-6.09, 5.25)	0.826(-8.29, 3.05)	0.217(-9.39, 1.95)	1.000(-8.41, 4.01)	0.529(-9.51, 2.91)	1.000(-7.31, 5.11)
Left	1.000(-5.76, 5.33)	1.000(-6.01, 5.08)	0.046(-10.21, .88)	1.000(-6.32, 5.82)	0.118(-10.52, 1.62)	0.164(-10.27, 1.87)
Extension						
Overall	1.000(-7.80, 9.85)	1.000(-11.80, 5.85)	1.000(-11.32, 6.32)	1.000(-13.67, 5.67)	1.000(-13.19, 6.14)	1.000(-9.19, 10.14)
Right	1.000(-6.40, 11.16)	1.000(-11.15, 6.41)	1.000(-10.20, 7.36)	0.675(-14.37, 4.87)	1.000(-13.42, 5.82)	1.000(-8.67, 10.57)
Left	1.000(-9.54, 8.87)	1.000(-12.79, 5.62)	1.000(-12.79, 5.62)	1.000(-13.33, 6.83)	1.000(-13.33, 6.83)	1.000(-10.08, 10.08)

*** statistically significant difference (p<0.01)**

Table 12: Difference between the amounts of hip active range of motion for each age group (p-value and 99% confidence interval).

MOTIONS	AGE GROUPS					
	(18-29) x (30-49)	(18-29) x (40-49)	(18-29) x (50-59)	(30-39) x (40-49)	(30-39) x (50-59)	(40-49) x (50-59)
	p-value (99% confidence interval)					
HIP						
Abduction						
Overall	1.000(-4.24, 9.26)	1.000(-4.24, 9.26)	0.203(-2.26, 11.23)	1.000(-7.39, 7.39)	1.000(-5.42, 9.37)	1.000(-5.42, 9.37)
Right	1.000(-4.40, 10.50)	1.000(-4.55, 10.35)	0.663(-3.75, 11.15)	1.000(-8.31, 8.01)	1.000(-7.51, 8.81)	1.000(-7.36, 8.96)
Left	1.000(-5.66, 9.59)	1.000(-5.51, 9.74)	0.165(-2.36, 12.89)	1.000(-8.20, 8.50)	1.000(-5.05, 11.65)	1.000(-5.20, 11.50)
Adduction						
Overall	0.600(-10.38, 3.35)	0.810(-10.06, 3.68)	0.740(-10.16, 3.58)	1.000(-7.20, 7.85)	1.000(-7.30, 7.75)	1.000(-7.62, 7.42)
Right	0.806(-10.18, 3.71)	1.000(-9.13, 4.76)	1.000(-9.58, 4.31)	1.000(-6.56, 8.66)	1.000(-7.01, 8.21)	1.000(-8.06, 7.16)
Left	0.678(-11.51, 3.91)	0.482(-11.91, 3.51)	0.598(-11.66, 3.76)	1.000(-8.84, 8.04)	1.000(-8.59, 8.29)	1.000(-8.19, 8.69)
Flexion						
Overall	0.068(-18.68, 2.11)	0.089(-18.35, 2.44)	* 0.006(-21.38, -.59)	1.000(-11.06, 11.71)	1.000(-14.09, 8.69)	1.000(-14.41, 8.36)
Right	0.918(-16.26, 6.26)	0.319(-18.06, 4.46)	0.024(-21.51, 1.01)	1.000(-14.13, 10.53)	1.000(-17.58, 7.08)	1.000(-15.78, 8.88)
Left	* 0.004(-22.20, -.93)	0.040(-19.75, 1.52)	* 0.003(-22.35, -1.08)	1.000(-9.20, 14.10)	1.000(-11.80, 11.50)	1.000(-14.25, 9.05)
Extension						
Overall	1.000(-3.61, 4.72)	0.400(-1.78, 6.55)	1.000(-2.53, 5.80)	1.000(-2.74, 6.39)	1.000(-3.49, 5.64)	1.000(-5.31, 3.81)
Right	1.000(-3.77, 6.10)	0.945(-2.77, 7.10)	1.000(-3.12, 6.75)	1.000(-4.40, 6.40)	1.000(-4.75, 6.05)	1.000(-5.75, 5.05)
Left	1.000(-5.11, 5.01)	0.593(-2.46, 7.66)	1.000(-3.61, 6.51)	0.745(-2.89, 8.19)	1.000(-4.04, 7.04)	1.000(-6.69, 4.39)
Internal Rotation						
Overall	1.000(-6.71, 5.36)	1.000(-5.73, 6.33)	1.000(-6.63, 5.43)	1.000(-5.63, 7.58)	1.000(-6.53, 6.68)	1.000(-7.51, 5.71)
Right	1.000(-7.21, 7.14)	1.000(-5.61, 8.74)	1.000(-7.56, 6.79)	1.000(-6.26, 9.46)	1.000(-8.21, 7.51)	1.000(-9.81, 5.91)
Left	1.000(-7.87, 5.24)	1.000(-7.52, 5.59)	1.000(-7.37, 5.74)	1.000(-6.83, 7.53)	1.000(-6.68, 7.68)	1.000(-7.03, 7.33)
External Rotation						
Overall	0.401(-2.27, 8.34)	0.240(-1.90, 8.71)	0.173(-1.67, 8.94)	1.000(-5.44, 6.19)	1.000(-5.21, 6.41)	1.000(-5.59, 6.04)
Right	0.440(-2.85, 10.05)	0.543(-3.05, 9.85)	0.299(-2.50, 10.40)	1.000(-7.26, 6.86)	1.000(-6.71, 7.41)	1.000(-6.51, 7.61)
Left	1.000(-3.48, 8.41)	0.393(-2.53, 9.36)	0.442(-2.63, 9.26)	1.000(-5.56, 7.46)	1.000(-5.66, 7.36)	1.000(-6.61, 6.41)

*** statistically significant difference (p<0.01)**

Table 13: Difference between the amounts of shoulder active range of motion for each age group (p-value and 99% confidence interval).

MOTIONS	AGE GROUPS					
	(18-29) x (30-49)	(18-29) x (40-49)	(18-29) x (50-59)	(30-39) x (40-49)	(30-39) x (50-59)	(40-49) x (50-59)
	p-value (99% confidence interval)					
SHOULDER						
Glenohumeral Abduction						
Overall	1.000(-10.22, 24.57)	0.692(-8.87, 25.92)	1.000(-13.12, 21.67)	1.000(-17.71, 20.41)	1.000(-21.96, 16.16)	1.000(-23.31, 14.81)
Right	0.867(-9.84, 26.17)	0.958(-10.14, 25.87)	1.000(-14.39, 21.62)	1.000(-20.03, 19.43)	1.000(-24.28, 15.18)	1.000(-23.98, 15.48)
Left	1.000(-13.09, 25.45)	0.753(-10.09, 28.45)	1.000(-14.34, 24.20)	1.000(-18.11, 24.11)	1.000(-22.36, 19.86)	1.000(-25.36, 16.86)
Shoulder Complex Abduction						
Overall	1.000(-12.52, 15.42)	1.000(-13.05, 14.90)	0.930(-7.80, 20.15)	1.000(-15.83, 14.78)	1.000(-10.58, 20.03)	1.000(-10.06, 20.56)
Right	1.000(-11.30, 13.54)	1.000(-10.25, 14.59)	0.445(-5.50, 19.34)	1.000(-12.56, 14.66)	1.000(-7.81, 19.41)	1.000(-8.86, 18.36)
Left	1.000(-15.57, 19.14)	1.000(-17.67, 17.04)	1.000(-11.92, 22.79)	1.000(-21.11, 16.91)	1.000(-15.36, 22.66)	1.000(-13.26, 24.76)
Glenohumeral Flexion						
Overall	1.000(-10.04, 15.24)	0.810(-6.77, 18.52)	1.000(-9.94, 15.34)	1.000(-10.57, 17.12)	1.000(-13.75, 13.95)	1.000(-17.02, 10.67)
Right	1.000(-12.36, 15.63)	1.000(-9.51, 18.48)	1.000(-11.66, 16.33)	1.000(-12.48, 18.18)	1.000(-14.63, 16.03)	1.000(-17.48, 13.18)
Left	1.000(-11.73, 18.86)	0.760(-8.03, 22.56)	1.000(-12.23, 18.36)	1.000(-13.06, 20.46)	1.000(-17.26, 16.26)	1.000(-20.96, 12.56)
Shoulder Complex Flexion						
Overall	1.000(-5.49, 11.23)	0.183(-2.69, 14.03)	1.000(-5.87, 10.85)	1.000(-6.36, 11.96)	1.000(-9.53, 8.78)	1.000(-12.33, 5.98)
Right	1.000(-5.72, 12.25)	0.262(-3.32, 14.65)	1.000(-7.02, 10.95)	1.000(-7.44, 12.24)	1.000(-11.14, 8.54)	1.000(-13.54, 6.14)
Left	1.000(-6.32, 11.25)	0.235(-3.12, 14.45)	1.000(-5.77, 11.80)	1.000(-6.42, 12.82)	1.000(-9.07, 10.17)	1.000(-12.27, 6.97)
Glenohumeral Extension						
Overall	1.000(-5.61, 7.30)	0.583(-3.12, 9.79)	1.000(-3.72, 9.19)	1.000(-4.58, 9.56)	1.000(-5.18, 8.96)	1.000(-7.67, 6.47)
Right	1.000(-5.25, 8.03)	0.484(-3.03, 10.26)	1.000(-3.88, 9.41)	1.000(-5.05, 9.50)	1.000(-5.90, 8.65)	1.000(-8.13, 6.43)
Left	1.000(-7.75, 8.35)	1.000(-5.00, 11.10)	1.000(-5.35, 10.75)	1.000(-6.06, 11.56)	1.000(-6.41, 11.21)	1.000(-9.16, 8.46)
Shoulder Complex Extension						
Overall	0.471(-4.67, 16.02)	1.000(-7.59, 13.09)	0.146(-3.04, 17.64)	1.000(-14.26, 8.41)	1.000(-9.71, 12.96)	1.000(-6.78, 15.88)
Right	0.820(-6.39, 17.39)	1.000(-9.04, 14.74)	0.345(-4.84, 18.94)	1.000(-15.67, 10.37)	1.000(-11.47, 14.57)	1.000(-8.82, 17.22)
Left	0.623(-5.70, 17.40)	1.000(-8.90, 14.20)	0.220(-4.00, 19.10)	1.000(-15.85, 9.45)	1.000(-10.95, 14.35)	1.000(-7.75, 17.55)
Glenohumeral Internal Rotation						
Overall	1.000(-10.94, 11.03)	1.000(-11.35, 10.62)	1.000(-13.48, 8.50)	1.000(-12.45, 11.62)	1.000(-14.57, 9.50)	1.000(-14.16, 9.91)
Right	1.000(-13.91, 11.03)	1.000(-12.44, 12.50)	1.000(-15.29, 9.65)	1.000(-12.19, 15.14)	1.000(-15.04, 12.29)	1.000(-16.51, 10.81)
Left	1.000(-10.76, 13.82)	1.000(-13.06, 11.52)	1.000(-14.46, 10.12)	1.000(-15.76, 11.16)	1.000(-17.16, 9.76)	1.000(-14.86, 12.06)
Shoulder Complex Internal Rotation						
Overall	1.000(-9.60, 12.80)	1.000(-10.57, 11.82)	1.000(-15.07, 7.32)	1.000(-13.24, 11.29)	0.906(-17.74, 6.79)	1.000(-16.77, 7.77)
Right	1.000(-9.89, 15.09)	1.000(-9.19, 15.79)	1.000(-14.44, 10.54)	1.000(-12.98, 14.38)	1.000(-18.23, 9.13)	1.000(-18.93, 8.43)
Left	1.000(-11.82, 13.02)	1.000(-14.47, 10.37)	0.799(-18.22, 6.62)	1.000(-16.25, 10.95)	0.782(-20.00, 7.20)	1.000(-17.35, 9.85)
Glenohumeral External Rotation						
Overall	0.028(-.95, 17.34)	0.046(-1.45, 16.84)	* 0.000(3.25, 21.54)	1.000(-10.52, 9.52)	1.000(-5.82, 14.22)	0.789(-5.32, 14.72)
Right	0.047(-1.85, 20.99)	0.336(-4.60, 18.24)	* 0.003(1.40, 24.24)	1.000(-15.26, 9.76)	1.000(-9.26, 15.76)	0.739(-6.51, 18.51)
Left	0.182(-3.24, 16.87)	0.042(-1.49, 18.62)	* 0.001(1.91, 22.02)	1.000(-9.26, 12.76)	0.796(-5.86, 16.16)	1.000(-7.61, 14.41)
Shoulder Complex External Rotation						
Overall	1.000(-9.22, 8.27)	1.000(-5.17, 12.32)	* 0.009(.06, 17.54)	1.000(-5.53, 13.63)	0.014(-.30, 18.85)	0.480(-4.35, 14.80)
Right	1.000(-7.49, 11.66)	0.719(-4.94, 14.21)	* 0.008(.21, 19.36)	1.000(-7.94, 13.04)	0.116(-2.79, 18.19)	0.687(-5.34, 15.64)
Left	1.000(-13.15, 7.08)	1.000(-7.60, 12.63)	0.084(-2.30, 17.93)	0.645(-5.53, 16.63)	0.012(-.23, 21.93)	0.744(-5.78, 16.38)

*** statistically significant difference (p<0.01)**

Table 14: Difference between the amounts of elbow and wrist active range of motion for each age group (p-value and 99% confidence interval).

MOTIONS	AGE GROUPS					
	(18-29) x (30-49)	(18-29) x (40-49)	(18-29) x (50-59)	(30-39) x (40-49)	(30-39) x (50-59)	(40-49) x (50-59)
	p-value (99% confidence interval)					
ELBOW						
Flexion						
Overall	1.000(-4.52, 6.12)	1.000(-5.34, 5.29)	1.000(-5.59, 5.04)	1.000(-6.65, 5.00)	1.000(-6.90, 4.75)	1.000(-6.07, 5.57)
Right	1.000(-4.42, 7.58)	1.000(-5.12, 6.88)	1.000(-5.62, 6.38)	1.000(-7.27, 5.87)	1.000(-7.77, 5.37)	1.000(-7.07, 6.07)
Left	1.000(-5.91, 5.94)	1.000(-6.86, 4.99)	1.000(-6.86, 4.99)	1.000(-7.44, 5.54)	1.000(-7.44, 5.54)	1.000(-6.49, 6.49)
Extension						
Overall	1.000(-2.90, 4.70)	0.456(-1.70, 5.90)	* 0.006(.20, 7.80)	1.000(-2.96, 5.36)	0.106(-1.06, 7.26)	0.849(-2.26, 6.06)
Right	1.000(-3.42, 4.69)	0.207(-1.37, 6.74)	* 0.009(.03, 8.14)	0.827(-2.39, 6.49)	0.081(-.99, 7.89)	1.000(-3.04, 5.84)
Left	1.000(-3.35, 5.69)	1.000(-3.00, 6.04)	0.037(-.60, 8.44)	1.000(-4.60, 5.30)	0.450(-2.20, 7.70)	0.716(-2.55, 7.35)
Pronation						
Overall	1.000(-4.50, 8.93)	1.000(-4.12, 9.31)	1.000(-6.27, 7.16)	1.000(-6.98, 7.73)	1.000(-9.13, 5.58)	1.000(-9.51, 5.21)
Right	1.000(-5.80, 9.80)	1.000(-7.95, 7.65)	1.000(-8.10, 7.50)	1.000(-10.69, 6.39)	1.000(-10.84, 6.24)	1.000(-8.69, 8.39)
Left	1.000(-4.88, 9.75)	0.121(-1.98, 12.65)	1.000(-6.13, 8.50)	1.000(-5.11, 10.91)	1.000(-9.26, 6.76)	0.578(-12.16, 3.86)
Supination						
Overall	1.000(-9.23, 8.49)	1.000(-6.50, 11.22)	0.116(-2.35, 15.37)	1.000(-6.98, 12.43)	0.143(-2.83, 16.58)	1.000(-5.56, 13.86)
Right	1.000(-9.80, 9.53)	1.000(-5.95, 13.38)	0.130(-2.70, 16.63)	1.000(-6.74, 14.44)	0.193(-3.49, 17.69)	1.000(-7.34, 13.84)
Left	1.000(-10.42, 9.22)	1.000(-8.82, 10.82)	0.292(-3.77, 15.87)	1.000(-9.15, 12.35)	0.287(-4.10, 17.40)	0.786(-5.70, 15.80)
WRIST						
Flexion						
Overall	1.000(-7.92, 5.49)	1.000(-4.95, 8.47)	1.000(-6.87, 6.54)	1.000(-4.37, 10.32)	1.000(-6.30, 8.40)	1.000(-9.27, 5.42)
Right	1.000(-9.00, 6.70)	1.000(-7.00, 8.70)	1.000(-10.15, 5.55)	1.000(-6.60, 10.60)	1.000(-9.75, 7.45)	1.000(-11.75, 5.45)
Left	1.000(-8.94, 6.37)	1.000(-4.99, 10.32)	1.000(-5.69, 9.62)	0.779(-4.44, 12.34)	1.000(-5.14, 11.64)	1.000(-9.09, 7.69)
Extension						
Overall	0.954(-5.35, 13.69)	1.000(-8.25, 10.79)	0.080(-2.10, 16.94)	1.000(-13.33, 7.53)	1.000(-7.18, 13.68)	0.353(-4.28, 16.58)
Right	1.000(-7.20, 13.84)	1.000(-11.20, 9.84)	0.096(-2.55, 18.49)	1.000(-15.52, 7.52)	1.000(-6.87, 16.17)	0.101(-2.87, 20.17)
Left	0.661(-5.07, 15.11)	1.000(-6.87, 13.31)	0.179(-3.22, 16.96)	1.000(-12.85, 9.25)	1.000(-9.20, 12.90)	1.000(-7.40, 14.70)
Ulnar Deviation						
Overall	1.000(-7.90, 4.42)	1.000(-7.70, 4.62)	1.000(-5.62, 6.69)	1.000(-6.55, 6.95)	1.000(-4.47, 9.02)	1.000(-4.67, 8.82)
Right	1.000(-9.66, 4.06)	1.000(-9.66, 4.06)	1.000(-6.61, 7.11)	1.000(-7.52, 7.52)	1.000(-4.47, 10.57)	1.000(-4.47, 10.57)
Left	1.000(-7.93, 6.56)	1.000(-7.53, 6.96)	1.000(-6.43, 8.06)	1.000(-7.54, 8.34)	1.000(-6.44, 9.44)	1.000(-6.84, 9.04)
Radial Deviation						
Overall	1.000(-4.04, 8.74)	0.114(-1.69, 11.09)	1.000(-4.71, 8.06)	1.000(-4.65, 9.35)	1.000(-7.67, 6.32)	0.984(-10.02, 3.97)
Right	1.000(-4.86, 7.66)	0.370(-2.61, 9.91)	1.000(-5.61, 6.91)	1.000(-4.61, 9.11)	1.000(-7.61, 6.11)	0.954(-9.86, 3.86)
Left	1.000(-4.93, 11.53)	0.155(-2.48, 13.98)	1.000(-5.53, 10.93)	1.000(-6.56, 11.46)	1.000(-9.61, 8.41)	1.000(-12.06, 5.96)

*** statistically significant difference (p<0.01)**

Table 15: Difference between the amounts of ankle and knee passive range of motion for each age group (p-value and 99% confidence interval).

MOTIONS	AGE GROUPS					
	(18-29) x (30-49)	(18-29) x (40-49)	(18-29) x (50-59)	(30-39) x (40-49)	(30-39) x (50-59)	(40-49) x (50-59)
	p-value (99% confidence interval)					
ANKLE						
Dorsiflexion						
Overall	0.384(-11.81, 3.16)	1.000(-10.31, 4.66)	0.182(-12.56, 2.41)	1.000(-6.70, 9.70)	1.000(-8.95, 7.45)	1.000(-10.45, 5.95)
Right	0.553(-23.04, 7.24)	1.000(-21.20, 10.38)	0.559(-24.40, 7.70)	1.000(-13.30, 18.28)	1.000(-16.50, 15.60)	1.000(-19.61, 13.73)
Left	0.938(-23.31, 9.11)	1.000(-23.94, 9.88)	0.602(-25.94, 8.44)	1.000(-16.84, 16.98)	1.000(-18.84, 15.54)	1.000(-19.58, 16.14)
Plantarflexion						
Overall	1.000(-20.98, 8.56)	0.084(-26.18, 3.36)	0.520(-22.65, 6.89)	1.000(-21.38, 10.98)	1.000(-17.85, 14.50)	1.000(-12.65, 19.70)
Right	0.897(-20.95, 7.99)	0.072(-25.90, 3.04)	0.185(-24.25, 4.69)	1.000(-20.80, 10.90)	1.000(-19.15, 12.55)	1.000(-14.20, 17.50)
Left	1.000(-22.34, 10.47)	0.161(-27.79, 5.02)	1.000(-22.39, 10.42)	1.000(-23.42, 12.52)	1.000(-18.02, 17.92)	1.000(-12.57, 23.37)
Inversion						
Overall	0.629(-10.43, 3.43)	* 0.001(-15.48, -1.62)	0.377(-10.96, 2.91)	0.202(-12.64, 2.54)	1.000(-8.12, 7.07)	0.338(-3.07, 12.12)
Right	0.328(-12.75, 3.19)	* 0.001(-17.70, -1.76)	0.070(-14.30, 1.64)	0.415(-13.68, 3.78)	1.000(-10.28, 7.18)	1.000(-5.33, 12.13)
Left	1.000(-10.19, 5.76)	0.021(-15.34, .61)	1.000(-9.69, 6.26)	0.354(-13.89, 3.59)	1.000(-8.24, 9.24)	0.232(-3.09, 14.39)
Eversion						
Overall	1.000(-7.66, 8.61)	0.393(-3.46, 12.81)	1.000(-10.84, 5.44)	0.778(-4.71, 13.11)	1.000(-12.09, 5.74)	0.052(-16.29, 1.54)
Right	1.000(-10.63, 8.23)	1.000(-6.63, 12.23)	0.072(-16.88, 1.98)	1.000(-6.33, 14.33)	0.316(-16.58, 4.08)	0.011(-20.58, .08)
Left	1.000(-6.98, 11.28)	0.133(-2.58, 15.68)	1.000(-7.08, 11.18)	0.941(-5.60, 14.40)	1.000(-10.10, 9.90)	0.887(-14.50, 5.50)
KNEE						
Flexion						
Overall	1.000(-5.78, 4.60)	1.000(-6.31, 4.07)	0.715(-7.71, 2.67)	1.000(-6.21, 5.16)	1.000(-7.61, 3.76)	1.000(-7.09, 4.29)
Right	1.000(-5.60, 5.90)	1.000(-7.20, 4.30)	0.968(-8.25, 3.25)	1.000(-7.89, 4.69)	1.000(-8.94, 3.64)	1.000(-7.34, 5.24)
Left	1.000(-6.70, 4.03)	1.000(-6.15, 4.58)	0.773(-7.90, 2.83)	1.000(-5.32, 6.42)	1.000(-7.07, 4.67)	1.000(-7.62, 4.12)
Extension						
Overall	1.000(-8.77, 8.50)	0.521(-13.25, 4.03)	1.000(-11.92, 5.35)	0.770(-13.94, 4.99)	1.000(-12.61, 6.31)	1.000(-8.14, 10.79)
Right	1.000(-9.96, 9.49)	0.580(-14.76, 4.69)	1.000(-13.31, 6.14)	0.884(-15.46, 5.86)	1.000(-14.01, 7.31)	1.000(-9.21, 12.11)
Left	1.000(-8.52, 8.46)	0.680(-12.67, 4.31)	1.000(-11.47, 5.51)	0.906(-13.45, 5.15)	1.000(-12.25, 6.35)	1.000(-8.10, 10.50)

*** statistically significant difference (p<0.01)**

Table 16: Difference between the amounts of hip passive range of motion for each age group (p-value and 99% confidence interval).

MOTIONS	AGE GROUPS					
	(18-29) x (30-49)	(18-29) x (40-49)	(18-29) x (50-59)	(30-39) x (40-49)	(30-39) x (50-59)	(40-49) x (50-59)
	p-value (99% confidence interval)					
	HIP					
Abduction						
Overall	1.000(-4.70, 7.32)	1.000(-4.68, 7.34)	0.062(-1.15, 10.87)	1.000(-6.56, 6.61)	0.502(-3.03, 10.13)	0.515(-3.06, 10.11)
Right	1.000(-5.27, 8.14)	1.000(-4.62, 8.79)	0.033(-.82, 12.59)	1.000(-6.69, 7.99)	0.314(-2.89, 11.79)	0.579(-3.54, 11.14)
Left	1.000(-5.51, 7.88)	1.000(-6.11, 7.28)	0.399(-2.86, 10.53)	1.000(-7.93, 6.73)	1.000(-4.68, 9.98)	0.923(-4.08, 10.58)
Adduction						
Overall	1.000(-7.10, 6.63)	1.000(-8.70, 5.03)	1.000(-9.35, 4.38)	1.000(-9.12, 5.92)	1.000(-9.77, 5.27)	1.000(-8.17, 6.87)
Right	1.000(-6.52, 7.05)	1.000(-7.57, 6.00)	1.000(-8.92, 4.65)	1.000(-8.48, 6.38)	1.000(-9.83, 5.03)	1.000(-8.78, 6.08)
Left	1.000(-8.58, 7.11)	1.000(-10.73, 4.96)	1.000(-10.68, 5.01)	1.000(-10.74, 6.44)	1.000(-10.69, 6.49)	1.000(-8.54, 8.64)
Flexion						
Overall	1.000(-9.61, 5.48)	1.000(-10.58, 4.50)	* 0.002(-16.36, -1.27)	1.000(-9.24, 7.29)	0.057(-15.01, 1.51)	0.155(-14.04, 2.49)
Right	1.000(-6.50, 9.00)	1.000(-8.55, 6.95)	* 0.008(-15.70, -.20)	1.000(-10.54, 6.44)	* 0.004(-17.69, -.71)	0.045(-15.64, 1.34)
Left	0.286(-14.08, 3.32)	0.311(-13.98, 3.42)	* 0.003(-18.38, -.98)	1.000(-9.43, 9.63)	0.880(-13.83, 5.23)	0.826(-13.93, 5.13)
Extension						
Overall	1.000(-2.94, 3.69)	1.000(-2.02, 4.62)	1.000(-2.12, 4.52)	1.000(-2.71, 4.56)	1.000(-2.81, 4.46)	1.000(-3.73, 3.53)
Right	1.000(-4.37, 4.57)	1.000(-3.47, 5.47)	1.000(-3.92, 5.02)	1.000(-3.99, 5.79)	1.000(-4.44, 5.34)	1.000(-5.34, 4.44)
Left	1.000(-3.47, 4.77)	1.000(-2.52, 5.72)	0.891(-2.27, 5.97)	1.000(-3.56, 5.46)	1.000(-3.31, 5.71)	1.000(-4.26, 4.76)
Internal Rotation						
Overall	1.000(-3.93, 7.23)	1.000(-4.46, 6.71)	1.000(-3.61, 7.56)	1.000(-6.64, 5.59)	1.000(-5.79, 6.44)	1.000(-5.27, 6.97)
Right	1.000(-5.60, 7.44)	1.000(-4.45, 8.59)	0.943(-3.65, 9.39)	1.000(-5.99, 8.29)	1.000(-5.19, 9.09)	1.000(-6.34, 7.94)
Left	1.000(-4.06, 8.83)	1.000(-6.26, 6.63)	1.000(-5.36, 7.53)	1.000(-9.26, 4.86)	1.000(-8.36, 5.76)	1.000(-6.16, 7.96)
External Rotation						
Overall	1.000(-3.33, 7.41)	0.017(-.30, 10.43)	* 0.007(.22, 10.96)	0.591(-2.86, 8.91)	0.320(-2.33, 9.43)	1.000(-5.36, 6.41)
Right	1.000(-5.04, 8.20)	0.361(-2.74, 10.50)	* 0.008(.16, 13.40)	1.000(-4.95, 9.55)	0.134(-2.05, 12.45)	1.000(-4.35, 10.15)
Left	1.000(-3.32, 8.32)	* 0.005(.43, 12.07)	0.097(-1.42, 10.22)	0.357(-2.62, 10.12)	1.000(-4.47, 8.27)	1.000(-8.22, 4.52)

* **statistically significant difference (p<0.01)**

Table 17: Difference between the amounts of shoulder passive range of motion for each age group (p-value and 99% confidence interval).

MOTIONS	AGE GROUPS (18-29) x (30-49)	(18-29) x (40-49)	(18-29) x (50-59)	(30-39) x (40-49)	(30-39) x (50-59)	(40-49) x (50-59)
	p-value (99% confidence interval)					
SHOULDER						
Glenohumeral Abduction						
Overall	0.309(-6.51, 26.71)	0.309(-6.51, 26.71)	1.000(-11.01, 22.21)	1.000(-18.19, 18.19)	1.000(-22.69, 13.69)	1.000(-22.69, 13.69)
Right	0.294(-6.55, 27.48)	0.180(-5.45, 28.58)	1.000(-10.00, 24.03)	1.000(-17.54, 19.74)	1.000(-22.09, 15.19)	1.000(-23.19, 14.09)
Left	0.505(-8.35, 27.82)	0.750(-9.45, 26.72)	1.000(-13.90, 22.27)	1.000(-20.91, 18.71)	1.000(-25.36, 14.26)	1.000(-24.26, 15.36)
Shoulder Complex Abduction						
Overall	1.000(-12.86, 12.54)	1.000(-11.86, 13.54)	0.497(-5.83, 19.57)	1.000(-12.91, 14.91)	0.629(-6.89, 20.94)	0.980(-7.89, 19.94)
Right	1.000(-12.32, 14.09)	1.000(-13.17, 13.24)	0.850(-7.17, 19.24)	1.000(-15.31, 13.61)	1.000(-9.31, 19.61)	1.000(-8.46, 20.46)
Left	1.000(-14.35, 11.95)	1.000(-11.50, 14.80)	0.363(-5.45, 20.85)	1.000(-11.55, 17.25)	0.288(-5.50, 23.30)	1.000(-8.35, 20.45)
Glenohumeral Flexion						
Overall	0.089(-2.63, 19.90)	0.186(-3.66, 18.87)	0.135(-3.21, 19.32)	1.000(-13.36, 11.31)	1.000(-12.91, 11.76)	1.000(-11.89, 12.79)
Right	0.016(-.63, 25.10)	0.464(-5.78, 19.95)	0.024(-1.13, 24.60)	1.000(-19.24, 8.94)	1.000(-14.59, 13.59)	1.000(-9.44, 18.74)
Left	1.000(-8.39, 18.45)	0.314(-5.29, 21.55)	1.000(-9.04, 17.80)	1.000(-11.60, 17.80)	1.000(-15.35, 14.05)	1.000(-18.45, 10.95)
Shoulder Complex Flexion						
Overall	1.000(-5.43, 12.23)	0.092(-2.11, 15.56)	1.000(-5.31, 12.36)	1.000(-6.35, 13.00)	1.000(-9.55, 9.80)	1.000(-12.87, 6.47)
Right	1.000(-6.60, 12.97)	0.767(-5.15, 14.42)	1.000(-8.60, 10.97)	1.000(-9.27, 12.17)	1.000(-12.72, 8.72)	1.000(-14.17, 7.27)
Left	1.000(-5.53, 12.76)	0.014(-.33, 17.96)	0.241(-3.28, 15.01)	0.573(-4.81, 15.21)	1.000(-7.76, 12.26)	1.000(-12.96, 7.06)
Glenohumeral Extension						
Overall	1.000(-5.17, 8.44)	1.000(-4.72, 8.89)	0.776(-3.59, 10.01)	1.000(-7.00, 7.90)	1.000(-5.88, 9.03)	1.000(-6.33, 8.58)
Right	1.000(-4.73, 9.27)	1.000(-5.53, 8.47)	0.357(-2.88, 11.12)	1.000(-8.47, 6.87)	1.000(-5.82, 9.52)	1.000(-5.02, 10.32)
Left	1.000(-7.85, 9.85)	1.000(-6.15, 11.55)	1.000(-6.55, 11.15)	1.000(-8.00, 11.40)	1.000(-8.40, 11.00)	1.000(-10.10, 9.30)
Shoulder Complex Extension						
Overall	0.675(-5.38, 15.88)	1.000(-6.33, 14.93)	0.297(-4.11, 17.16)	1.000(-12.60, 10.70)	1.000(-10.37, 12.92)	1.000(-9.42, 13.87)
Right	0.261(-4.10, 18.13)	0.725(-5.75, 16.48)	0.144(-3.25, 18.98)	1.000(-13.83, 10.53)	1.000(-11.33, 13.03)	1.000(-9.68, 14.68)
Left	1.000(-8.10, 15.06)	1.000(-8.35, 14.81)	0.899(-6.40, 16.76)	1.000(-12.93, 12.43)	1.000(-10.98, 14.38)	1.000(-10.73, 14.63)
Glenohumeral Internal Rotation						
Overall	0.888(-6.33, 16.68)	1.000(-7.08, 15.93)	1.000(-11.98, 11.03)	1.000(-13.36, 11.86)	0.896(-18.26, 6.96)	1.000(-17.51, 7.71)
Right	1.000(-9.85, 15.12)	1.000(-8.10, 16.87)	1.000(-14.30, 10.67)	1.000(-11.92, 15.42)	1.000(-18.12, 9.22)	0.868(-19.87, 7.47)
Left	0.350(-5.34, 20.77)	1.000(-8.59, 17.52)	1.000(-12.19, 13.92)	1.000(-17.55, 11.05)	0.742(-21.15, 7.45)	1.000(-17.90, 10.70)
Shoulder Complex Internal Rotation						
Overall	1.000(-13.07, 10.51)	1.000(-15.11, 8.47)	1.000(-16.71, 6.87)	1.000(-14.95, 10.88)	1.000(-16.55, 9.28)	1.000(-14.51, 11.31)
Right	1.000(-14.78, 12.13)	1.000(-15.45, 11.45)	1.000(-16.95, 9.95)	1.000(-15.41, 14.06)	1.000(-16.91, 12.56)	1.000(-16.24, 13.24)
Left	1.000(-14.18, 11.71)	1.000(-17.58, 8.31)	0.695(-19.28, 6.61)	1.000(-17.58, 10.78)	1.000(-19.28, 9.08)	1.000(-15.88, 12.48)
Glenohumeral External Rotation						
Overall	0.028(-.94, 17.15)	0.028(-.94, 17.15)	* 0.000(4.66, 22.75)	1.000(-9.91, 9.91)	0.420(-4.31, 15.51)	0.420(-4.31, 15.51)
Right	* 0.006(.56, 22.34)	0.043(-1.64, 20.14)	* 0.000(5.31, 27.09)	1.000(-14.13, 9.73)	1.000(-7.18, 16.68)	0.372(-4.98, 18.88)
Left	0.636(-4.71, 14.24)	0.115(-2.51, 16.44)	* 0.001(1.74, 20.69)	1.000(-8.18, 12.58)	0.280(-3.93, 16.83)	1.000(-6.13, 14.63)
Shoulder Complex External Rotation						
Overall	1.000(-7.56, 10.69)	1.000(-7.43, 10.81)	0.013(-.26, 17.99)	1.000(-9.87, 10.12)	0.120(-2.69, 17.29)	0.133(-2.82, 17.17)
Right	1.000(-6.67, 14.11)	1.000(-7.87, 12.91)	0.010(-.02, 20.76)	1.000(-12.58, 10.18)	0.367(-4.73, 18.03)	0.166(-3.53, 19.23)
Left	1.000(-10.87, 9.70)	1.000(-9.42, 11.15)	0.134(-2.92, 17.65)	1.000(-9.82, 12.72)	0.146(-3.32, 19.22)	0.387(-4.77, 17.77)

* **statistically significant difference ($p<0.01$)**

Table 18: Difference between the amounts of elbow and wrist passive range of motion for each age group (p-value and 99% confidence interval).

MOTIONS	AGE GROUPS					
	(18-29) x (30-49)	(18-29) x (40-49)	(18-29) x (50-59)	(30-39) x (40-49)	(30-39) x (50-59)	(40-49) x (50-59)
	p-value (99% confidence interval)					
ELBOW						
Flexion						
Overall	1.000(-5.41, 7.26)	1.000(-5.54, 7.14)	1.000(-6.79, 5.89)	1.000(-7.06, 6.81)	1.000(-8.31, 5.56)	1.000(-8.19, 5.69)
Right	1.000(-5.90, 7.54)	1.000(-5.05, 8.39)	1.000(-4.45, 8.99)	1.000(-6.51, 8.21)	1.000(-5.91, 8.81)	1.000(-6.76, 7.96)
Left	1.000(-7.33, 9.39)	1.000(-8.43, 8.29)	1.000(-11.53, 5.19)	1.000(-10.26, 8.06)	0.841(-13.36, 4.96)	1.000(-12.26, 6.06)
Extension						
Overall	1.000(-4.27, 4.50)	1.000(-2.72, 6.05)	0.079(-.97, 7.80)	1.000(-3.25, 6.35)	0.169(-1.50, 8.10)	1.000(-3.05, 6.55)
Right	1.000(-3.78, 5.38)	1.000(-2.63, 6.53)	0.303(-1.78, 7.38)	1.000(-3.87, 6.17)	1.000(-3.02, 7.02)	1.000(-4.17, 5.87)
Left	1.000(-5.57, 4.43)	1.000(-3.62, 6.38)	0.063(-.97, 9.03)	1.000(-3.53, 7.43)	0.047(-.88, 10.08)	0.719(-2.83, 8.13)
Pronation						
Overall	1.000(-3.61, 7.39)	1.000(-4.38, 6.62)	1.000(-4.58, 6.42)	1.000(-6.80, 5.25)	1.000(-7.00, 5.05)	1.000(-6.22, 5.82)
Right	0.697(-3.22, 9.39)	1.000(-6.22, 6.39)	1.000(-5.87, 6.74)	0.973(-9.91, 3.91)	1.000(-9.56, 4.26)	1.000(-6.56, 7.26)
Left	1.000(-5.94, 7.34)	1.000(-4.49, 8.79)	1.000(-5.24, 8.04)	1.000(-5.82, 8.72)	1.000(-6.57, 7.97)	1.000(-8.02, 6.52)
Supination						
Overall	1.000(-10.67, 7.00)	1.000(-8.75, 8.93)	1.000(-5.50, 12.18)	1.000(-7.76, 11.61)	0.518(-4.51, 14.86)	1.000(-6.43, 12.93)
Right	1.000(-11.37, 8.27)	1.000(-8.07, 11.57)	0.653(-4.92, 14.72)	1.000(-7.45, 14.05)	0.329(-4.30, 17.20)	1.000(-7.60, 13.90)
Left	1.000(-11.40, 7.17)	1.000(-10.85, 7.72)	1.000(-7.50, 11.07)	1.000(-9.62, 10.72)	1.000(-6.27, 14.07)	1.000(-6.82, 13.52)
WRIST						
Flexion						
Overall	1.000(-7.68, 5.50)	1.000(-4.91, 8.27)	1.000(-6.06, 7.12)	1.000(-4.44, 9.99)	1.000(-5.59, 8.84)	1.000(-8.37, 6.07)
Right	1.000(-9.60, 5.90)	1.000(-6.20, 9.30)	1.000(-8.10, 7.40)	1.000(-5.09, 11.89)	1.000(-6.99, 9.99)	1.000(-10.39, 6.59)
Left	1.000(-7.43, 6.77)	1.000(-5.28, 8.92)	1.000(-5.68, 8.52)	1.000(-5.63, 9.93)	1.000(-6.03, 9.53)	1.000(-8.18, 7.38)
Extension						
Overall	1.000(-4.13, 8.08)	1.000(-5.98, 6.23)	0.884(-3.36, 8.86)	1.000(-8.54, 4.84)	1.000(-5.91, 7.46)	1.000(-4.06, 9.31)
Right	1.000(-4.93, 8.93)	1.000(-5.08, 8.78)	0.096(-1.68, 12.18)	1.000(-7.74, 7.44)	1.000(-4.34, 10.84)	0.898(-4.19, 10.99)
Left	1.000(-5.24, 9.14)	1.000(-8.79, 5.59)	1.000(-6.94, 7.44)	0.882(-11.42, 4.32)	1.000(-9.57, 6.17)	1.000(-6.02, 9.72)
Ulnar Deviation						
Overall	1.000(-8.95, 4.54)	1.000(-8.90, 4.59)	1.000(-7.80, 5.69)	1.000(-7.34, 7.44)	1.000(-6.24, 8.54)	1.000(-6.29, 8.49)
Right	0.846(-10.78, 4.01)	1.000(-10.48, 4.31)	1.000(-8.28, 6.51)	1.000(-7.80, 8.40)	1.000(-5.60, 10.60)	1.000(-5.90, 10.30)
Left	1.000(-8.52, 6.46)	1.000(-8.72, 6.26)	1.000(-8.72, 6.26)	1.000(-8.41, 8.01)	1.000(-8.41, 8.01)	1.000(-8.21, 8.21)
Radial Deviation						
Overall	1.000(-4.68, 6.00)	1.000(-3.20, 7.47)	1.000(-5.25, 5.42)	1.000(-4.37, 7.32)	1.000(-6.42, 5.27)	1.000(-7.90, 3.80)
Right	1.000(-5.45, 6.05)	0.350(-2.35, 9.15)	1.000(-5.65, 5.85)	0.683(-3.20, 9.40)	1.000(-6.50, 6.10)	0.556(-9.60, 3.00)
Left	1.000(-4.97, 7.00)	1.000(-5.12, 6.85)	1.000(-5.92, 6.05)	1.000(-6.71, 6.41)	1.000(-7.51, 5.61)	1.000(-7.36, 5.76)

*** statistically significant difference (p<0.01)**

A decrease in ROM with age was found for the following groups:

Between the 18 to 29 age group and the 50 to 59 age group:

- passive hip flexion in the overall ROM, right and left sides
- active hip flexion in the overall ROM and left side
- passive hip external rotation in the overall ROM and right side
- passive and active glenohumeral external rotation in the overall ROM, right and left sides
- active shoulder complex external rotation in the overall ROM and right side
- active elbow extension in the overall ROM and right side

Between the 18 to 29 age group and the 40 to 49 age group:

- passive hip external rotation on the left side

Between the 18 to 29 age group and the 30 to 39 age group:

- active hip flexion on the left side
- passive glenohumeral external rotation passive on the right side

An increase in ROM with age was found for the following groups:

Between the 18 to 29 age group and the 40 to 49 age group:

- passive ankle inversion in the overall ROM and right side
- active ankle eversion in the overall ROM

Between the 40 to 49 age group and the 50 to 59 age group:

- active ankle eversion in the overall ROM

For the majority of the differences specified above, there was decrease of range of motion with age but for passive ankle inversion in overall ROM and right side that increased with age. Active ankle eversion in the overall ROM where the only values for the 40 to 49 age group were higher than for all of the other age groups.

Post hoc power calculation for the interaction between age groups demonstrated a power varying from 0.02 to 0.96 (see Table 19). The movements that were found to have a statistically significant difference between age groups had power between 0.64 to 0.96. Only passive and active glenohumeral external rotation had power above 0.80, which is considered the ideal power.[61]

There were many movements that had a significant difference between the right and left sides. The p value and the confidence intervals for the difference between right and left sides for each age group and overall age groups are presented on Table 20 and 21 for the active range of motion and Table 22 and 23 for the passive range of motion.

The range of motion for the overall group (all age groups combined) presented greater significant differences between right and left sides than for each age group separately. There was no motion that had a difference between sides in a specific group that did not have difference in the overall group. The motions that had more difference between sides when considering each age group separately were active shoulder complex external rotation and passive and active radial deviation.

Since the majority of the participants were right side as dominant, there was no important difference in the results of the differences between sides (right and left) and the results of the difference between dominant and non dominant sides. There were only 8 subjects of the 90 total who had left hand dominance and only 4 that had left leg dominant. For each age group separately, there were 2 people who had left hand dominance and 1 person with left leg dominance. All of the motions that had a significant difference in the amount of range of motion between dominant and non dominant sides for separate age groups also had a difference on the overall group. P values and confidence intervals are presented on Table 24 and 25 for active range of motion and Table 26 and 27 for passive range of motion. The motions that had the greatest difference between sides per group were passive and active radial deviation.

Post hoc power calculation for the interaction between sides was calculated only for the dominant and non dominant sides since the comparisons between right and left and dominant and non dominant sides were similar. The results demonstrated a power varying from 0.01 to 1.00 (see Table 19). The movements that were found to have a statistically significant difference between sides had a power between 0.52 to 1. Comparisons between sides for passive and active knee flexion, active hip external rotation, passive shoulder complex abduction, passive shoulder complex abduction, passive and active glenohumeral internal rotation, passive shoulder complex internal rotation, passive and active shoulder complex external rotation, active glenohumeral external rotation, passive and active supination, passive and active wrist extension, passive and active wrist radial deviation, active wrist flexion and active wrist ulnar deviation all had a power above 0.80, which is considered the ideal power.[61]

Table 19: Post hoc power calculation for the interactions between age groups and the interaction between sides

MOTIONS	POWER			
	ACTIVE	PASSIVE	ACTIVE	PASSIVE
	INTERACTION AGE GROUPS		INTERACTION SIDES	
Ankle range of motion				
Dorsiflexion (talocrural joint)	0.07	0.26	0.03	0.44
Plantarflexion (talocrural joint)	0.23	0.32	0.75	0.38
Eversion (tarsal joint)	0.72	0.35	0.05	0.01
Inversion (tarsal joint)	0.18	0.79	0.18	0.05
Knee range of motion				
Flexion	0.26	0.09	* 0.80	* 0.82
Extension	0.09	0.16	0.20	0.13
Hip range of motion				
Abduction	0.20	0.33	0.53	0.21
Adduction	0.16	0.06	0.76	0.12
Flexion	0.72	0.74	* 0.96	0.02
Extension	0.15	0.07	0.18	0.05
Internal rotation	0.02	0.05	0.78	0.39
External rotation	0.33	0.76	1.00	0.08
Shoulder range of motion				
Abduction				
Glenohumeral abduction	0.11	0.24	0.06	0.04
Shoulder complex abduction	0.07	0.14	0.02	* 0.82
Flexion				
Glenohumeral flexion	0.07	0.45	0.04	0.11
Shoulder complex flexion	0.20	0.28	0.04	0.03
Extension				
Glenohumeral extension	0.11	0.08	0.77	0.79
Shoulder complex extension	0.28	0.20	0.58	* 0.93
Internal (medial) rotation				
Glenohumeral internal rotation	0.02	0.14	* 0.87	* 1
Shoulder complex internal rotation	0.08	0.07	* 1	* 0.98
External (lateral) rotation				
Glenohumeral external rotation	* 0.92	* 0.96	* 0.86	0.57
Shoulder complex external rotation	0.69	0.55	* 1	* 0.98
Elbow range of motion				
Flexion	0.02	0.02	0.30	0.09
Extension	0.64	0.37	0.08	0.27
Pronation	0.07	0.04	0.18	0.03
Supination	0.33	0.11	0.73	* 0.97
Wrist range of motion				
Flexion	0.06	0.05	0.73	0.01
Extension	0.34	0.10	0.76	* 0.98
Ulnar deviation	0.06	0.05	0.52	0.09
Radial deviation	0.24	0.06	* 1	* 1

* power greater than 0.80

Table 20: Difference between right and left sides (p-values and 99% confidence interval) for ankle, knee and hip active range of motions.

MOTIONS	ACTIVE				
	18-29	30-39	40-49	50-59	OVERALL
	p-value (99% confidence interval)				
Ankle range of motion					
Dorsiflexion (talocrural joint)	0.506(-4.22, 2.52)	0.227(-1.82, 4.92)	0.018(-.30, 7.01)	0.930(-3.89, 3.64)	0.147(-.79, 2.75)
Plantarflexion (talocrural joint)	0.268(-6.95, 2.82)	* 0.000(-14.38, -2.42)	0.015(-11.63, .33)	0.947(-5.83, 6.13)	* 0.000(-6.86, -1.13)
Eversion (tarsal joint)	0.201(-2.02, 5.88)	0.291(-2.89, 6.79)	0.745(-5.44, 4.24)	0.357(-3.14, 6.54)	0.160(-1.07, 3.56)
Inversion (tarsal joint)	0.760(-5.44, 4.30)	0.613(-7.12, 4.82)	1.000(-5.97, 5.97)	0.313(-3.67, 8.27)	0.893(-2.71, 3.00)
Knee range of motion					
Flexion	* 0.005(-4.41, -.19)	0.035(-4.68, .48)	0.879(-2.73, 2.43)	* 0.001(-5.83, -.67)	* 0.000(-3.18, -.72)
Extension	0.261(-1.02, 2.55)	0.021(-4.13, .23)	0.589(-2.63, 1.73)	0.095(-3.58, .78)	0.059(-1.80, .29)
Hip range of motion					
Abduction	0.074(-5.81, 1.08)	0.034(-7.67, .77)	0.053(-7.37, 1.07)	0.619(-5.02, 3.42)	* 0.002(-4.46, -.42)
Adduction	0.262(-3.78, 1.51)	0.170(-4.94, 1.54)	0.012(-6.39, .09)	0.050(-5.69, .79)	* 0.001(-3.66, -.56)
Flexion	0.536(-4.37, 2.70)	* 0.000(-11.73, -3.07)	0.058(-7.48, 1.18)	0.165(-6.63, 2.03)	* 0.000(-5.49, -1.35)
Extension	0.557(-3.46, 2.20)	0.163(-5.32, 1.62)	0.880(-3.67, 3.27)	0.449(-4.47, 2.47)	0.147(-2.58, .74)
Internal rotation	* 0.005(.35, 7.11)	0.123(-1.69, 6.59)	0.447(-2.94, 5.34)	0.039(-.84, 7.44)	* 0.001(.69, 4.65)
External rotation	0.011(-6.56, .03)	* 0.005(-8.43, -.37)	0.037(-7.28, .78)	0.013(-7.93, .13)	* 0.000(-5.63, -1.77)

*** statistically significant difference ($p<0.01$)**

Table 21: Difference between right and left sides (p-values and 99% confidence interval) for shoulder, elbow and wrist active range of motions.

MOTIONS	ACTIVE				
	18-29	30-39	40-49	50-59	OVERALL
	p-value (99% confidence interval)				
Shoulder range of motion					
Abduction					
Glenohumeral abduction	0.168(-3.26, 10.52)	0.608(-6.79, 10.09)	0.126(-3.49, 13.39)	0.126(-3.49, 13.39)	0.015(-.24, 7.83)
Shoulder complex abduction	0.952(-5.72, 5.98)	0.769(-6.36, 7.96)	0.390(-9.51, 4.81)	0.621(-8.51, 5.81)	0.597(-4.12, 2.74)
Flexion					
Glenohumeral flexion	0.383(-10.15, 5.08)	0.866(-9.93, 8.73)	0.944(-9.08, 9.58)	0.612(-11.13, 7.53)	0.492(-5.64, 3.29)
Shoulder complex flexion	0.670(-2.58, 3.58)	0.835(-4.08, 3.48)	0.728(-3.28, 4.28)	0.283(-2.23, 5.33)	0.415(-1.25, 2.37)
Extension					
Glenohumeral extension	0.062(-6.31, 1.04)	0.032(-8.22, .77)	0.064(-7.70, 1.30)	0.117(-7.20, 1.80)	* 0.000(-5.22, -.91)
Shoulder complex extension	0.140(-8.85, 2.45)	0.281(-9.77, 4.07)	0.199(-10.32, 3.52)	0.307(-9.62, 4.22)	0.018(-6.35, .28)
Internal (medial) rotation					
Glenohumeral internal rotation	* 0.004(-12.46, -.74)	0.187(-10.80, 3.55)	* 0.008(-14.57, -.23)	0.032(-13.12, 1.22)	* 0.000(-9.33, -2.46)
Shoulder complex internal rotation	0.124(-8.89, 2.29)	0.044(-12.15, 1.55)	* 0.001(-15.50, -1.80)	* 0.007(-14.00, -.30)	* 0.000(-9.38, -2.82)
External (lateral) rotation					
Glenohumeral external rotation	* 0.005(.48, 12.12)	0.193(-3.57, 10.67)	* 0.004(.93, 15.17)	0.047(-1.67, 12.57)	* 0.000(2.43, 9.25)
Shoulder complex external rotation	* 0.000(4.32, 13.62)	0.078(-1.84, 9.54)	* 0.002(1.16, 12.54)	* 0.002(1.31, 12.69)	* 0.000(3.94, 9.39)
Elbow range of motion					
Flexion	0.013(-.11, 5.44)	0.396(-2.30, 4.50)	0.511(-2.55, 4.25)	0.298(-2.05, 4.75)	0.018(-.13, 3.12)
Extension	0.671(-2.40, 1.73)	0.835(-2.33, 2.73)	0.121(-4.03, 1.03)	0.603(-3.03, 2.03)	0.249(-1.74, .68)
Pronation	0.136(-5.60, 1.53)	0.337(-5.96, 2.76)	0.040(-.91, 7.81)	0.741(-4.91, 3.81)	0.818(-2.27, 1.91)
Supination	0.248(-5.99, 2.32)	0.237(-7.39, 2.79)	0.021(-9.64, .54)	0.158(-7.84, 2.34)	* 0.003(-5.29, -.42)
Wrist range of motion					
Flexion	0.630(-3.26, 4.73)	0.748(-4.30, 5.50)	0.174(-2.35, 7.45)	* 0.009(.10, 9.90)	0.014(-.12, 4.56)
Extension	* 0.006(-8.35, -.25)	0.171(-7.57, 2.37)	0.832(-5.37, 4.57)	* 0.005(-10.37, -.43)	* 0.001(-5.55, -.80)
Ulnar deviation	0.012(-7.01, .07)	0.414(-5.69, 2.99)	0.565(-5.29, 3.39)	0.082(-7.24, 1.44)	* 0.007(-4.24, -.09)
Radial deviation	* 0.000(-10.95, -3.65)	* 0.002(-9.87, -.93)	* 0.003(-9.67, -.73)	* 0.003(-9.72, -.78)	* 0.000(-7.93, -3.65)

*** statistically significant difference (p<0.01)**

Table 22: Difference between right and left sides (p-values and 99% confidence interval) for ankle, knee and hip passive range of motions.

MOTIONS	PASSIVE				
	18-29	30-39	40-49	50-59	OVERALL
	p-value (99% confidence interval)				
Ankle range of motion					
Dorsiflexion (talocrural joint)	0.049(-1.01, 7.31)	0.014(-.21, 8.11)	0.372(-2.98, 6.04)	0.122(-1.90, 7.40)	* 0.005(.21, 4.46)
Plantarflexion (talocrural joint)	0.016(-9.12, .32)	0.083(-9.63, 1.93)	0.051(-10.13, 1.43)	0.785(-6.38, 5.18)	* 0.002(-6.07, -.53)
Eversion (tarsal joint)	0.376(-5.41, 2.68)	0.525(-3.75, 6.15)	0.596(-3.95, 5.95)	0.087(-1.70, 8.20)	0.260(-1.35, 3.39)
Inversion (tarsal joint)	0.024(-8.58, .58)	0.761(-6.26, 4.96)	0.907(-5.86, 5.36)	0.012(-.11, 11.11)	0.883(-2.54, 2.84)
Knee range of motion					
Flexion	0.046(-3.61, .47)	* 0.002(-5.55, -.55)	0.345(-3.40, 1.60)	0.095(-4.10, .90)	* 0.000(-2.98, -.58)
Extension	0.144(-4.74, 1.34)	0.291(-5.22, 2.22)	0.549(-4.57, 2.87)	0.438(-4.82, 2.62)	0.060(-3.07, .49)
Hip range of motion					
Abduction	0.545(-3.74, 2.34)	0.503(-4.67, 2.77)	0.123(-5.92, 1.52)	0.055(-6.47, .97)	0.017(-3.43, .13)
Adduction	0.621(-2.15, 3.15)	0.686(-3.75, 2.75)	0.198(-4.85, 1.65)	0.872(-3.45, 3.05)	0.448(-2.01, 1.11)
Flexion	* 0.009(.03, 6.83)	0.046(-7.37, .97)	0.509(-5.22, 3.12)	0.285(-2.47, 5.87)	0.771(-1.77, 2.22)
Extension	0.114(-4.50, 1.10)	0.380(-4.58, 2.28)	0.401(-4.53, 2.33)	0.760(-3.83, 3.03)	0.085(-2.73, .56)
Internal rotation	0.052(-.85, 5.91)	0.013(-.14, 8.14)	0.680(-3.49, 4.79)	0.634(-3.39, 4.89)	0.010(.00, 3.97)
External rotation	0.647(-3.82, 2.68)	0.817(-3.63, 4.33)	0.237(-2.18, 5.78)	0.054(-6.93, 1.03)	0.638(-2.25, 1.56)

*** statistically significant difference (p<0.01)**

Table 23: Difference between right and left sides (p-values and 99% confidence interval) for shoulder, elbow and wrist passive range of motions.

MOTIONS	PASSIVE 18-29	PASSIVE 30-39	PASSIVE 40-49	PASSIVE 50-59	PASSIVE OVERALL
	p-value (99% confidence interval)				
Shoulder range of motion					
Abduction					
Glenohumeral abduction	0.239(-3.22, 8.49)	0.487(-5.27, 9.07)	0.912(-7.47, 6.87)	0.942(-7.37, 6.97)	0.441(-2.42, 4.44)
Shoulder complex abduction	* 0.007(-7.36, -.17)	* 0.001(-10.25, -1.45)	0.202(-6.55, 2.25)	0.212(-6.50, 2.30)	* 0.000(-5.57, -1.36)
Flexion					
Glenohumeral flexion	0.201(-3.56, 10.36)	0.243(-12.32, 4.72)	0.173(-4.07, 12.97)	0.225(-12.47, 4.57)	0.987(-4.05, 4.10)
Shoulder complex flexion	0.043(-6.24, .77)	0.162(-6.59, 1.99)	0.376(-2.84, 5.74)	0.235(-2.34, 6.24)	0.602(-2.46, 1.65)
Extension					
Glenohumeral extension	0.065(-7.31, 1.25)	0.034(-9.54, .94)	0.368(-7.04, 3.44)	0.017(-10.09, .39)	* 0.000(-6.01, -.99)
Shoulder complex extension	0.622(-4.85, 3.32)	0.026(-9.30, .70)	0.130(-7.90, 2.10)	0.073(-8.45, 1.55)	* 0.002(-5.25, -.46)
Internal (medial) rotation					
Glenohumeral internal rotation	* 0.000(-14.82, -3.44)	0.129(-11.02, 2.92)	* 0.001(-16.02, -2.08)	0.017(-13.42, .52)	* 0.000(-10.51, -3.83)
Shoulder complex internal rotation	0.016(-11.77, .43)	0.053(-13.04, 1.89)	* 0.004(-15.77, -.83)	* 0.004(-15.97, -1.03)	* 0.000(-10.59, -3.43)
External (lateral) rotation					
Glenohumeral external rotation	* 0.001(1.78, 11.49)	0.982(-5.99, 5.89)	0.057(-1.59, 10.29)	0.467(-4.29, 7.59)	* 0.005(.30, 5.99)
Shoulder complex external rotation	* 0.006(.31, 10.29)	0.667(-5.11, 7.11)	0.119(-2.46, 9.76)	0.324(-3.81, 8.41)	* 0.007(.14, 5.99)
Elbow range of motion					
Flexion	0.057(-1.15, 7.41)	0.096(-1.89, 8.59)	0.484(-3.84, 6.64)	0.251(-7.54, 2.94)	0.146(-1.11, 3.91)
Extension	0.661(-2.33, 1.66)	0.071(-4.15, .75)	0.335(-3.35, 1.55)	0.335(-1.55, 3.35)	0.256(-1.68, .66)
Pronation	0.861(-3.28, 3.74)	0.191(-6.45, 2.15)	0.162(-2.00, 6.60)	0.464(-3.10, 5.50)	0.614(-1.66, 2.45)
Supination	0.175(-5.66, 1.79)	0.152(-7.06, 2.06)	* 0.003(-9.81, -.69)	* 0.005(-9.61, -.49)	* 0.000(-5.87, -1.50)
Wrist range of motion					
Flexion	0.386(-4.70, 2.36)	0.832(-3.97, 4.67)	0.585(-5.22, 3.42)	0.715(-3.72, 4.92)	0.723(-2.35, 1.79)
Extension	0.173(-5.54, 1.74)	0.252(-6.41, 2.51)	* 0.002(-9.81, -.89)	* 0.000(-11.36, -2.44)	* 0.000(-6.16, -1.89)
Ulnar deviation	0.053(-5.63, .83)	0.973(-4.00, 3.90)	0.715(-4.50, 3.40)	0.070(-6.70, 1.20)	0.048(-3.33, .45)
Radial deviation	* 0.000(-7.57, -2.56)	* 0.000(-7.42, -1.28)	* 0.000(-10.67, -4.53)	* 0.000(-8.17, -2.03)	* 0.000(-7.00, -4.06)

*** statistically significant difference ($p<0.01$)**

Table 24: Difference between dominant and non dominant sides (p-values and 99% confidence interval) for ankle, knee and hip active range of motions.

MOTIONS	ACTIVE				
	18-29	30-39	40-49	50-59	OVERALL
	p-value (99% confidence interval)				
Ankle range of motion					
Dorsiflexion (talocrural joint)	0.666(-3.54, 2.54)	0.751(-3.28, 4.18)	0.100(-1.38, 6.08)	0.751(-4.18, 3.28)	0.496(-1.32, 2.25)
Plantarflexion (talocrural joint)	0.358(-6.67, 3.21)	* 0.001(-14.35, -2.25)	0.031(-11.10, 1.00)	0.811(-5.50, 6.60)	* 0.001(-6.53, -.74)
Eversion (tarsal joint)	0.252(-2.23, 5.70)	0.345(-3.10, 6.60)	0.552(-3.75, 5.95)	0.449(-3.45, 6.25)	0.093(-.83, 3.82)
Inversion (tarsal joint)	0.986(-4.87, 4.80)	0.108(-9.57, 2.27)	0.929(-5.72, 6.12)	0.929(-5.72, 6.12)	0.448(-3.66, 2.01)
Knee range of motion					
Flexion	0.008(-4.40, -.06)	0.095(-4.36, .96)	0.961(-2.71, 2.61)	* 0.008(-5.41, -.09)	* 0.001(-2.95, -.41)
Extension	0.128(-.74, 2.81)	0.020(-4.12, .22)	0.586(-2.62, 1.72)	0.093(-3.57, .77)	0.083(-1.73, .35)
Hip range of motion					
Abduction	0.113(-5.56, 1.36)	0.046(-7.49, .99)	0.035(-7.69, .79)	0.757(-3.74, 4.74)	* 0.008(-4.10, -.05)
Adduction	0.153(-4.14, 1.21)	0.048(-5.78, .78)	0.121(-5.23, 1.33)	0.103(-5.33, 1.23)	* 0.001(-3.56, -.42)
Flexion	0.298(-5.04, 2.17)	* 0.001(-10.21, -1.39)	0.032(-8.06, .76)	0.046(-7.81, 1.01)	* 0.000(-5.68, -1.46)
Extension	0.475(-3.58, 2.05)	0.104(-5.60, 1.30)	0.819(-3.75, 3.15)	0.447(-4.45, 2.45)	0.096(-2.71, .60)
Internal rotation	* 0.009(.07, 6.86)	0.140(-1.81, 6.51)	0.570(-3.26, 5.06)	0.025(-.56, 7.76)	* 0.001(.59, 4.57)
External rotation	* 0.008(-6.55, -.12)	* 0.001(-8.83, -.97)	0.038(-7.08, .78)	* 0.003(-8.43, -.57)	* 0.000(-5.85, -2.09)

*** statistically significant difference (p<0.01)**

Table 25: Difference between dominant and non dominant sides (p-values and 99% confidence interval) for shoulder, elbow and wrist active range of motions.

MOTIONS	ACTIVE 18-29	30-39	40-49	50-59	OVERALL
	p-value (99% confidence interval)				
Shoulder range of motion					
Abduction					
Glenohumeral abduction	0.683(-5.98, 8.18)	0.797(-9.52, 7.82)	0.423(-6.02, 11.32)	0.277(-5.07, 12.27)	0.305(-2.52, 5.77)
Shoulder complex abduction	0.976(-5.79, 5.92)	0.884(-6.77, 7.57)	0.596(-8.62, 5.72)	0.476(-9.12, 5.22)	0.575(-4.17, 2.70)
Flexion					
Glenohumeral flexion	0.582(-9.23, 6.03)	0.779(-10.35, 8.35)	0.747(-10.50, 8.20)	0.674(-10.85, 7.85)	0.442(-5.79, 3.16)
Shoulder complex flexion	0.754(-2.70, 3.43)	0.576(-4.56, 2.96)	0.210(-1.96, 5.56)	0.507(-2.81, 4.71)	0.399(-1.22, 2.38)
Extension					
Glenohumeral extension	0.242(-5.29, 2.02)	0.100(-7.30, 1.65)	0.015(-8.67, .27)	0.179(-6.77, 2.17)	* 0.001(-4.88, -.60)
Shoulder complex extension	0.052(-9.66, 1.40)	0.044(-12.02, 1.52)	0.756(-7.57, 5.97)	0.143(-10.57, 2.97)	* 0.006(-6.74, -.25)
Internal (medial) rotation					
Glenohumeral internal rotation	* 0.009(-12.14, -.13)	0.101(-11.98, 2.73)	0.012(-14.56, .16)	0.403(-9.71, 5.01)	* 0.000(-8.60, -1.55)
Shoulder complex internal rotation	0.114(-9.44, 2.31)	0.103(-11.70, 2.70)	0.022(-13.55, .85)	0.049(-12.65, 1.75)	* 0.000(-8.41, -1.52)
External (lateral) rotation					
Glenohumeral external rotation	0.012(-.18, 11.84)	0.132(-3.11, 11.61)	0.020(-.71, 14.01)	0.248(-4.11, 10.61)	* 0.000(1.47, 8.52)
Shoulder complex external rotation	* 0.000(3.87, 13.66)	0.029(-.95, 11.05)	0.023(-.75, 11.25)	0.057(-1.60, 10.40)	* 0.000(3.00, 8.74)
Elbow range of motion					
Flexion	0.107(-1.07, 4.54)	0.879(-3.24, 3.64)	0.468(-2.49, 4.39)	0.075(-1.09, 5.79)	0.039(-.34, 2.95)
Extension	0.671(-2.40, 1.73)	0.835(-2.33, 2.73)	0.121(-4.03, 1.03)	0.603(-3.03, 2.03)	0.243(-1.73, .66)
Pronation	0.136(-5.59, 1.52)	0.064(-7.46, 1.26)	0.321(-2.71, 6.01)	0.266(-6.21, 2.51)	0.096(-3.42, .75)
Supination	0.159(-6.37, 1.91)	0.235(-7.37, 2.77)	0.049(-8.92, 1.22)	0.061(-8.72, 1.42)	* 0.002(-5.44, -.58)
Wrist range of motion					
Flexion	0.309(-2.42, 5.48)	0.118(-1.94, 7.74)	0.245(-2.69, 6.99)	0.011(-.04, 9.64)	* 0.002(.53, 5.16)
Extension	* 0.006(-8.35, -.25)	0.171(-7.57, 2.37)	0.832(-5.37, 4.57)	* 0.005(-10.37, -.43)	* 0.001(-5.55, -.67)
Ulnar deviation	0.041(-6.36, .76)	0.786(-4.81, 3.91)	0.242(-6.31, 2.41)	0.049(-7.66, 1.06)	* 0.009(-4.21, -.04)
Radial deviation	* 0.000(-9.54, -1.59)	0.010(-9.77, -.03)	0.010(-9.77, -.03)	0.021(-9.22, .52)	* 0.000(-7.26, -2.60)

*** statistically significant difference ($p<0.01$)**

Table 26: Difference between dominant and non dominant sides (p-values and 99% confidence interval) for ankle, knee and hip passive range of motions.

MOTIONS	PASSIVE				
	18-29	30-39	40-49	50-59	OVERALL
	p-value (99% confidence interval)				
Ankle range of motion					
Dorsiflexion (talocrural joint)	0.070(-1.11, 6.25)	0.125(-1.86, 7.16)	0.541(-3.46, 5.56)	0.283(-2.66, 6.36)	0.015(-.13, 4.19)
Plantarflexion (talocrural joint)	0.144(-7.61, 2.15)	0.197(-8.93, 3.03)	0.102(-9.73, 2.23)	0.792(-6.58, 5.38)	0.023(-5.37, .35)
Eversion (tarsal joint)	0.653(-4.79, 3.39)	0.675(-4.21, 5.81)	0.793(-4.51, 5.51)	0.167(-2.36, 7.66)	0.374(-1.58, 3.21)
Inversion (tarsal joint)	0.083(-7.68, 1.55)	0.256(-8.10, 3.20)	0.944(-5.80, 5.50)	0.014(-.25, 11.05)	0.948(-2.77, 2.64)
Knee range of motion					
Flexion	0.033(-3.77, .37)	0.010(-5.08, -.02)	0.535(-3.13, 1.93)	0.081(-4.23, .83)	* 0.001(-2.85, -.42)
Extension	0.200(-4.56, 1.56)	0.294(-5.24, 2.24)	0.752(-4.19, 3.29)	0.674(-4.34, 3.14)	0.140(-2.81, .78)
Hip range of motion					
Abduction	0.591(-3.73, 2.46)	0.511(-4.74, 2.84)	0.130(-5.99, 1.59)	0.426(-4.94, 2.64)	0.077(-3.05, .58)
Adduction	0.609(-2.07, 3.07)	* 0.007(-6.44, -.16)	0.617(-3.74, 2.54)	0.867(-2.94, 3.34)	0.165(-2.31, .71)
Flexion	0.026(-.49, 6.56)	0.466(-5.51, 3.11)	0.563(-5.26, 3.36)	0.808(-3.91, 4.71)	0.683(-1.74, 2.39)
Extension	0.114(-4.51, 1.11)	0.304(-4.79, 2.09)	0.593(-2.74, 4.14)	1.000(-3.44, 3.44)	0.350(-2.23, 1.06)
Internal rotation	0.129(-1.44, 5.44)	0.036(-.81, 7.61)	0.732(-3.66, 4.76)	0.436(-2.96, 5.46)	0.021(-.22, 3.82)
External rotation	0.725(-3.67, 2.80)	0.974(-3.91, 4.01)	0.643(-3.26, 4.66)	0.017(-7.61, .31)	0.250(-2.73, 1.06)

*** statistically significant difference (p<0.01)**

Table 27: Difference between dominant and non dominant sides (p-values and 99% confidence interval) for shoulder, elbow and wrist passive range of motions.

MOTIONS	PASSIVE				
	18-29	30-39	40-49	50-59	OVERALL
	p-value (99% confidence interval)				
Shoulder range of motion					
Abduction					
Glenohumeral abduction	0.251(-3.28, 8.41)	0.714(-8.16, 6.16)	0.883(-6.76, 7.56)	0.442(-5.06, 9.26)	0.437(-2.41, 4.45)
Shoulder complex abduction	0.013(-7.27, .14)	* 0.004(-9.58, -.52)	0.506(-5.68, 3.38)	0.248(-6.53, 2.53)	* 0.001(-5.11, -.77)
Flexion					
Glenohumeral flexion	0.420(-4.80, 9.07)	0.242(-12.30, 4.70)	0.889(-8.05, 8.95)	0.029(-15.65, 1.35)	0.179(-6.16, 1.98)
Shoulder complex flexion	0.159(-5.52, 1.65)	0.283(-6.19, 2.59)	0.270(-2.54, 6.24)	0.928(-4.54, 4.24)	0.525(-2.61, 1.59)
Extension					
Glenohumeral extension	0.069(-7.37, 1.31)	0.078(-8.92, 1.72)	0.106(-8.62, 2.02)	0.091(-8.77, 1.87)	* 0.001(-5.89, -.80)
Shoulder complex extension	0.361(-5.29, 2.55)	* 0.002(-10.50, -.90)	0.128(-7.60, 2.00)	0.014(-9.35, .25)	* 0.000(-5.90, -1.31)
Internal (medial) rotation					
Glenohumeral internal rotation	* 0.000(-14.66, -3.34)	0.049(-12.19, 1.69)	* 0.001(-16.29, -2.41)	0.029(-12.79, 1.09)	* 0.000(-10.68, -4.04)
Shoulder complex internal rotation	0.055(-10.83, 1.63)	0.049(-13.41, 1.86)	* 0.009(-15.33, -.07)	* 0.006(-15.73, -.47)	* 0.000(-10.20, -2.89)
External (lateral) rotation					
Glenohumeral external rotation	* 0.001(1.42, 11.18)	0.677(-5.03, 6.93)	0.044(-1.33, 10.63)	0.878(-5.63, 6.33)	* 0.006(.20, 5.93)
Shoulder complex external rotation	0.025(-.69, 9.55)	0.503(-4.67, 7.87)	0.722(-5.42, 7.12)	0.403(-4.27, 8.27)	0.055(-.78, 5.22)
Elbow range of motion					
Flexion	0.142(-1.92, 6.85)	0.252(-3.02, 7.72)	0.591(-4.27, 6.47)	0.660(-6.27, 4.47)	0.202(-1.32, 3.82)
Extension	0.661(-2.33, 1.66)	0.071(-4.15, .75)	0.335(-3.35, 1.55)	0.335(-1.55, 3.35)	0.049(-2.07, .29)
Pronation	0.501(-2.61, 4.41)	0.057(-7.45, 1.15)	0.855(-4.00, 4.60)	0.951(-4.40, 4.20)	0.514(-2.57, 1.55)
Supination	0.083(-6.18, 1.24)	0.076(-7.64, 1.44)	0.028(-8.39, .69)	* 0.001(-10.29, -1.21)	* 0.000(-5.97, -1.62)
Wrist range of motion					
Flexion	0.441(-4.55, 2.49)	0.484(-3.16, 5.46)	0.465(-5.51, 3.11)	0.807(-3.91, 4.71)	0.828(-2.23, 1.89)
Extension	0.295(-5.25, 2.25)	0.034(-8.34, .84)	* 0.002(-10.14, -.96)	* 0.008(-9.29, -.11)	* 0.000(-6.07, -1.68)
Ulnar deviation	0.261(-4.66, 1.86)	0.450(-2.84, 5.14)	0.767(-4.44, 3.54)	0.063(-6.84, 1.14)	0.224(-2.80, 1.02)
Radial deviation	* 0.004(-6.03, -.37)	* 0.004(-7.42, -.48)	* 0.000(-10.67, -3.73)	* 0.000(-8.57, -1.63)	* 0.000(-6.52, -3.20)

*** statistically significant difference**

The results for the overall age groups (all age groups combined) for the differences between right and left and the difference between dominant and non dominant sides are presented on Table 28, 29 and 30.

Table 28: Difference between right and left sides and dominant and non dominant sides for the overall age group for active and passive ankle, knee and hip range of motion.

MOTIONS	STUDIES: dominant and non dominant	STUDIES: right and left
Ankle range of motion		
passive		
Dorsiflexion (talocrural joint)	x	difference p=0.005
Plantarflexion (talocrural joint)	x	difference p=0.002
Eversion (tarsal joint)	x	x
Inversion (tarsal joint)	x	x
active		
Dorsiflexion (talocrural joint)	x	x
Plantarflexion (talocrural joint)	non dominant greater p=0.001	difference p=0.000
Eversion (tarsal joint)	x	x
Inversion (tarsal joint)	x	x
Knee range of motion		
passive		
Flexion	dominant greater p=0.001	difference p=0.000
Extension	x	x
active		
Flexion	dominant greater p=0.001	difference p=0.000
Extension	x	x
Hip range of motion		
passive		
Abduction	x	x
Adduction	x	x
Flexion	x	x
Extension	x	x
Internal rotation	x	x
External rotation	x	x
active		
Abduction	dominant greater p=0.008	difference p=0.002
Adduction	dominant greater p=0.001	difference p=0.001
Flexion	x	difference p=0.000
Extension	x	x
Internal rotation	dominant greater p=0.001	difference p=0.001
External rotation	non dominant greater p=0.000	difference p=0.000

difference = statistical significant difference between right and left sides
dominant greater = statistical significant difference with dominant side greater than non dominant side
non dominant greater = statistical significant difference with non dominant side greater than dominant side
x = no statistical significant difference between sides
grey cells= the study perfomed a comparison between sides for that motion

Table 29: Difference between right and left sides and dominant and non dominant sides for the overall age group for active and passive shoulder range of motion.

MOTIONS	STUDIES: dominant and non dominant	STUDIES: right and left
Shoulder range of motion		
Abduction		
passive		
Glenohumeral abduction	x	x
Shoulder complex abduction	non dominant greater p=0.001	difference p=0.000
active		
Glenohumeral abduction	x	x
Shoulder complex abduction	x	x
Flexion		
passive		
Glenohumeral flexion	x	x
Shoulder complex flexion	x	x
active		
Glenohumeral flexion	x	x
Shoulder complex flexion	x	x
Extension		
passive		
Glenohumeral extension	non dominant greater p=0.001	difference p=0.000
Shoulder complex extension	non domimant greater p=0.000	difference p=0.002
active		
Glenohumeral extension	non dominat greater p=0.001	difference p=0.000
Shoulder complex extension	non dominant greater p=0.006	x
Internal (medial) rotation		
passive		
Glenohumeral internal rotation	non dominant greater p=0.000	difference p=0.000
Shoulder complex internal rotation	non dominant greater p=0.000	difference p=0.000
active		
Glenohumeral internal rotation	non dominant greater p=0.000	difference p=0.000
Shoulder complex internal rotation	non dominant greater p=0.000	difference p=0.000
External (lateral) rotation		
passive		
Glenohumeral external rotation	dominant greater p=0.006	difference p=0.005
Shoulder complex external rotation	x	difference p=0.007
active		
Glenohumeral external rotation	dominant greater p=0.000	difference p=0.000
Shoulder complex external rotation	dominant greater p=0.000	difference p=0.000

difference = statistical significant difference between right and left sides

dominant greater = statistical significant difference with dominant side greater than non dominant side

non dominant greater = statistical significant difference with non dominant side greater than dominant side

x = no statistical significant difference between sides

grey cells= the study perfomed a comparison between sides for that motion

Table 30: Difference between right and left sides and dominant and non dominant sides for the overall age group for active and passive elbow and wrist range of motion.

MOTIONS	STUDIES: dominant and non dominant	STUDIES: right and left
Elbow range of motion		
passive		
Flexion	x	x
Extension	x	x
Pronation	x	x
Supination	non dominant greater p=0.000	difference p=0.000
active		
Flexion	x	x
Extension	x	x
Pronation	x	x
Supination	non dominant greater p=0.002	difference 0.003
Wrist range of motion		
passive		
Flexion	x	x
Extension	non dominant greater p=0.000	difference p=0.000
Ulnar deviation	x	x
Radial deviation	non dominant greater p=0.000	difference p=0.000
active		
Flexion	non dominant greater p=0.002	x
Extension	non dominant greater p=0.001	difference p=0.001
Ulnar deviation	non dominant greater p=0.009	difference p=0.007
Radial deviation	non dominant greater p=0.000	difference p=0.000

difference = statistical significant difference between right and left sides
dominant greater = statistical significant difference with dominant side greater than non dominant side
non dominant greater = statistical significant difference with non dominant side greater than dominant side
x = no statistical significant difference between sides
grey cells= the study perfomed a comparison between sides for that motion

Further analysis of the amount of range of motion between women using contraceptives or not using contraceptives and also between menopausal women using hormonal replacement and not using replacement therapy were not performed in this study because there was not a significant sample size that would produce a significant power to support any results.

CHAPTER 5: DISCUSSION

5.1 PILOT STUDY

The results of this study showed only 6 measurements that had a reliability smaller than ICC <0.70. The movements were left active knee extension, left passive knee extension, left passive ankle inversion, right active ankle inversion, left passive eversion of the foot. These ICC were, however, greater than an ICC>0.60 and are considered poor to good. The SEM of these motions were smaller than 7.28 showing a small variability within subjects. This small variability is accepted by the literature as a standard error of measurement.[14,26,52,79] Therefore, the resultant small ICC found in this study might not represent a low reliability. According to the literature, the error due to bias or mistakes during ROM measurement can be as high as 7 degrees meaning that any change in range of motion of up to 7 degrees could be due only to a random error that is expected to happen during a range of motion measurement.

Based on the formula of ICC[61], one can analyze the findings for ICC found to be smaller than 0.70. For left passive eversion, right passive inversion, right active inversion and left active elbow flexion, the standard error of measurement was 4.70, 7.28, 4.12 and 5.81 respectively. These were one of the largest errors of measurement found in this study. According to the ICC formula when one increases measurement error, reliability decreases. These findings would not explain the low reliability of the left active and passive knee extension since they had errors of measurement of 2.52, 1.51 respectively. However, the knee extension movements were very similar between subjects leading to a low variability between subjects. This low variability can be seen in the results between subjects mean square values given by the F-test used in this study. In this case, according to the formula for the ICC, a decrease in the variability between subjects also decreases reliability. This second case can be considered as an artifact in the formula of ICC because the low reliability is probably due to a sampling bias and not from measurement error as seen in the first case.

5.2 MAIN STUDY

The present study was performed with the primary objective of creating a normative database for women range of motion. This study presented values for range of motion for upper and lower extremities (shoulder, elbow, wrist, hip, knee and ankle). The descriptive statistics of the range of motion values were described for the overall female population and for each age group separately. The groups were separated because of the suggestion in the literature that range of motion decreases with age. However, the findings of this study showed that only some movements had a significant difference of range of motion between age groups with the younger being greater than the older group. The findings of this study did not reveal that there was a consistent difference between right and left sides, and dominant and non-dominant sides in relation to all of the joints of the body. This study found that only some motions were significantly different between sides.

The values found in this study for Caucasian women ROM can contribute to the overall normative databases available in the literature. These values can be used to performed comparisons with injured sides, to compare with values used to establish risk factors for injuries and any other ROM comparisons. According to Brown[17] "Although one's placement in the normative ranking does not relate directly to disease or health status, knowledge of one's position to the population distribution may be useful for motivating behavioral change or evaluating individual improvement relative to that of the population" (p.77),

The values found in this study were not compared with the findings of ROM by other authors because most of the papers available in the literature used different methodologies and comparisons are inappropriate. The use of different methodology itself could lead to different values of ROM making comparisons inappropriate. However a comparison with the values found by Boone[13], the most cited normative range of motion data base for male subjects, was performed to see if there was a trend for a difference in the values between men and women. There were 24 comparable motions and comparisons were performed with active ROM of the overall age group population of this study. Women had all motions greater than men for the elbow. Almost all of the ankle, shoulder and wrist motion were greater in women while men had greater hip ROM (see Table 31). It is important to remember that this comparison should be looked at with caution because the measurements were taken with different protocols. For the 24 motions tested in the present study, men had greater ROM in 29% of the cases and there was no difference between men and women in 9% of the cases.

Table 31: Comparison between the results found for Boone[13] in male subjects and the results of this study that was performed in female subjects.

Motions	Active ROM	
	Boone 1979	Present study
Shoulder Complex		
abduction	182.7 (4.9)	187.4 (16.0)
flexion	165.0 (5.0)	184.5 (9.5)
extension	57.3 (8.1)	55.2 (12.7)
internal rotation	67.1 (4.1)	90.7 (13.5)
external rotation	99.6 (7.6)	99.4 (11.5)
Elbow		
flexion	140.5 (4.9)	146.7 (6.3)
extension	0.3 (2.7)	3.1 (4.8)
pronation	75 (5.3)	90.8 (8.1)
supination	81.1 (4.0)	93.9 (10.6)
Wrist		
flexion	74.8 (6.6)	86.0 (8.3)
extension	74.0 (6.6)	74.1 (11.3)
radial deviation	21.1 (4.0)	19.9 (8.4)
ulnar deviation	35.3 (3.8)	41.9 (7.6)
Hip		
flexion	121.1 (6.4)	116.8 (12.4)
extension	12.1 (5.4)	12.4 (5.3)
abduction	40.5 (6.0)	62.6 (8.2)
adduction	25.6 (3.6)	14.6 (7.9)
internal rotation	44.4 (4.3)	34.5 (7.4)
external rotation	44.2 (4.8)	24.8 (6.9)
Knee		
flexion	141.2 (5.3)	141.1 (6.2)
Ankle		
plantarflexion	54.3 (5.9)	56.7 (17.2)
dorsiflexion	12.2 (4.1)	9.8 (8.6)
inversion	36.2 (4.2)	44.6 (9.6)
eversion	19.2 (4.9)	28.2 (11.9)

An important finding during the range of motion measurements was related to the active range of motion of the glenohumeral joint. Like any other active range of motion, the amount of range of motion found is dependant on the strength of the subject and their capacity to hold the joint at the end of range. However when measuring the active glenohumeral ROM, the strength was related to the capacity of the scapular muscles to stabilize the scapula, since the movements were performed until there was a movement on the scapula. It was crucial that the subjects were capable of holding the scapula steady. In this case, the actual construct being measured was the strength of the scapular stabilization muscles and the ROM values were solely dependant on this factor.

The results of this study regarding the difference of range of motion between age groups showed that there were some motions that decreased with age. These results conflict with some findings in the literature that suggest that all motions decrease with age.[53,79] Some studies[41,79] involving older populations tended to conclude that there was a decrease in ROM with age when comparing their findings with previous findings in the literature. However, the range of motion of different studies might have been measured with different techniques and comparisons might be inappropriate.[79] Another point is that these comparisons are often done with the values from the AAOS that have been found to overestimate the ROM values.[53]

Some authors have found that only some shoulder movements were affected by age.[9,13] However, in this study, only shoulder external rotation showed a difference between age groups and the ankle, hip and elbow also showed differences between age groups.

This study showed that of the motions in which a decrease with age was found, the difference was greatest when comparing the 18 to 29 group and the 50 to 59 group. The difference found between these age groups could lead one to the conclusion that there is a gradual decrease in these motions that can only be seen when these changes are looked at throughout all the decades combined. There was no statistically significant difference in ROM between age groups when comparing groups that were closer in age, but there was a significant difference when comparing the younger group (18-29) with the older age group (50-59).

There is still a question as to why there was a decrease in ROM only in some specific joint motions with age and whether this difference was a true difference. Since there was not a general decrease in ROM seen in consecutive age groups, it seems that the changes in the collagen tissue with age are not the major cause of the decrease in ROM. Postures adopted by the population and daily life activities are important factors that may be responsible for the decrease in ROM. Hip flexion, hip external rotation, shoulder external rotation and elbow extension were motions that presented with a greatest decrease in ROM with age. If one takes into consideration the position adopted by most people for many hours per day, sitting in front of the computer or a desk, with shoulder protrusion and elbow flexion, one could expect that as the years pass, there would be a decrease in range of motion of the motions found decreased in this study. On the other hand, aside from the physiological explanation, there have been suggestions that the changes are totally related to random findings.[13]

The hypothesis that there would be a difference of active and passive range of motions with the younger age having greater range of motion was confirmed for some range of motions. This hypothesis was true for: hip flexion, hip external rotation, shoulder external rotation and elbow extension especially when comparing the younger group (18-29) with the older group (50 to 59).

The findings of this study regarding the difference between right and left sides are similar to previous findings that found that only some motions were different between sides. However, when comparing the differences between the literature and this present study, only some movements had similar results. There were five studies in total that compared the ROM between right and left sides[3,13,38,64,72] and each study measured different joints and different motions. The results of these studies for the difference between sides and the results of this study for the overall age group (mean between all age groups) are presented in Table 32, 33 and 34.

Three studies compared right and left sides of ankle ROM (one passive and two active), two studies compare right and left sides of knee ROM (one active and one passive) and three studies compared right and left sides of hip ROM (2 active and 1 passive). None of these studies found a significant difference between right and left sides that differed from the findings of this study that found some of the ankle, knee and hip motions to be significantly different between right and left sides.

Three studies compared the right and left sides of shoulder ROM (two active and one active and passive). Only one study found a significant difference between shoulder right and left sides. The findings that coincided with the findings of this study were for passive and active shoulder complex internal rotation and passive and active shoulder complex external rotation that were significant different between sides.

There were 2 studies that compared the difference between right and left sides for elbow ROM (one active and one active and passive) and 3 studies that compared sides for wrist ROM (two active and one active and passive). Only one study found a significant difference between elbow right and left sides. The motions that had similar results with this present study were passive and active supination, passive and active wrist extension and passive and active radial deviation.

The results of this study did not confirm the hypothesis that there would not be a difference in range of motion between right and left sides because there was a significant difference in range of motion between sides for: passive dorsiflexion, active and passive plantar flexion, active and passive knee flexion, active hip abduction, active hip adduction, active hip flexion, active hip internal rotation, active hip external rotation, passive shoulder complex abduction, active and passive glenohumeral extension, passive shoulder complex extension, active and passive shoulder complex and glenohumeral internal and external rotation, active and passive supination, active and passive wrist extension, active and passive wrist radial deviation and active wrist ulnar deviation.

According to the results of this study and previous findings in the literature, there is a tendency for the active and passive shoulder complex internal rotation, shoulder complex external rotation, supination, wrist extension and radial deviation to be different between right and left sides.

Table 32: Results for statistically significant difference between right and left sides for ankle, knee and hip motions.

MOTIONS	STUDIES					
	This study	Gunal 1996	Stephanyshyn 1993	Allander 1974	Boone 1979	Roaas 1982
Ankle range of motion						
passive						
Dorsiflexion (talocrural joint)	difference p=0.005					x
Plantarflexion (talocrural joint)	difference p=0.002					x
Eversion (tarsal joint)	x					x
Inversion (tarsal joint)	x					x
active						
Dorsiflexion (talocrural joint)	x		x		x	
Plantarflexion (talocrural joint)	difference p=0.000		x		x	
Eversion (tarsal joint)	x		x		x	
Inversion (tarsal joint)	x		x		x	
Knee range of motion						
passive						
Flexion	difference p=0.000					x
Extension	x					x
active						
Flexion	difference p=0.000				x	
Extension	x					
Hip range of motion						
passive						
Abduction	x					x
Adduction	x					x
Flexion	x					x
Extension	x					x
Internal rotation	x					x
External rotation	x					x
active						
Abduction	difference p=0.002				x	
Adduction	difference p=0.001				x	
Flexion	difference p=0.000				x	
Extension	x				x	
Internal rotation	difference p=0.001			x	x	
External rotation	difference p=0.000				x	

difference = statistical significant difference between right and left sides
x = no statistical significant difference between right and left sides
grey cells= the study perfomed a comparison between right and left sides for that motion

Table 33: Results for statistically significant difference between right and left sides for shoulder motions.

MOTIONS	This study	Gunal 1996	Stephanyshyn 1993	Allander 1974	Boone 1979	Roaas 1982
	STUDIES					
Shoulder range of motion						
Abduction						
passive						
Glenohumeral abduction	x					
Shoulder complex abduction	difference p=0.000	x				
active						
Glenohumeral abduction	x	difference p<0.001				
Shoulder complex abduction	x	x			x	
Flexion						
passive						
Glenohumeral flexion	x					
Shoulder complex flexion	x					
active						
Glenohumeral flexion	x					
Shoulder complex flexion	x				x	
Extension						
passive						
Glenohumeral extension	difference p=0.000					
Shoulder complex extension	difference p=0.002					
active						
Glenohumeral extension	difference p=0.000					
Shoulder complex extension	x				x	
Internal (medial) rotation						
passive						
Glenohumeral internal rotation	difference p=0.000					
Shoulder complex internal rotation	difference p=0.000	difference p< 0.001				
active						
Glenohumeral internal rotation	difference p=0.000					
Shoulder complex internal rotation	difference p=0.000	difference p<0.001			x	
External (lateral) rotation						
passive						
Glenohumeral external rotation	difference p=0.005					
Shoulder complex external rotation	difference p=0.007	difference p<0.01				
active						
Glenohumeral external rotation	difference p=0.000					
Shoulder complex external rotation	difference p=0.000	difference p<0.01		x	x	

difference = statistical significant difference between right and left sides
x = no statistical significant difference between right and left sides
grey cells= the study perfomed a comparison between right and left sides for that motion

Table 34: Results for statistically significant difference between right and left sides for elbow and wrist motions.

MOTIONS	STUDIES: This study	Gunal 1996	Stephanyshyn 1993	Allander 1974	Boone 1979	Roaas 1982
Elbow range of motion						
passive						
Flexion	x	difference p<0.001				
Extension	x	difference p<0.001				
Pronation	x					
Supination	difference p=0.000	difference p<0.001				
active						
Flexion	x	difference p<0.001			x	
Extension	x	difference p<0.001			x	
Pronation	x				x	
Supination	difference 0.003	difference p<0.05			x	
Wrist range of motion						
passive						
Flexion	x					
Extension	difference p=0.000	difference p<0.001				
Ulnar deviation	x					
Radial deviation	difference p=0.000	difference p<0.001				
active						
Flexion	x				x	
Extension	difference p=0.001	difference p<0.001		x	x	
Ulnar deviation	difference p=0.007				x	
Radial deviation	difference p=0.000	difference p<0.001			x	

difference = statistical significant difference between right and left sides
x = no statistical significant difference between right and left sides
grey cells= the study perfomed a comparison between right and left sides for that motion

The results of the difference between dominant and non dominant sides were similar from the results for right and left sides. The results of this study were also similar to the results in the literature because it was found that only some motions had a difference between dominant and non dominant sides. It seems that there are some motions greater on the dominant side and some motions greater on the non dominant side. Four studies in the literature were found that compared the ROM between dominant and non dominant sides (one active and three active and passive).[9,27,38,54] Each study compared the sides for different joints and different motions. The results of these studies for the difference between dominant and non dominant sides and the results of this present study for the overall age group (mean between all age groups) are presented in Table 35, 36 and 37.

There were no papers that compared the dominant and non dominant sides for the ankle, knee and hip joints. There were 4 studies that compared the dominant and non dominant sides for shoulder ROM. The findings that were similar to the findings of this present study were passive and active shoulder complex extension, passive and active shoulder complex internal rotation and active glenohumeral internal rotation and active shoulder complex external rotation. According to these findings, there is a tendency for active glenohumeral internal rotation, active and passive shoulder complex internal rotation and shoulder complex extension to be greater on the non dominant side and for active shoulder complex external rotation to greater on the dominant side.

Some authors have talked about the decrease in range of motion of the internal rotators of the shoulder compared to the external rotators.[9,27] Barnes[9] said that these findings, even though they were found in specific athletic populations such as tennis players and swimmers, and although the results seemed to be related to the type of activity, might also be present in a global population. In his study, Barnes[9] found that the normal non athletic population also had a decrease in the amount of shoulder internal rotation range of motion. The findings of the present study support this conclusion.

There was only one study that compared the dominant and non dominant sides for elbow and wrist ROM (active and passive)[38]. This author had similar results with the present study for active and passive supination, wrist extension and radial deviation where the non dominant side was significant greater than the dominant side.

The results of this study did not confirm the hypothesis that there would not be a difference in range of motion between dominant and non dominant sides because there was a significant difference in range of motion between sides for: active plantar flexion, active and passive knee flexion, active hip abduction, active hip adduction, active hip internal rotation, active hip external rotation, passive shoulder complex abduction, active and passive shoulder complex and glenohumeral extension, active and passive shoulder complex and glenohumeral internal rotation, active and passive glenohumeral external rotation, active shoulder complex external rotation, active and passive supination, active wrist flexion, active and passive wrist extension, active and passive wrist radial deviation and active wrist ulnar deviation.

According to the results of this study and previous findings in the literature, there is a tendency for the active and passive shoulder complex internal rotation, active glenohumeral internal rotation, active and passive shoulder complex extension, active and passive supination, active and passive wrist extension and active and passive radial deviation to be greater on the non dominant side and for active shoulder complex external rotation to be greater on the dominant side.

The differences between right and left sides and dominant and non dominant sides were similar except for shoulder complex extension which was found to be greater on the non dominant side. The similarity between the findings occurred because only 8 subjects of the 90 in the present study had dominance in the left hand and only 4 of the 90 subjects were dominant in the left leg. For each age group, there were 2 people who had dominance in the left hand and 1 person with dominance in the left leg.

It has been suggested that the changes occurring between sides are related to overuse of the joints and that the changes occurring between sides are due to over stress in the tissue that would lead to micro injuries, the presence of scar tissue and consequently, reduction in the amount of range of motion.[3] If one takes into consideration the movements that are significantly greater on the dominant side in the present study and the previous studies, it is noticeable that they are motions performed constantly throughout daily life activities especially on the dominant side. The only movement that was greater on the dominant side was the shoulder complex external rotation. This change can be explained by the constant shoulder internal rotation movement performed with the dominant arm that would put the internal rotators in a shortened position, reducing over time the amount of shoulder complex external rotation ROM.

Table 35: Results for statistically significant difference between dominant and non dominant sides for ankle, knee and hip motions.

MOTIONS	STUDIES This study	Gunal 1996	Murray 1985	Barnes 2001	Ellenbecker 1992
Ankle range of motion					
passive					
Dorsiflexion (talocrural joint)	x				
Plantarflexion (talocrural joint)	x				
Eversion (tarsal joint)	x				
Inversion (tarsal joint)	x				
active					
Dorsiflexion (talocrural joint)	x				
Plantarflexion (talocrural joint)	non dominant greater p=0.001				
Eversion (tarsal joint)	x				
Inversion (tarsal joint)	x				
Knee range of motion					
passive					
Flexion	dominant greater p=0.001				
Extension	x				
active					
Flexion	dominant greater p=0.001				
Extension	x				
Hip range of motion					
passive					
Abduction	x				
Adduction	x				
Flexion	x				
Extension	x				
Internal rotation	x				
External rotation	x				
active					
Abduction	dominant greater p=0.008				
Adduction	dominant greater p=0.001				
Flexion	x				
Extension	x				
Internal rotation	dominant greater p=0.001				
External rotation	non dominant greater p=0.000				

dominant greater = statistical significant difference with dominant side greater than non dominant side

non dominant greater = statistical significant difference with non dominant side greater than dominant side

x = no statistical significant difference between sides

grey cells= the study perfomed a comparison between sides for that motion

Table 36: Results for statistically significant difference dominant and non dominant sides for shoulder motions.

MOTIONS	STUDIES: This study	Gunal 1996	Murray 1985	Barnes 2001	Ellenbecker 1992
Shoulder range of motion					
Abduction					
passive					
Glenohumeral abduction	x				
Shoulder complex abduction	non dominant greater p=0.001	x		x	
active					
Glenohumeral abduction	x	non dominant greater p<0.001			
Shoulder complex abduction	x	x	x	x	
Flexion					
passive					
Glenohumeral flexion	x				
Shoulder complex flexion	x			x	
active					
Glenohumeral flexion	x				
Shoulder complex flexion	x		x	x	
Extension					
passive					
Glenohumeral extension	non dominant greater p=0.001				
Shoulder complex extension	non dominant greater p=0.000			non dominant greater p=0.013	
active					
Glenohumeral extension	non dominat greater p=0.001				
Shoulder complex extension	non dominant greater p=0.006		x	non dominant greater p<0.01	
Internal (medial) rotation					
passive					
Glenohumeral internal rotation	non dominant greater p=0.000				
Shoulder complex internal rotation	non dominant greater p=0.000	non dominant greater p<0.001		dominant greater p<0.01	non dominant greater p<0.01
active					
Glenohumeral internal rotation	non dominant greater p=0.000			dominant greater p<0.01	
Shoulder complex internal rotation	non dominant greater p=0.000	non dominant greater p<0.001	x		
External (lateral) rotation					
passive					
Glenohumeral external rotation	dominant greater p=0.006				
Shoulder complex external rotation	x	non dominant greater p<0.01		dominant greater p<0.01	
active					
Glenohumeral external rotation	dominant greater p=0.000				
Shoulder complex external rotation	dominant greater p=0.000	non dominant greater p<0.01	dominant greater p<0.01	dominant greater p<0.01	dominant greater p<0.05

dominant greater = statistical significant difference with dominant side greater than non dominant side
non dominant greater = statistical significant difference with non dominant side greater than dominant side
x = no statistical significant difference between sides
grey cells= the study perfomed a comparison between sides for that motion

Table 37: Results for statistically significant difference between dominant and non dominant sides for elbow and wrist motions.

MOTIONS	STUDIES				
	This study	Gunal 1996	Murray 1985	Barnes 2001	Ellenbecker 1992
Elbow range of motion					
passive					
Flexion	x	non dominant greater $p<0.001$			
Extension	x	non dominant greater $p<0.001$			
Pronation	x				
Supination	non dominant greater $p=0.000$	non dominant greater $p<0.001$			
active					
Flexion	x	non dominant greater $p<0.001$			
Extension	x	non dominant greater $p<0.001$			
Pronation	x				
Supination	non dominant greater $p=0.002$	non dominant greater $p<0.05$			
Wrist range of motion					
passive					
Flexion	x				
Extension	non dominant greater $p=0.000$	non dominant greater $p<0.001$			
Ulnar deviation	x				
Radial deviation	non dominant greater $p=0.000$	non dominant greater $p<0.001$			
active					
Flexion	non dominant greater $p=0.002$				
Extension	non dominant greater $p=0.001$	non dominant greater $p<0.001$			
Ulnar deviation	non dominant greater $p=0.009$				
Radial deviation	non dominant greater $p=0.000$	non dominant greater $p<0.001$			

dominant greater = statistical significant difference with dominant side greater th

non dominant greater = statistical significant difference with non dominant side greater than dominant side

x = no statistical significant difference between sides

grey cells= the study perfomed a comparison between sides for that motion

Another point to consider regarding the comparisons between sides is that the mean differences between sides (the mean of the differences between right and left sides and the mean of the differences between dominant and non dominant sides) for the motions that were significantly different varied from about 3 to 7 degrees. These values fall within the measurement error that is acceptable for the goniometric measurements. Measurement errors have been found in the literature to fall around 7 degrees and the higher error of measurement (SEM) found in this study was 7.28. For this reason, all of the comparisons between sides performed in this study should be observed with caution because they could be related to measurement error. On the other hand, these differences that are smaller than seven degrees might be significantly different but not clinically significant. For example, active shoulder complex internal rotation was found to be significantly different between dominant and non dominant sides. This difference was of 5 degrees for a motion of 90 degrees, less than 6% of the total range available in the joint. Is a change of this length important enough that it would be a risk factor for injury or decrease functionality of a joint? There have been studies that suggested that a decrease in range of motion is related to risk factors for injuries. [23,78] However, there still needs to be more studies to determine if this correlation is true and also how big a difference is necessary to influence the functionality of the joint and be a risk factor for injuries. Similarly, there is still the question as to what the clinical implications are for the motions that decrease ROM with age and how these changes and how many degrees of ROM are necessary to decrease to influence the functionality of a joint.

Post hoc power calculation demonstrated a low power (less than 0.80) for the majority of the comparisons between age groups. However, movements that were significantly different between age groups had greater power than the movements with no significant difference between groups (power ranging from 0.64 to 0.96). The comparisons between body sides also had a low power for the majority of the comparisons, with power being greater for the movements with a statistically significant difference. The power for the movements with statistically significant differences between sides ranged from 0.52 to 1. When results are significantly different, the effect size is greater leading to a larger power. However, when there is no significant difference, the effect sizes are smaller and the chance of getting a large power is low. Therefore, results of post hoc power calculation for non statistically significant difference have to be looked at with caution because only with a very large sample size would there be a good power and in the majority of the cases, it is unviable to collect a sample size this large.

The results of this study have to be viewed with caution because of the small power, small sample size and large error of measurement given by the goniometer. More studies with larger sample sizes, literature reviews, and meta analysis are needed to confirm the results of this study and exclude the hypothesis of random error.

CHAPTER 6: CONCLUSION

This study presented a normative database for Caucasian women range of motion of the ankle, knee, hip, shoulder, elbow and wrist that can be used as a reference for research and in the clinic. According to this study, there was not a significant difference between age groups in the majority of the cases. There seemed to be a gradual decrease in ROM with age throughout the decades for some motions. Even though there was no significant difference between all age groups for these motions, a trend of a decrease in ROM could be seen and a significant difference was present when comparing the younger age group with the older age group. These findings allow one to conclude that there is a trend of decreasing ROM with age for active and passive hip flexion, passive hip external rotation, active and passive glenohumeral external rotation, active shoulder complex external rotation and active elbow extension. These changes could be related with the functional activities performed and postures adopted throughout the years, however, more research still needs to be done to confirm this possibility.

The results of this study regarding the difference between right and left and dominant and non dominant sides were similar because of the small amount of women with left dominant hand or foot. Comparing the results of this study with the results of previous studies in the literature can lead one to the conclusion that there is a significant difference between right and left sides for active and passive shoulder complex internal rotation, shoulder complex external rotation, supination, wrist extension and radial deviation. Active and passive shoulder complex internal rotation, active glenohumeral internal rotation, active and passive shoulder complex extension, active and passive supination, active and passive wrist extension and active and passive radial deviation are greater on the non dominant side and active shoulder complex external rotation are greater on the dominant side. These differences seem to be related to overuse and functional activities but further research to confirm this hypothesis is still needed. The result of this study regarding difference between sides leads one to the conclusion that there is a significant difference between sides for some specific ROM, however, the clinical application of these changes is still questionable.

The conclusions of this study are:

1. There was no general statistical difference of active and passive range of motion with the younger groups having greater range of motion than the older groups as proposed by the hypothesis of this study. However, some movements had a statistically significant decrease of range of motion with age. For these motions the range of motion had a trend to decrease with age between each age group but the difference was not statistically different between all age groups. The only statistical significance was for: hip flexion, hip external rotation, shoulder external rotation and elbow extension especially when comparing the younger group (18-29) with the older group (50 to 59).
2. There was a significant difference in range of motion between right and left sides sides for most of the movements, specifically: passive dorsiflexion, active and passive plantar flexion, active and passive knee flexion, active hip abduction, active hip adduction, active hip flexion, active hip internal rotation, active hip external rotation, passive shoulder complex abduction, active and passive glenohumeral extension, passive shoulder complex extension, active and passive

shoulder complex and glenohumeral internal and external rotation, active and passive supination, active and passive wrist extension, active and passive wrist radial deviation and active wrist ulnar deviation.

3. The was a significant difference between dominant and non dominant sides for most of the movements specifically: active plantarflexion, active and passive knee flexion, active hip abduction, active hip adduction, active hip internal rotation, active hip external rotation, passive shoulder complex abduction, active and passive shoulder complex and glenohumeral extension, active and passive shoulder complex and glenohumeral internal rotation, active and passive glenohumeral external rotation, active shoulder complex external rotation, active and passive supination, active wrist flexion, active and passive wrist extension, active and passive wrist radial deviation and active wrist ulnar deviation.

6.1 STRENGTHS OF THE STUDY

The standardized protocol used in this study adds strength to the results. It is known that to increase reliability of range of motion measurements and guarantee comparability of the values, the use of a well standardized protocol is necessary. The use of a well defined population of Caucasian women permitted the inclusion of less confounders in the study which adds strength to the study.

6.2 WEAKNESSES OF THE STUDY

The low reliability of some range of motion measurements could have influenced the results of the range of motion found in the tested joints. Since this reliability was tested before the beginning of the study, extra caution was taken when measuring these specific motions. However, the goniometric measurements consist of subjective steps like palpation and end feel sensation and are hard to control.

The population of the study involving only Caucasian women can also, be considered a weakness since the results can not be generalized to the entire population. Also, a convenience sample was used consisting primarily of a population attending the University of Alberta. This sample could have influenced the results of the study because this population does not necessarily represent a broad spectrum of the total population. One can also observe that some age groups have more people in the lower age groups and others in the higher age groups. Also, there is a difference in height and type of occupation between groups. These unbalanced groups could have added confounders to the study since they might influence range of motion and consequently to misleading results.

There are many factors that can influence range of motion. Some were controlled in this study (i.e. temperature, previous injuries, therapists and subjects positions during the measurements). However, there could factors that potentially influence range of motion and have not been cited on the literature and were not controlled on this study.

A low post hoc power found in this study for some of the comparisons performed can also be considered a weakness of the study. Statistically significant differences have low generalizability when there is a small power to support the conclusions.

6.3 DIRECTIONS FOR FUTURE RESEARCH

Future research related to range of motion measurements are still needed to ensure a better understanding of this important variable. A prospective study following the range of motion of the same subjects from younger to older ages would give more information about the gradual changes happening in range of motion throughout the years. Studies that compared the range of motion between races are necessary to confirm if there is a difference in range of motion between races. Studies with a bigger population of men and women are still needed to test the hypothesis that women have greater range of motion than men. More clinical studies are also needed to test the clinical importance of the changes in range of motion and to determine if range of motion is a risk factor for muscle injuries and how big these changes have to be to be considered a risk factor.

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APPENDIX 1

Types of End Feel

End-feel classification systems

	Cyriax	Kaltenborn	Paris
Normal	1. Capsular *	1. Soft	1. Soft Tissue approximation
	2. Bone-to-bone *	2. Firm	2. Muscular
	3. Tissue approximation	3. Hard	3. Ligamentous
			4. Cartilaginous
			5. Capsular
Abnormal-Pathologic	1. Capsular * early in range	An end-feel "that occurs at another	6. Capsular (chronic/acute)
			7. Adhesions and scarning
	2. Bone-to-bone *	place or is of another	
	4. Spasm	quality than is charactherirstic	8. Bony block
	5. Springy block	for the joint being tested"	9. Bony grate
	6. Empty		10. Springy rebound
			11. Pannus
			12. Loose
			13. Empty
			14. Painful
			15. Muscle

*Capsular and bone-to-bone end-feels can be normal or abnormal-pathologic, depending on the motion and the point in the range at which they occur

Table 1 from Petersen, C. M. H., K.W.: Construct validity of Cyriax's selective tissue examination: association of end-feels with pain at the knee and shoulder. *J. Orthop. Sports. Phys. Ther.,* 30: 512-521, 2000.[59]

APPENDIX 2

Information letter to subjects

Title of the research project:

NORMAL RANGE OF MOTION OF JOINTS IN FEMALE SUBJECTS IN DIFFERENT AGE GROUPS

Researcher:

Luciana Macedo, Master of Science in Physical Therapy student at the University of Alberta under the supervision of Dr. D. Magee, Professor in the Department of Physical Therapy, Faculty of Rehabilitation Medicine at the University of Alberta.

Purpose/ Background:

Range of motion (ROM) is one of the most common measurements used in rehabilitation medicine. It is used to evaluate treatments in the clinical and research field. It helps in diagnosis and it helps to assess risk factors for injuries. Normal data for ROM is important when treating, tracing goals for treatments, comparing groups of subjects and doing research. There are no good quality studies of normal data for range of motion on woman. Thus the purpose of this study is to develop some normal data of active and passive ROM in woman in 4 age groups. The joints to be measure are the shoulder, elbow, wrist, hip, knee and ankle.

Procedure:

The procedure of this study will be performed on one day taking about 2 hours. If you participate, you will need to come to the lab wearing shorts, sports bra, tank top or t-shirt with no sleeves. The examiner will have to see the skin over your shoulder, elbow, hip, knee and ankle. You will be asked other questions to make sure that you can be included in the study. You will be asked your age, occupation and level of physical activity. You will be asked which limb you throw a ball with and which foot you kick a ball with. You will also be asked if you use hormonal contraceptives, hormone replacement therapy or if you had been pregnant. These questions are important as these factors could influence ROM. Your height and weight will be measured. After you answer these questions, your body temperature will be measured. An oral thermometer will be used. The temperature will be measured to be sure it is within the normal range (36.1 to 37.8 Celsius). Once your body temperature is found to be in the normal range, the ROM will be measured. The ROM of the hip, knee, ankle, shoulder, elbow and wrist will be measured in a randomly selected order. During the measurements you will be asked to sit or lie facing up or down depending on the measurement being taken. Several movements will be performed to each joint. The movements will go all the way to the end of your ROM. Some of these movements will be done by the examiner. Similar movements will be done actively by you. During some of these motions, the examiner will have put one of her hands over your limbs, pelvis or back to avoid movements that could cause the measurement to be incorrect. For each movement you will be asked to hold the position of the end of ROM for a few seconds, while the measurement is taken. The instrument used to measure ROM is the goniometer and looks like a plastic ruler.

Benefits/ risks:

Your participation in this research will help us to create normal data for ROM in women. In the future, it will help people who have musculoskeletal problems. This normal data will be also useful for clinical and research field. No risks are involved related to the procedure itself. The movements that will be performed will not hurt you in any way. You may feel some stretching at the end of the movement. If this happens it would be only temporary until the measurement is completed.

Privacy/ confidentiality:

All data will be kept private. The data you give will be kept for at least 5 years after the study is completed. The data will be kept in a safe area (i.e. a locked filing cabinet). Your name or any other identifying data will not be attached to the data collected on your test. Your name will never be used in any presentations or publications related of the study results. The data from this study may be looked at again in the future to help us answer other study questions. If so, an ethics board will first review the study to make sure that the data are used ethically.

Freedom to withdraw

Your participation is completely voluntary. If at any time you wish to withdraw you are completely free to do so.

Contact information

If you have any questions, concerns or complaints regarding the study and procedures, please feel free to contact Dr. Paul Hagler (492-9674), Associate Dean – Research in the Faculty of Rehabilitation Medicine.

Department of Physical Therapy
Faculty of Rehabilitation Medicine
University of Alberta
3-50 Corbett Hall
Edmonton- Canada
T6G2G4
Phone: Luciana Gazzi Macedo (780-492-4824)
Dr. David Magee (780-492-5765)

APPENDIX 3

Subject consent form

Title of Project: Normal range of motion of joints in female subjects Part 1: Researcher Information		
Name of Principal Investigator: Dr. David Magee Affiliation: Physical Therapy Contact Information: 780 – 492-5765		
Name of Co-Investigator: Luciana Gazzi Macedo Affiliation: Graduate Student, Department of Physical Therapy Contact Information: 780 – 492-4824		
Part 2: Consent of Subject		
	Yes	**No**
Do you understand that you have been asked to be in a research study?		
Have you read and received a copy of the attached information sheet?		
Do you understand the benefits and risks involved in taking part in this research study?		
Have you had an opportunity to ask questions and discuss the study?		
Do you understand that you are free to refuse to participate or withdraw from the study at any time? You do not have to give a reason and it will not affect your care.		
Has the issue of confidentiality been explained to you? Do you understand who will have access to your records/information?		
Part 3: Signatures		
I have read the information sheet and this study was explained to me by: ______________________________ Date: ______________________________		
I agree to take part in this study. Signature of Research Participant: ____________________ Printed Name: ______________________________		
Witness (if available): ______________________________ Printed Name: ______________________________		
I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate. *Researcher:* ______________________________ *Printed Name:* ______________________________ ______________________________ * *A copy of this consent form must be given to the subject.*		

APPENDIX 4

Ethics approval

Health Research Ethics Board

213 Heritage Medical Research Centre
University of Alberta, Edmonton, Alberta T6G 2S
p.780.492.9724 (Biomedical Panel)
p.780.492.0302 (Health Panel)
p.780.492.0459
p.780.492.0839
f.780.492.7808

July 13, 2005

Dr. David Magee
Physical Therapy
3-50 Corbett Hall

File# B-470605

Dear Dr. Magee,

Re: Normal Range of Motion of Joints in Female Subjects in Different Age Groups

Thank you for Ms. Luciana Macedo's correspondence of July 13th, 2005, which addressed the requested changes to the above-mentioned study. These revisions have been reviewed and approved on behalf of the Research Ethics Board. Your approval letter is attached.

Next year, a few weeks prior to the expiration of your approval, a Progress Report will be sent to you for completion. If there have been no major changes in the protocol, your approval will be renewed for another year. All protocols may be subject to re-evaluation after three years.

For studies where investigators must obtain informed consent, signed copies of the consent form must be retained, and be available on request. They should be kept for the duration of the project and for a full calendar year following its completion.

Approval by the Health Research Ethics Board does not encompass authorization to access the patients, staff or resources of Capital Health or other local health care institutions for the purposes of research. Enquiries regarding Capital Health administrative approval, and operational approval for areas impacted by research, should be directed to the Capital Health Regional Research Administration office, #1800 College Plaza, phone 407-6041.

Sincerely,

Charmaine N. Kabatoff
Administrative Coordinator
Health Research Ethics Board (Panel B)

UNIVERSITY OF ALBERTA   Capital Health   CARITAS HEALTH GROUP

213 Heritage Medical Research Centre
University of Alberta, Edmonton, Alberta T6G 2S2
p.780.492.9724 (Biomedical Panel)
p.780.492.0302 (Health Panel)
p.780.492.0459
p.780.492.0839
f.780.492.7808

HEALTH RESEARCH ETHICS APPROVAL FORM

Date: June 2005

Name of Applicant: Dr. David Magee

Organization: University of Alberta

Department: Physical Therapy

Project Title: **Normal Range of Motion of Joints in Female Subjects in Different Age Groups**

The Health Research Ethics Board (HREB) has reviewed the protocol for this project and found it to be acceptable within the limitations of human experimentation. The HREB has also reviewed and approved the subject information letter and consent form.

Special Comments:

Glenn G. Griener

Dr. Glenn Griener, PhD
Chair of the Health Research Ethics Board
(B: Health Research)

JUL 13 2005
Date of Approval Release

File Number: B-470605

UNIVERSITY OF ALBERTA — Capital Health — CARITAS HEALTH GROUP

APPENDIX 5

Tables of Range of Motion by Norkin and White (2003)

Tables of "Normative range of motion values" from the book *"Measurements of a Joint: a guide to goniometry"* from Norkin and White, pages 375 to 379, 2003.

Shoulder, Elbow, Forearm and Wrist Motions: Mean Values in Degrees							
	Wanatable et 0-2 yrs n = 45	oone and 1-54 yrs n = 19 (M)	Azereen and Wo 18-55 yrs n = 20 (10 M, 10 F)	Wlaker et al 68-85 yrs n = 60 (30 M, 30 F)	Downey et al 61-93 yrs n = 106 (60 M, 140 F)	AAOS	AMA
Motion							
SHOULDER COMPLEX							
Flexion	172-180	167	156	165	165	180	150
Extension	78-89	62	44	44		60	50
Abduction	177-181	184	165	165	158	180	180
Medial rotatic	72-90	69	62	62	65	70	90
Lateral rotatic	118-134	104	81	81	81	90	90
ELBOW AND FOREARM							
Flexion	148-158	143	145	143		150	140
Extension		1		-4 *		0	0
Pronation	90-96	76	84	71		80	80
Supination	81-93	82	77	74		80	80
WRIST							
Flexion	88-96	76	73	64		80	60
Extension	82-89	65	65	63		70	60
Radial deviation		25	25	19		20	20
Ulnar deviation		39	39	26		30	30

AAOS = American Association of Orthopaedic Surgeons; AMA = American Medical Association; M = r

Values obtained with a universal goniometer

* Minus sign indicates flexed position

Glenohumeral Motions: Mean Values in Degrees				
	Ellenbecker et al 11-17 yrs n = 113 (M)	Ellenbecker et al 11-17 yrs n = 90 (F)	Boon & Smith 12-18 yrs n = 50 (18 M, 32 F)	Lannan et al 21-40 yrs n = 60 (20 M, 40 F)
Motion				
GLENOHUMERAL				
Flexion				106
Extension				20
Abduction				129
Medial rotation	51	56	63	49
Lateral rotation	103	105	108	94

M= males; F= females

Values obtained with a universal goniometer

Hip and Knee Motions: Mean Values in Degrees

Motion	Waugh et al 6-65 hrs n = 40	Drews et al 12hrs-6 days n = 54 (26 M, 28 F)	Schwarze and Denton 1-3 days n = 1000 (473 M, 527 F)	Watanabe et al 8-12 months n = 45	Phels et al 24 months n = 18 (M, F)	Boone and Azen 1-54 yrs n = 109 (109 M)	Roach and Miles 25-74 yrs n = 1683 (821 M, 862 F)	AAOS
HIP								
Flexion						122	121	120
Extension	46 *	28 *	20 *	3 *	3 *	10	19	•20
Abduction		55	78			46	42	45
Adduction		6	15					30
Medial rotation		80	58	38	52	27	32	45
Lateral Rotation			80	79	47	47	32	45
KNEE								
Flexion			150	148-159		142	132	135
Extension	15 *	20 *	15 *					10

AAOS = American Association of Orthopaedic Surgeons; AMA = American Medical Association; M = males; F = females

Values obtained with a universal goniometer

* values refer to extension limitations

• A 1994 AAOS value

Ankle Motions: Mean Values in Degrees

Motion	Waugh et al 6-65 hrs n = 40 (18 M, 22 F)	Vatanabe et 4-8 months n = 54	soone and Aze 1-54 yrs n= 109 (M)	McPoil and Cornwall x= 26.1 yrs n = 27 (9 M, 18 F)	Mecagni et al 64-87 yrs n = 34 (F)	AAOS	AMA
ANKLE							
Dorsiflexion	59	51	13	16	11	20	20
Plantar Flexic	26	60	56		64	50	40
Inversion			37	19(subtalar)	26	26	30
Eversion			21	12 (subtalar)	17	17	20

AAOS = American Association of Orthopaedic Surgeons; AMA = American Medical Association; M = males; F = fei

All range of motion values in the table obtained with a universal goniometer

APPENDIX 6

Most commonly used oral contraceptives in Canada

- Brevicon 0.5/35[5]
- Brevicon 1/35[5]
- Cyclen[7]
- Demulen 30[2]
- Demulen 50[2]
- Loestrin 1.5/30[4]
- Marvelon[1]
- Minestrin 1/20[4]
- Min-Ovral[3]
- Norinyl 1/50[5]
- Ortho 1/35[5]
- Ortho 0.5/35[5]
- Ortho 7/7/7[5]
- Ortho 10/11[5]
- Ortho-Cept[1]
- Ortho-Novum 1/50[6]
- Ovral[8]
- Select 1/35[5]
- Synphasic[5]
- Tri-Cyclen[7]
- Triphasil[3]
- Triquilar[3]

Notes:

1. Desogestrel and Ethinyl Estradiol (des-oh-JES-trel and ETH-in-il es-tra-DYE-ole)
2. Ethynodiol Diacetate and Ethinyl Estradiol (e-thye-noe-DYE-ole dye-AS-e-tate and ETH-in-il es-tra-DYE-ole)
3. Levonorgestrel and Ethinyl Estradiol (LEE-voh-nor-jes-trel and ETH-in-il es-tra-DYE-ole)
4. Norethindrone Acetate and Ethinyl Estradiol (nor-eth-IN-drone AS-e-tate and ETH-in-il es-tra-DYE-ole)

5. Norethindrone and Ethinyl Estradiol (nor-eth-IN-drone and ETH-in-il es-tra-DYE-ole)
6. Norethindrone and Mestranol (nor-eth-IN-drone and MES-tra-nole)
7. Norgestimate and Ethinyl Estradiol (nor-JES-ti-mate and ETH-in-il es-tra-DYE-ole)
8. Norgestrel and Ethinyl Estradiol (nor-JES-trel and ETH-in-il es-tra-DYE-ole)

Doses

- Desogestrel (0.15 mg) and Ethinyl Estradiol (0.03 mg, 0.02mg or 0.01mg) (des-oh-JES-trel and ETH-in-il es-tra-DYE-ole)
- Ethynodiol Diacetate (1mg or 0.05 mg) and Ethinyl Estradiol (0.035 mg)(e-thye-noe-DYE-ole dye-AS-e-tate and ETH-in-il es-tra-DYE-ole)
- Levonorgestrel (0.1 mg, 0.15 mg or 0.05 mg) and Ethinyl Estradiol (0.02 mg, 0.01mg, 0.03 mg or 0.04 mg) (LEE-voh-nor-jes-trel and ETH-in-il es-tra-DYE-ole)
- Norethindrone Acetate (0.25 mg, 0.18 mg or 0.215 mg) and Ethinyl Estradiol (0.035 mg) (nor-eth-IN-drone AS-e-tate and ETH-in-il es-tra-DYE-ole)
- Norethindrone (0.25 mg, 0.18 mg or 0.215 mg)and Ethinyl Estradiol (0.035 mg) (nor-eth-IN-drone and ETH-in-il es-tra-DYE-ole)
- Norgestimate (0.25 mg, 0.215 mg or 0.18 mg) and Ethinyl Estradiol (0.035 mg)(nor-JES-ti-mate and ETH-in-il es-tra-DYE-ole)
- Norgestrel (0.5 mg or 0.3 mg) and Ethinyl Estradiol (0.03 mg or 0.05 mg) (nor-JES-trel and ETH-in-il es-tra-DYE-ole)

APPENDIX 7

Sample size calculation
(Keppel 1991)[44]

The sample size calculation was base on F test ratio -ANOVA procedure considering:

- $\alpha = 0.01$
- effect size = 0.25 (medium)
- Power = 0.96

Formula: $$\hat{\phi}^2_A = n' \frac{\hat{\omega}^2_A}{1 - \hat{\omega}^2_A}$$

Where n' is the sample size and $\hat{\omega}^2_A$ is the magnitude of the effect size

df_{num} = groups – 1

df_{denom} = (n' – 1)groups

Range of Motion for each joint to be measured				
joint	18-29 age	30-40 age	41-50 age	51-60 age
ROM				

$$\hat{\phi}^2_A = n' \times \frac{0.25}{1 - 0.25}$$

$$\hat{\phi}_A^2 = n' \times \frac{0.25}{0.75} = n' \times 0.33$$

$$\hat{\phi}_A^2 = 20 \times 0.33 = 6.6$$

$$\hat{\phi}_A = 2.57$$

$df_{num} = 4-1 = 3$

$df_{denom} = (20-1)4 = 19 \times 4 = 76$

Looking at the power calculation Appendix C at Keppel 1991[44] with $df_{num} = 3$, $df_{denom} = 76$, $\alpha = 0.01$, and $n' = 20$, the power would be around 0.96.

APPENDIX 8

Advertising for recruiting subjects

Women

Are you Caucasian?

Are you healthy?

Are you between 18 and 59 years old?

Are you a non athlete or a non competitive athlete?

Do you have no musculoskeletal injury?

We invite you to participate in our study. We are trying to establish normal range of motion data for females. We will be looking at the range of motion of the hip, knee, ankle, shoulder, elbow and wrist. We need only 2 hours from your time. If you wish participate call Luciana at 780 -492-4824 or e-mail lmacedo@ualberta.ca.

Thank you in advance.

APPENDIX 9

Screening questions for inclusion and exclusion criteria

INCLUSION AND EXCLUSION CRITERIA:

__ How old are you?

__ Do you have chronic pain or musculoskeletal pain?

__ Do you have chronic pathology (i.e. arthritis, lupus)?

__ Do you have any neurological pathology?

__ Do you have any rheumatic pathology?

__ Do you have any hormonal alterations due to any type of pathology or surgery?

__ Have you had any fracture or important musculoskeletal injury?

__ Did you have any musculoskeletal injury in the past year?

__ Have you had any surgery? Which one?

__ Did you do any physical therapy treatment on the past year?

__ Have you ever been pregnant? When did your last pregnancy ended?

__ Have you been involved in a high level or professional level of sports activities in the past year?

APPENDIX 10

Questionnaire for demographic data collection

1. Name:			
2. Age:	**3.** Weight:		**4.** Height:
5. Caucasian		yes	no
6. When was the last time you practiced any physical activity?			
7. Dominant upper limb		right	left
8. Dominant lower limb		right	left
9. Have you gone through menopause (12 months with no period)		yes	no
Are presently undergoing hormone replacement therapy?		yes	no
10. Do you use a contraceptive method		yes	no
How long have you been using it?			
11. Occupation	Classification according to NOC		

APPENDIX 11

Short form of the International Physical Activity Questionnaire (IPAQ)

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days. Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ **days per week**

   ☐ No vigorous physical activities ➡ ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____ **hours per day**

   _____ **minutes per day**

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days. Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ **days per week**

☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days.** This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

APPENDIX 12

Scoring system for the International Physical Activity Questionnaire (IPAQ)

Categorical Score

1. Inactive (category 1)

This is the lowest level of physical activity. Those individuals who not meet criteria for categories 2 or 3 are considered inactive.

2. Minimally Active (category 2)

Any one of the following 3 criteria
• 3 or more days of vigorous activity of at least 20 minutes per day OR
• 5 or more days of moderate-intensity activity or walking of at least 30 minutes per day OR
• 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week.

3. HEPA Active (category 3)

Any one of the following 2 criteria
• Vigorous-intensity activity on at least 3 days and accumulating at least 1500 MET-minutes/
week OR
• 7 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 3000 MET-minutes/week

APPENDIX 13

Pilot study sample size calculation

The sample size calculation for the reliability of the pilot study is based on an Adapted table from Cohen (1998)[61].

The effect size is set according to the value of intraclass correlation desired. This study the ICC required is above 0.80 ICC and consequently the effect size is 0.80.

Using α= 0.01, a power of 0.80 and an effect size of 0.80, there will be necessary 12 subjects.

Table of intraclass correlation sample size calculation adapted by Portney (2000)[61] from Cohen (1998).

	$a_2 = 0.01(a_1=0.005)$								
	r								
Power	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
0.25	362	91	40	23	15	11	8	6	5
0.50	662	164	72	39	24	16	12	8	6
0.60	797	198	87	47	29	19	13	9	7
2/3	901	223	97	53	32	21	15	10	7
0.70	958	237	103	56	34	23	15	11	7
0.75	1052	260	113	62	37	25	17	11	8
0.80	1163	287	125	68	41	27	18	12	8
0.85	1229	320	139	76	45	30	20	13	9
0.90	1481	365	158	86	51	34	22	15	9
0.95	2390	436	189	102	62	40	26	17	11
0.99	2390	588	254	137	82	52	34	23	13

APPENDIX 14

Data collection sheet

Name: ______________________________
Age: ______________________________
Body core temperature: _________
Upper limb dominance: _________ **Lower limb Dominance:** ________

JOINT MOVEMENT	PASSIVE		ACTIVE	
	RIGHT	LEFT	RIGHT	LEFT
Ankle range of motion				
Dorsiflexion (talocrural joint)				
Plantarflexion (talocrural joint)				
Eversion (tarsal joint)				
Inversion (tarsal joint)				
Knee range of motion				
Flexion				
Extension				
Hip range of motion				
Abduction				
Adduction				
Flexion				
Extension				
Internal rotation				
External rotation				
Shoulder range of motion				
Abduction				
Glenohumeral abduction				
Shoulder complex abduction				
Flexion				
Glenohumeral flexion				
Shoulder complex flexion				
Extension				
Glenohumeral extension				
Shoulder complex extension				

	PASSIVE 1		ACTIVE 1	
	RIGHT	LEFT	RIGHT	LEFT
Internal (medial) rotation				
Glenohumeral internal rotation				
Shoulder complex internal rotation				
External (lateral) rotation				
Glenohumeral external rotation				
Shoulder complex external rotation				
Elbow range of motion				
Flexion				
Extension				
Pronation				
Supination				
Wrist range of motion				
Flexion				
Extension				
Ulnar deviation				
Radial deviation				